BUTTERFLIES OF SIKKIM WITH REFERENCE TO ELEVATIONAL GRADIENT IN SPECIES, ABUNDANCE, COMPOSITION, SIMILARITY AND RANGE SIZE DISTRIBUTION

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ABSTRACT

Sikkim is a part of Eastern Himalayas, which is recognized as one among the 34 global biodiversity hotspots. With the record of 689 species that comprises 50% of the species found in India subcontinent, the diversity of butterfly in Sikkim is very high considering its small geographical area. Vegetation in Sikkim is chiefly determined by climate, topography and elevation, and broadly changes at every 900 m interval depicting six major types. We studied butterfly diversity covering these vegetation types/altitudinal zones along the Teesta valley in Sikkim. We followed fixed width circular plot method for butterfly sampling covering 2,617 points spread along 23 transects at different elevations. All together, 6,075 butterflies representing 251 species and five families were observed during this study. Butterfly species richness, abundance and diversity peaked at low elevation tropical semi-deciduous forest (300-900 m) and declined towards mid to high elevations. Percentages of exclusive species also declined monotonically with elevation. Among five families, Nymphalidae dominated the butterfly community with highest species and abundance. Cluster analysis revealed that each forest types harbors unique community assemblages of butterflies. About 36% species were confined to single vegetation type reflecting their narrow distribution range. Since butterflies showed narrow tolerance to elevation and vegetation change, conservation of their habitats at landscape level is important for conservation of butterfly fauna in Sikkim.

KEYWORDS: *Butterfly, conservation, elevation zone, Sikkim, species richness, vegetation zone*

Blue Duchess *Euthalia duda*: Commonly observed during April-May at 1000-1400m.
A large number of individuals are seen at Sankalang area in Dzongu, North Sikkim

Large Silverstripe *Childrena childreni :* A species found in cultivated and disturbed habitat

INTRODUCTION

Eastern Himalaya is represented by diverse habitats, and has high variation in altitude and climate. Sikkim is located in the western extremities of the eastern Himalaya, which is recognized as one among the 34 global biodiversity hotspots (Mittermeier et al., 2005). Sikkim lies at the transition zone of Oriental and Palaearctic zoogeographical realms and Indian, Indochinese and Indomalayan zoogeographical regions (Olson et al., 2001).

A rugged mountain state of the Indian Union, Sikkim is geographically isolated from the rest of the country. It is encircled by mountain ranges on three sides i.e. Singalila and Kanchanjunga ridge on the west, Rishipangola on the east and the main axis of Himalaya on northern part giving the state a horse-shoe shape (Ali, 1962; Mani, 1974). It opens to the plains of India through southern side. The state is described as the catchment area of river Teesta (Risley, 1928). Teesta, the largest river and major physical feature of Sikkim originates at Cho Lhamo Lake (4800m amsl.) in north Sikkim which chiefly runs in a north-south direction throughout its entire length bisecting the state into two parts. Rangeet River running from the western parts of Sikkim merges with Teesta at Melli near Sikkim-West Bengal border (300 m amsl).

Among all the Indian states, Sikkim is undoubtedly the richest in biodiversity relative to its small area (7096 km^2). Although Sikkim occupies only 0.21% of the geographical area, it possesses around 43% mammals, 45% birds, 50% butterflies and 11% flowering plants that occur in the Indian subcontinent. Total forest cover of Sikkim is 3,357 km^2 which forms around 47% of the total geographical area of the state (FSI, 2009). This breathtaking diversity results from the geographical location of the state, its unique plate tectonic and palaeoclimatic history and an altitudinal and climatic regime that is unique in the world. That much of the biodiversity remain today is undoubtedly due to the low human population densities as well as to the biodiversity dependent and diverse human life style.

Along with the changes in vegetation, altitude, precipitation, topography and aspect, the faunal assemblages also change rapidly from tropical to subtropical, temperate, alpine and finally to cold desert forms. It follows from this rapid transition that all the floral and faunal taxa in Sikkim have very small distribution ranges within the State. Because of the diversity and high variation in physical and ecological features, Sikkim offers a unique opportunity for assessment of biodiversity along the elevation and vegetation gradient.

Biodiversity studies along elevation gradient have become important tool for rapid identification of hotspots areas especially in montane countries. The information thus obtained would be used to prioritize areas for conservation and management planning (Hunter and Yonzon, 1993; Kollmair et al., 2005). The pattern of species distribution along elevation varies among taxa, regions, methods used and width of the elevation considered (McCain, 2009). Previously species richness along elevation was thought to mirror the latitudinal pattern, and reported to follow monotonic decline from low elevation to high elevation. But recently various patterns have been recognized viz. monotonic decline, low elevation peak, mid elevation peak and monotonic increase in species richness with elevation (Rahbek, 2005).

The conservation programmes are based mostly on larger, charismatic species and the threats of many less glamorous taxa (such as butterflies and herpetofauna), but playing equally important role in ecosystem, go unnoticed. Hence, in this paper we have analysed the species richness, diversity and abundance pattern of butterflies along elevation and five major vegetation zones of Sikkim. At first, we estimated the number of species at each elevation zone based on Haribal (1992). Then we compared this pattern with our study conducted along the Teesta Valley in Sikkim during 2003-2006. Based on our data, we also document seasonality, family-wise pattern and community structure of butterflies. Elevational range size and species similarity looking at the transition zones (i.e. the elevation where species composition changes more rapidly) are also discussed.

MATERIALS AND METHODS

Vegetation types and zones

There is high variation in elevation in the state of Sikkim within a small geographical span. The elevation ranges from c. 300 m to above 8500 m. The climate, which is determined chiefly by geographical location and elevation, varies from hot tropical in the low elevation to temperate cool at mid and arctic cold in the higher elevation. Hooker (1854) documented the rich and diverse floristic wealth of Sikkim and categorized the vegetation into three major types- Tropical, Temperate and Alpine. Several authors followed this classification of vegetation (Ali, 1962; Mani, 1974; Hajra and Verma, 1996; Singh and Chauhan, 1998; Sudhakar et al., 1998). Depending on the elevation and various physical and ecological factors, broadly six major vegetation zones are recognized in Sikkim (Haribal, 1992) (Fig. 1). These are:

1. Tropical semi-deciduous forests (300 - 900 m)*:* These low elevation forests are largely altered for agriculture and teak plantation. However, remnant patches of original forest still exist in some areas.
2. Tropical moist and broad-leaved forests (900 - 1800 m): While majority of forest areas in this vegetation type are partially disturbed for cardamom plantation, it harbours high biodiversity (Acharya et al., 2011).
3. Temperate broad-leaved forests (1800 – 2800 m): This is one of the most undisturbed forests in Sikkim. Closed canopy of broadleaved trees covered by mosses and other epiphytes are characteristics of this forest type.
4. Temperate coniferous and broad-leaved forests (2800 – 3800 m): Here mono-specific pine dominates with Rhododendron undergrowth.
5. Sub-alpine vegetation (3800 – 4500 m): Vegetation becomes stunted above 3800 m and tree line occurs at around 4000 m.
6. Alpine zone (>4500 m): This zone represents Greater Himalaya and remains under snow cover for almost 6-7 months a year. The vegetation comprises seasonal herbs which completes life cycle within a short period (late June to early September).

This gradation is best experienced if one traverses the course of River Teesta. From remnant patches of tropical wet forest at the lowest altitudes, the vegetation changes rapidly along the course of the river within a distance of around 150 km. In this paper, these vegetation zones are referred as zone I, zone II, zone III, zone IV and zone V respectively. Sub-alpine and alpine zones are considered together as zone V. Since elevation determines the vegetation in the study area, zones used in this paper refers to elevation zones as well as vegetation types.

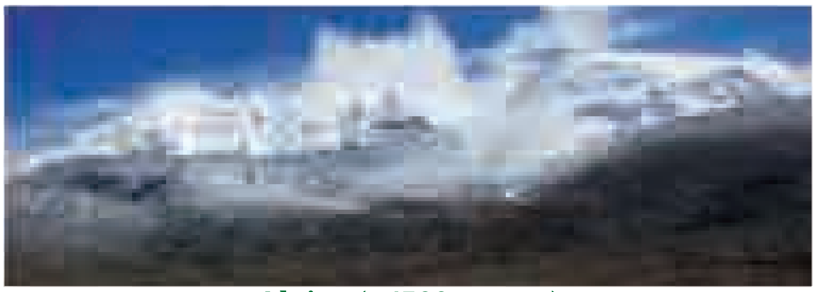
Secondary information

We prepared the checklist of the butterflies of Sikkim from the book 'The butterflies of Sikkim Himalaya' by Haribal (1992). A total of 689 species of butterflies have been recorded from Sikkim, and the book provides baseline information on their elevational range and natural history of over 450 species. Five altitudinal zones were chosen to look at the distribution pattern of butterflies with respect to altitude. We categorized species into various zones on the basis of their altitudinal distribution, and number of species likely to occur at each zone was estimated.

Data collection

We studied butterfly diversity along the Teesta valley in Sikkim covering major vegetation types/altitudinal zones during 2003-2006. We followed fixed width circular point count method along the transects. Transects are the trails established for locating the sampling points. Depending upon the availability of suitable plots and accessibility in the sloppy terrain, we laid five transects each in four zones (I, II, III and IV) and three transects in zone V keeping a minimum of 150 m elevational distance between any two transects. Thus a total of 23 transects were established covering various elevation and vegetation types. Along the transects, we established permanent points each of which spaced 50 m apart. We conducted 5 minutes count within the 5 m radius plot observing butterfly species and their abundance. Each point was sampled uniformly covering three major seasons- summer (Mar-May), monsoon (Jun-Aug) and post-monsoon (Sept-Nov). Thus, we covered a total of 2,617 point counts during our study.

Figure 1. Gradation of vegetation along the elevation gradient in Sikkim.



Alpine (>4500 meters)

Sub-alpine (3800-4500 meters)

Temperate coniferous (2800-3800 meters)

Temperate broad-leaved (1800-2800 meters)

Tropical broad-leaved (900-1800 meters)

Tropical semi-deciduous (300-900 meters)

Data analysis

We pooled the data from all points in one zone for analysis. We considered species richness as total number of species observed and species abundance as number of individual butterflies counted during sampling. We calculated Shannon-Weiner species diversity (H') using the formula: H' = -? p_i ln $p_{i,}$ where pi = proportion of total sample belonging to i^{th} species, ln = natural logarithm. All these parameters were estimated for zones, seasons and families. Exclusive species were considered as the species recorded from only one particular zone. We also calculated relative abundance (RA) of all the butterflies (in total as well as among zones) with the formula: RA = n_i*100/N, where, ni = number of Individuals of i^{th} species; N = total number of individuals of all species. Range of each butterfly species was estimated as difference between the lowest and highest elevation at which the species was observed during the study. The species are assumed to be present at all intermediate elevations between lowest and highest elevation (Brehm et al., 2007). We estimated the number of species at range size of every 500 m interval.

We obtained Jaccard similarity index between elevational transect pairs for all 253 pairs (resulted from pair-wise combination of 23 transects) using software EstimateS version 7 (Colwell, 2004). Based on Jaccard similarity index we performed cluster analysis producing dendrogram that illustrates similarities in butterfly community composition between sampled elevational transects. This analysis shows that how similar or dissimilar are the species reported at one elevation site from others.

RESULTS

Baseline information

The present checklist of butterflies consists of 689 species (Haribal, 1992), including 254 without specific distributional data. The secondary information indicated that maximum diversity of butterflies occur below 1800 m (Fig. 2). While the present data along Teesta Valley also depicted maximum species concentration below 1800 m, the species decline is monotonic unlike higher richness in zone II observed in existing information of the entire state.

Species richness, diversity and abundance

We observed a total of 6,075 butterflies representing 251 species and five families after the completion of 2,617 point counts during this study (2003 – 2006) along Teesta Valley in Sikkim. Among the total species, 106 species were exclusives (those species which are found only in one particular zone). Shannon-Weiner diversity index for overall data was 4.4. Butterfly species richness, abundance and diversity were highest in low elevation tropical semi-deciduous forest (zone I) and lowest in alpine and sub-alpine region (zone V). The trend of exclusive species is also coherent with the species richness and diversity (Table 1).

Common Map *Cyrestis thyodamas*: A butterfly species with a map like structure commonly observed at low elevation areas along the river valleys and streams. Wings are transparent and very delicate

Common Red Apollo *Parnassius epaphus*: A typical butterfly of the alpine region. It can withstand cold climatic conditions and strong wind currents prevalent at high elevations above 4000m

Eastern Courtier *Sephisa chandra*: A male individual. While Haribal (1992) reports as a common species, it is rarely observed in shaded areas along the streams at low to mid-elevations

Cruiser *Vindula erota*: One of the rare species of lower river valleys in Sikkim

Common Peacock *Princeps polyctor*: Common Peacock is found in hot summer months at low elevation areas. Inhabitant of open habitat and cultivated systems, it flees very swiftly during sunny days

Wax Dart *Cupitha purreea* at mating posture. Hesperid (moth like butterfly) found upto 2500m elevation in Sikkim.

Family-wise pattern

The observed butterflies of Teesta Valley represent five families namely, Papilionidae, Pieridae, Lycaenidae, Nymphalidae and Hesperiidae. Among these families, Nymphalidae was the most dominant comprising maximum species (47%) and abundance (46%) (Fig. 3). Lycaenidae followed Nymphalidae in terms of species, whereas the second most abundant family was Pieridae. As usual trend, Hesperids were least represented in the butterfly community of the Teesta Valley. Nymphalidae dominated with highest species and abundances in all the zones. Nymphalidae, Papilionidae and Pieridae showed decline in species as well as abundance with elevation, whereas Lycaenidae peaked at zone II (Tropical broad-leaved forest) (Fig. 4).

Seasonality

Species richness and abundance of butterflies varied among seasons. Overall, species richness was highest during monsoon and lowest during summer with the intermediate value during post-monsoon season (Fig. 5), whereas abundance pattern varied with maximum butterflies during post-monsoon and minimum during summer.

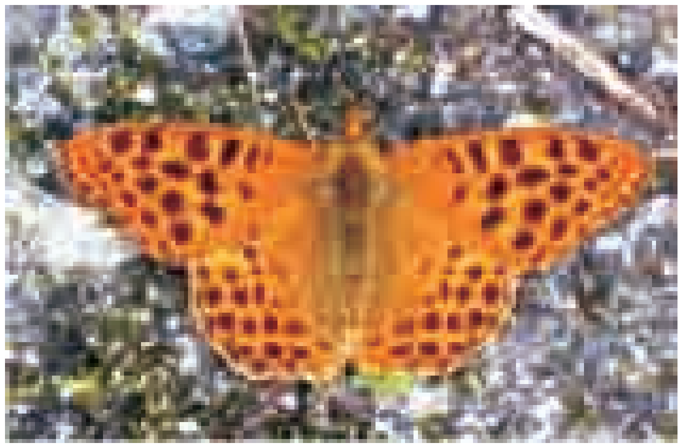
Community composition

Community composition of butterflies showed that most of the species are rare with very less abundance, whereas a few species dominated the butterfly community of the study region. The community has 32 singletons (species detected only once) and 25 doubletons (species detected twice). Of the 251 species recorded, 22 species (8.8%) comprised 50% of the total butterflies detected (Table 2). Indian Cabbage White *Pieris canidia* was the most dominant butterfly species (Relative Abundance = 10.9) followed by Common Sailer *Cyrestis thyodamas* (4.9), Large Yeoman *Cirrochroa aoris* (3.4), Red Helen *Princeps helenus* (2.8) and Common Earl *Tanaecia julii* (2.5). Abundant species varied among zones. Common Sailer (7.9) and Indian Cabbage White (6.2) in zone I, Indian Cabbage White (15.3) and Large Yeoman (3.6) in zone II, Indian Cabbage White (20.8) and Dark Clouded Yellow *Colias fieldii* (5.3) in zone III, Dark Clouded Yellow (28.2) and Mountain Tortoiseshell *Aglais rizana* (22.2) in zone IV and Dark Clouded Yellow (48) and Common Blue Apollo *Parnassius hardwickii* (27.3) in zone V were the most dominant species.

Species similarity

Dendrogram obtained taking Jaccard similarity index between different elevation sites formed two major clusters showing distinct species assemblages, low to mid-elevation 300 - 2650 m and high elevation 2850 - 4700 m (Fig. 6). The low elevation sites between 300 m and 1800 m showed species that are more similar in composition and clustered together. The species composition of butterflies between 1900 m and 2650 m was unique and formed a separate cluster. The high elevation butterfly community also formed two separate assemblages, one of 2850 - 3650 m and other 4000 - 4700 m. High transition in butterfly species composition occurred at 2850 m and 3650 m.

Paris Peacock *Princeps paris*: Very beautiful, large size butterfly found at open habitat and cultivated systems at low elevation. Fly fast along with other species of peacocks and helens.



Gem Silverspot *Argynnis gemmata*: Found above 2500m elevation in dry habitats and meadows.

Orange Oakleaf *Kallima inachus*: Found in shaded areas especially in bamboo plantations. Very difficult to locate at rest as its coloration resembles a dried leaf.

Large Yeoman *Cirrochroa aoris*: Abundantly seen during summer months along with Common Map near streams at low elevation belt.

Grass Yellows *Eurema sp*.: An aggregation of different species of Grass Yellows. This is a common feeding activity displayed by these butterflies during sunny days.

Popinjay *Stibochiona nicea*: It loves shades and damp patches in the tropical forests. A short flyer and feeds on sap of *Albizzia sp.*

Range size distribution

Butterfly species showed narrow tolerance to elevation *vis-a-vis* vegetation types. Number of species declined with increasing range size (Fig.7). Most of the butterflies had narrow distribution range, about 36% species confined to single zone. Of the total, 86 species had <500 m range comprising 39 species observed at single elevation site. Dark Clouded Yellow (*Colias fieldii*) was the most widely distributed species (range size >3500 m). None of the butterfly species occurred all along the gradient.

DISCUSSION

This paper reports the ecological study of butterflies at various vegetation/elevation zones in the Teesta Valley in Sikkim. We recorded 251 species of butterflies which makes up around 36% of the butterflies found in Sikkim. These species are sub-set of the total butterfly fauna of the state and reflects high potential of the valley in retaining and conserving butterflies. The recorded species in the Teesta Valley comprise tropical, sub-tropical and temperate forms contributing high diversity to the study area. The moist climate due to high rainfall and wide variation in elevation in the Valley and moderate habitat disturbances might have resulted in a variety of micro habitats and ecological niches for the existence of different species enhancing diversity.

Butterfly species richness, diversity, abundance and exclusive species recorded maximum value at below 1800 m elevation (zones I and II -tropical and sub-tropical forests) with the abrupt decline above this elevation. As the entire gradient of altitude, climate and vegetation of Sikkim is reflected along the Teesta Valley, the pattern obtained in the Valley can surrogate Sikkim. Uniyal (2007) made similar observation in a study in Himachal Pradesh. Negative correlation between butterflies species richness and elevation was also reported from Great Basin, USA (Fleishman et al., 1998) and Spain (Sanchez-Rodriguez and Baz, 1995). The decline trend might be attributed to decline in temperature and rainfall towards higher elevation. The rate of temperature decline in Sikkim was reported as -0.62°C at every 100 m rise in elevation (Acharya et al., 2011) but the rate changes above 2400 m (-1°C at every 100 m rise in elevation; Chettri et al., 2010). Butterfly needs certain level of temperature for their activity and hence unable to cope up with the extreme climatic conditions (Fleishman et al., 1998).

The differences in composition and patterns of abundance among assemblages suggest that the butterfly community is shaped by various factors such as food, breeding habitat, competition among co-existing species, climate, vegetation and disturbance level (Hamer et al., 1997; Spitzer et al., 1997; Hill,1999; Tokeshi, 1999; Willott et al., 2000). The type and quantity of resources as well as their distribution patterns, climatic conditions and disturbance levels are the major factors that determine the community structure of butterflies along elevation gradient (Fleishman et al., 1998; Foristera et al., 2010; Levanoni et al., 2010). As a result of the close links between butterfly diversity and health of their habitats, butterflies have been considered one of the best taxa as potential bioindicators of ecological changes in tropical regions (Spitzer et al., 1997).

Narrow range size of most species reflects that butterflies are very sensitive to changes in environmental parameters caused by changes in elevation and physiography (Levanoni et al., 2010). There are reports that the butterfly ranges are also affected by the global climate change (Parmesan et al., 1999; Foristera et al., 2010). The data shows that most of the species found at one elevation/vegetation type does not occur at other sites. The co-specificity of butterflies with climate and host plants for feeding and laying eggs make them unable to cope up with the changed habitats. It is now clear that the conservation efforts targeted at one or two zones would miss many species of conservation concern. Hence, the entire gradient needs conservation attention for the preservation of rich and unique butterflies of Sikkim.

High diversity of butterflies, and also plants and other animals at low to mid-elevation forests (Acharya, 2008; Chettri et al. 2010; Acharya et al., 2011) shows that the biological hotspots in Sikkim lies within 1800 m elevation. These forests in the Himalaya and elsewhere also harbor high diversity at this elevation but experiences immense anthropogenic pressures leading to many extinction (Khan et al., 1997; Pandit et al., 2007). The rate of extinction of species and reduction of biodiversity from hotspots regions due to disturbances and climate change is alarming (Kannan and James, 2009; Foristera et al., 2010). In Sikkim, 31% of the total geographical area is under protected area network but most of the protected areas are located above 1500 m (Anon, 2003; http://www.sikenvis.nic.in/Wildlife.htm). The distribution of protected areas and conservation efforts should be in accordance with distribution of biota, area and human population (Hunter and Yonzon, 1993; Khan et al., 1997; Harris et al., 2005; Shrestha et al., 2010). Considering high richness, narrow elevational range of most species and absence of PAs at low to mid-elevation, we suggest the extension of conservation efforts to these elevations. Recently, addition of the Kitam Bird Sanctuary in the lower elevation (320-875 m) belt has increased the PA coverage at hotspot areas (Government of Sikkim, 2005). However, since the area of this new PA is only 6 km^2, further expansion of PA network in areas below 1800 m is necessary. The up gradation of conservation status of the reserve forest along the Rangit and Teesta river valleys (FSI, 2009) to that of a PA would help to conserve rich biodiversity including butterflies.

Since areas below 1800 m (zone I and II) are almost entirely inhabited by people and the major chunk of forests fall under private holdings, conservation also can be achieved through the involvement of the local community as suggested for mountainous areas (Kollmair et al., 2005). Original remnant patches of forest and native vegetation among agricultural fields can be retained in consultation with various stakeholders and local communities and managed without further loss of biodiversity.

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Table 1. Species richness, abundance, exclusive species and Shannon-Weiner diversity (H') of butterflies in different elevation/vegetation zones of Sikkim

Zones	Species richness	Abundance	Exclusive sp.	Diversity (H´)
I	181	3217	56	4.1
II	166	1740	33	3.9
III	86	924	15	3.2
IV	9	117	1	1.6
V	4	77	1	1.2
Total	**251**	**6075**	**106**	**4.4**

Table 2. The most dominant butterfly species that comprised 50% butterfly in the study area

Sl No	Species	Relative abundance
1	Indian Cabbage White *Pieris canidia*	10.9
2	Common Sailer *Cyrestis thyodamas*	4.9
3	Large Yeoman *Cirrochroa aoris*	3.4
4	Red Helen *Princeps helenus*	2.8
5	Common Earl *Tanaecia julii*	2.5
6	Paris Peacock *Princeps paris*	2
7	Dark Clouded Yellow *Colias fieldii*	2
8	Common Cerulean *Jamides celeno*	1.8
9	Indian Tortoiseshell *Aglais cachmirensis*	1.8
10	Chocolate Soldier *Precis iphita*	1.6
11	Great Orangetip *Hebomoia glaucippe*	1.6
12	Common Fivering *Ypthima baldus*	1.5
13	Tree Yellow *Gandaca harina*	1.5
14	Common Grass Yellow *Eurema hecabe*	1.5
15	Yellow Helen *Princeps nephelus*	1.5
16	Straight Banded Treebrown *Neope verma*	1.4
17	Nigger *Orsotrioena medus*	1.4
18	Golden Sapphire *Heliophorus brahma*	1.3
19	Dark Cerulean *Jamides bochus*	1.2
20	Popinjay *Stibochiona nicea*	1.2
21	Chestnut Tiger *Parantica sita*	1.1
22	Yellow Orangetip *Ixias pyrene*	1.1
	Total	**50**

Figure 2. Distribution of butterflies in different vegetation (altitudinal) zones in Sikkim (based on literature and present study)

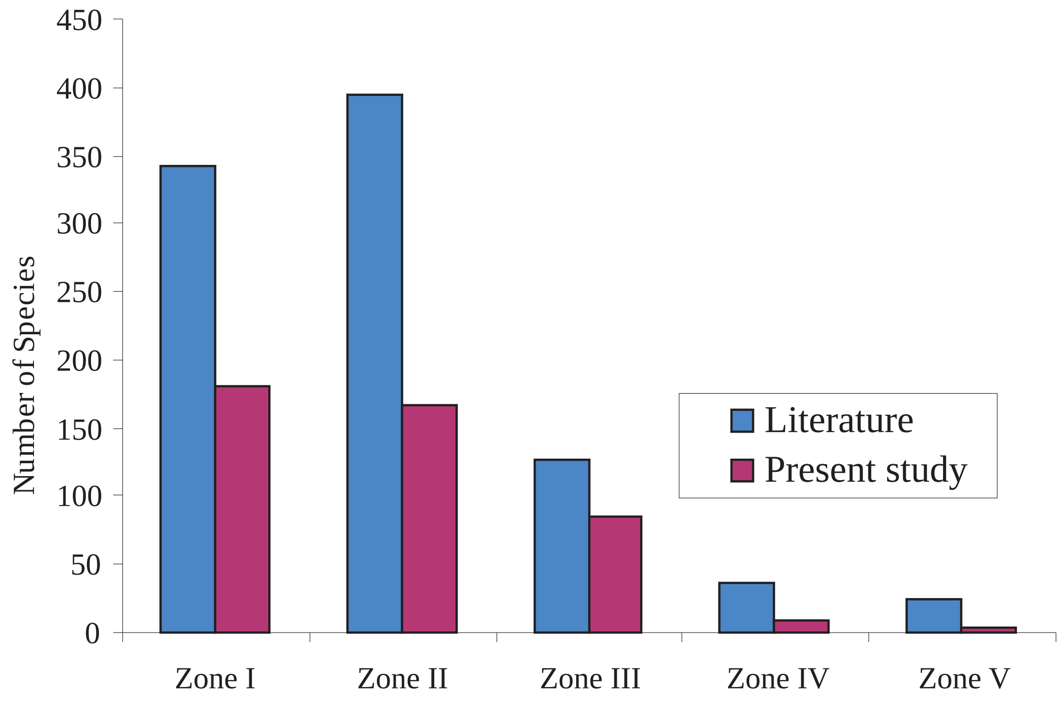


Figure 3. Family-wise representation in species richness (a) and abundances (b) of butterflies in Sikkim

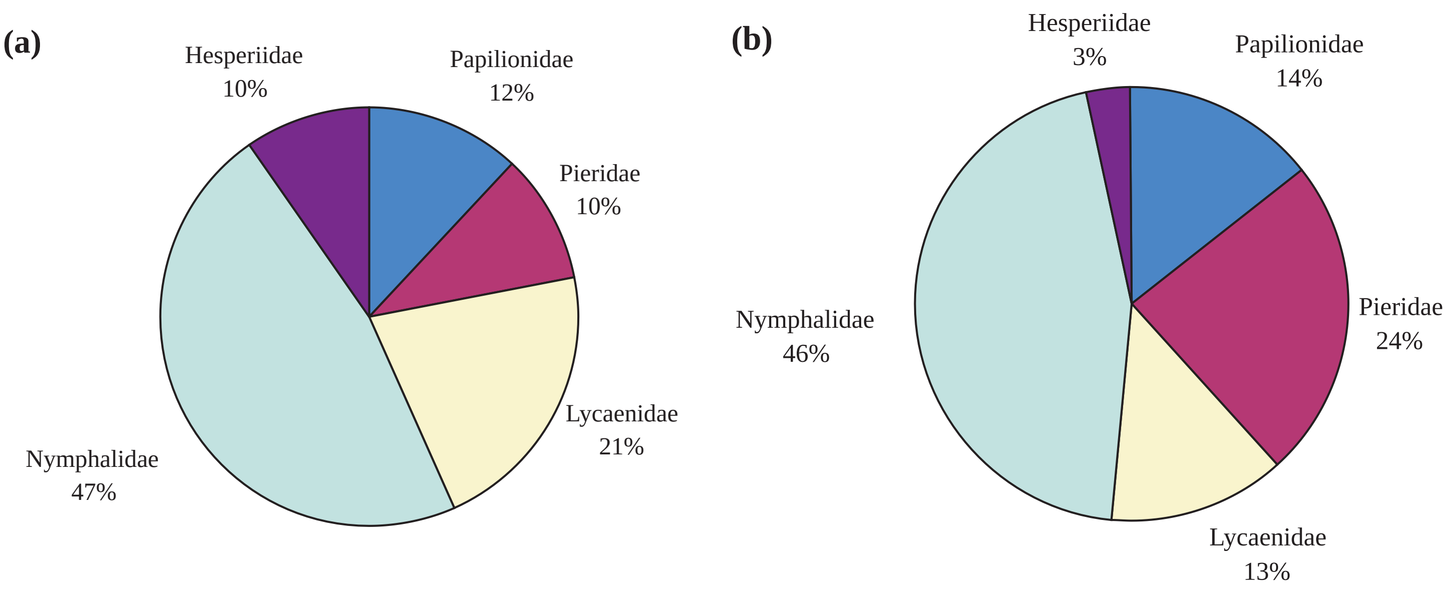


Figure 4. Family-wise trend in species richness (a) and abundances (b) of butterflies in different elevation/ vegetation zones in Sikkim

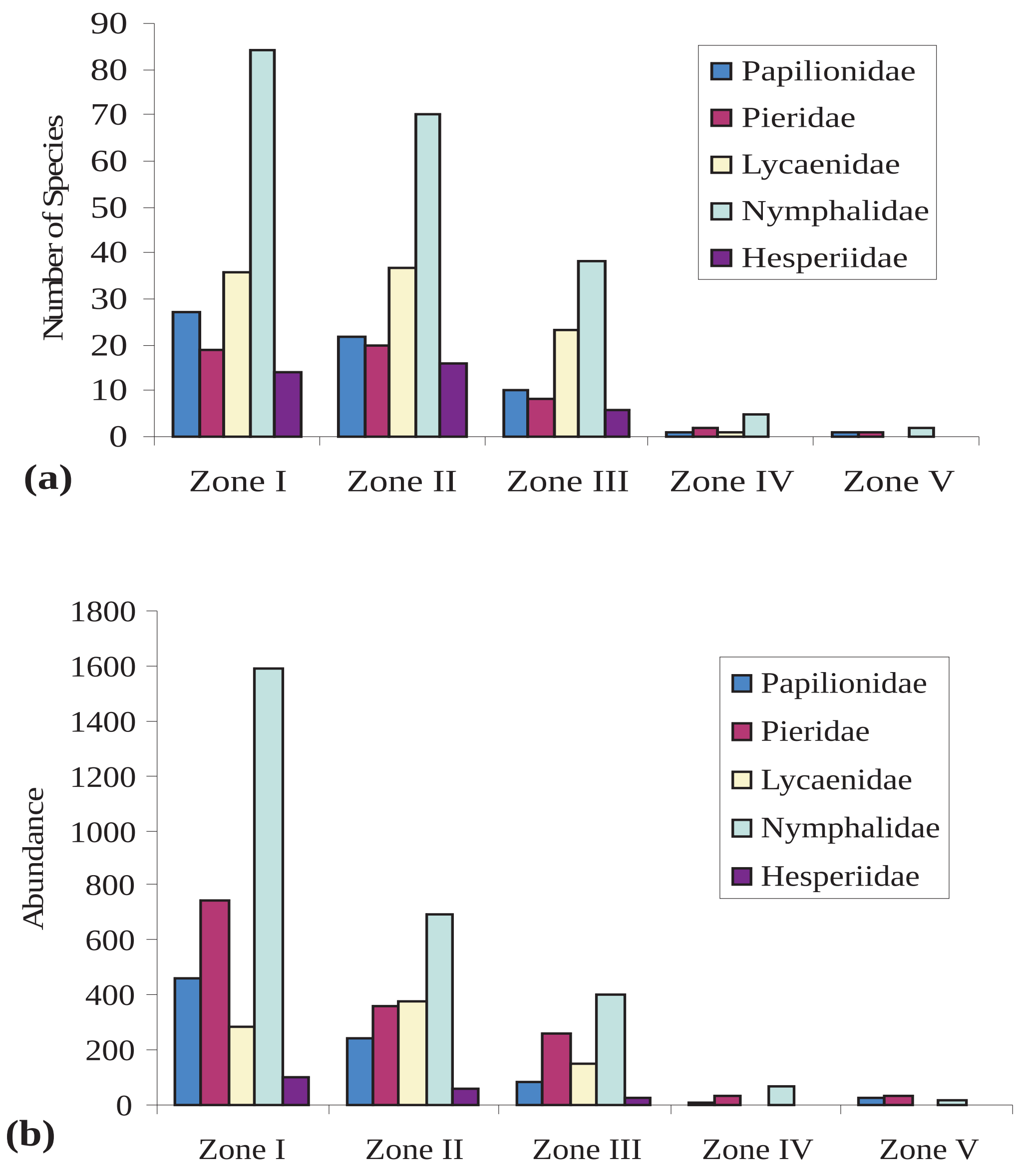


Figure 5. Seasonal variation in species richness (a) and abundances (b) of butterflies in Sikkim

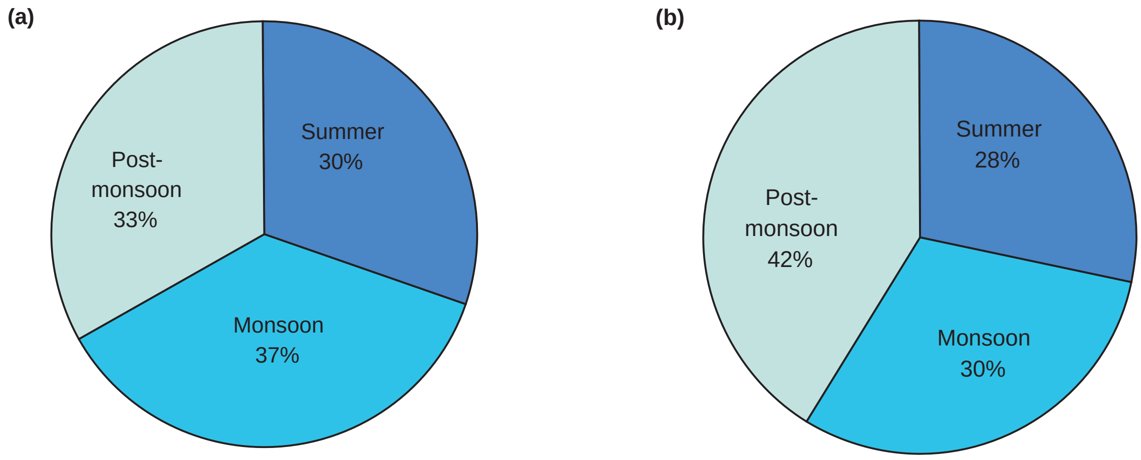


Figure 6. Dendrogram obtained taking Jaccard similarity index of butterflies among the elevational transects in Sikkim

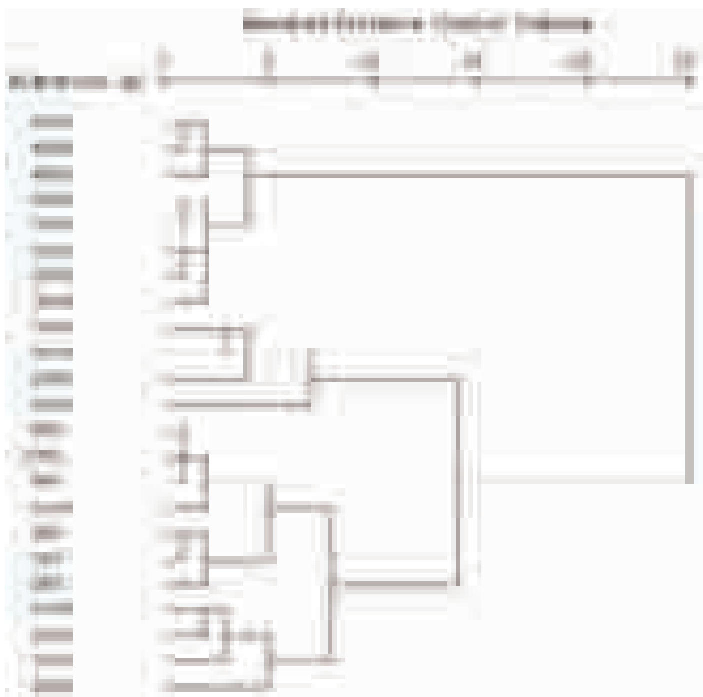
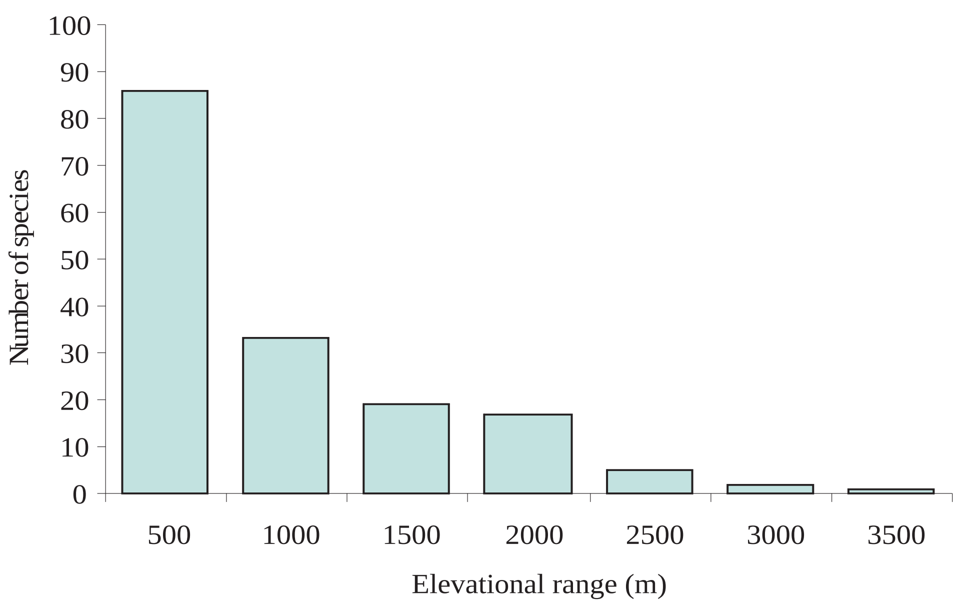


Figure 7. Elevational range size distribution of butterflies of Sikkim



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