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Butterfly diversity along the elevation gradient of Eastern Himalaya, India

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Abstract The species richness pattern along spatial scales (latitudinal or elevational) forms useful tools in understanding diversity gradients and their underlying mechanisms. Understanding elevational diversity patterns of biodiversity have strong conservation implications. Himalayas are unique systems in exploring such gradients as they harbor tallest mountains in the world. Here, we explored the elevational pattern, its underlying causes, turn over rate and range size distribution of butterflies in Sikkim, Eastern Himalaya, India. We followed fixed width point count method for sampling butterflies covering 1014 points spread over 23 transects along the elevation gradient (300–4700 m) in Sikkim. Data on environmental factors and habitat parameters were obtained from our published literatures of the same study system. During this study we observed a total of 2749 butterflies representing 161 species and six families. Species richness pattern of butterflies followed declining trend along the elevation gradient with a hump at around 1000 m. Various environmental factors and habitat variables correlated strongly with the species richness and abundance of butterflies. Among the set of factors, mean annual temperature and actual evapotranspiration remained the most important determinants reflecting the importance of energy and productivity for butterfly distribution in the Eastern Himalayan elevation gradient. Butterflies showed high turnover along the

gradient. Elevational range profile of butterflies showed that around 38.5 % species restricted below 2000 m elevation. We observed that low elevation areas are important for conservation of butterflies in the Eastern Himalaya although entire elevation gradient is crucial for small range-sized species.

Keywords Conservation · Energy · Productivity · Range size · Sikkim

Introduction

The species richness pattern along latitude and elevation gradient is a major focus of research in spatial ecology and biogeography and forms useful tools in understanding diversity gradients (Gaston and Blackburn 2000; Kraft et al. 2011; Ah-peng et al. 2012; Sanders and Rahbek 2012). Such studies are crucial in identifying hotspots and prioritizing areas for conservation and management of biodiversity (Hunter and Yonzon 1993; Kollmair et al. 2005; Shrestha et al. 2010; Aynekulu et al. 2012). Studies along elevation gradient involving various taxonomic groups have shown three general patterns viz., monotonic decline, mid elevation peak and linear increase in species richness with elevation (Rahbek 2005).

Several factors have been considered as determinants of elevational pattern of biodiversity. The factors such as contemporary climate and productivity (Rosenzweig 1995; Fu et al. 2007; Rowe 2009; Wang et al. 2009; Whittaker 2010; Acharya et al. 2011a), evolutionary history (Whittaker 2010; Machac et al. 2011), area (Rahbek 1997; Herzog et al. 2005; Romdal and Grytnes 2007) and geometric constraints (Colwell et al. 2004; McCain 2004; Brehm et al. 2007; Rowe 2009) are the most commonly discussed drivers of the elevational diversity gradients. However, the generality of the pattern across taxa and region, and the consensus on underlying mechanisms for the pattern has remained controversial and is much argued and discussed topic in

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spatial ecology (Oommen and Shanker 2005; Jankowski et al. 2012; Sanders and Rahbek 2012; Eisenlohr et al. 2013; Herzog et al. 2013).

Studies have found that increasing productivity and high energy potentially increases the diversity of organisms across spatial scales (Gaston 2000; Ding et al. 2005, 2006; Whittaker 2010; Craig and Klaver 2013). 'More Individuals Hypothesis' (Srivastava and Lawton 1998) or 'species-energy' theory' (Evans et al. 2005) argues that higher productivity leads to higher number of individuals thus increasing the number of species probably due to reduced extinction probabilities.

Himalayas harbors tallest mountains in the world and forms unique system in understanding elevation diversity gradients. One of the globally significant biodiversity hotspots (Mittermeier et al. 2005), Eastern Himalaya represents diverse habitats witnessing high variation in altitude and climate. 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. Sikkim is located in the western extremities of the Eastern Himalaya. It follows from this rapid transition that all the floral and faunal elements in Sikkim have very small distribution ranges. Because of the high variation in physical and ecological features within small geographical span, Sikkim offers a unique opportunity for assessment of biodiversity along the elevation and vegetation gradients (Chettri et al. 2010; Acharya et al. 2011a, b).

Elevational pattern of mammals, birds, reptiles, amphibians, fishes and plants have been reported from the Himalayan region (Bhattarai and Vetaas 2003; Bhattarai et al. 2004; Oommen and Shanker 2005; Behera and Kushwaha 2007; Chettri 2007; Thapa 2008; Chettri 2010a; Chettri et al. 2010; Acharya et al. 2011a, b; Khuroo et al. 2011; Price et al. 2011; Bhatt et al. 2012; Naithani and Bhatt 2012; Telwala et al. 2013). Despite being important part of an ecosystem (often considered as bio indicators) such studies on butterflies are scanty in the Himalayas (Bhardwaj et al. 2012) as well as at global level (Fleishman et al. 1998; Vu and Yuan 2003; Levani et al. 2011; Despland et al. 2012; Ilian et al. 2012). This study attempts to add up to the knowledge gap in diversity gradients of butterflies, a sensitive faunal group. Additionally, butterflies are facing risk of range contraction both along the latitudinal and elevational gradient mostly due to global climate change (Parmesan et al. 1999; Wilson et al. 2007; Forister et al. 2010; ESKILDSEN et al. 2013). Hence, documentation of elevational pattern and range size distribution along with understanding underlying causes are important either to get insights on diversity gradients or to formulate conservation programs in the face of recent global phenomenon (Ilian et al. 2012).

Here, we explore and describe the pattern of butterfly species richness along the elevation gradient in Sikkim, Eastern Himalaya, India covering a large elevation width (around 4500 m). We also evaluate the effects of envi-

ronmental factors [mean annual temperature (MAT), mean annual precipitation (MAP), moisture index (MI) and actual evapotranspiration (AET)] and habitat variables [tree species richness (TSR), tree density (TD), shrub species richness (SSR) and shrub density (SD)] on butterfly species richness and abundance. Additionally, we have assessed species turnover and elevational range size distribution of butterflies along the elevation gradient.

Materials and methods

Study area

This study was undertaken during 2004–2005 in Sikkim (27°03' to 28°07'N and 88°03' to 88°57'E) in the Eastern Himalaya, India. Sikkim forms a part of the inner mountain ranges of Himalaya and represents a hilly and rugged terrain. Within its small geographical span (7096 km²), Sikkim witnesses high variation in climate, elevation and vegetation types. The climate varies from hot tropical in the foothills to alpine cold at the summits. Elevation ranges from 300 m to above 8000 m. Similarly, the vegetation rapidly changes from tropical semi-deciduous and tropical wet forests at lower valleys, temperate broad-leaved forests at middle elevation and alpine vegetation at the higher reaches in Sikkim. We studied butterflies along an elevation gradient (300–4700 m) in Sikkim covering all major vegetation types (that changes roughly at 900 m interval) (Haribal 1992).

Data collection

We followed fixed width point count method along the transects for sampling butterflies. The commonly used methods for butterfly monitoring are the 'Pollard Walk Method' (Pollard 1977) and transect count method (Wood and Gilman 1998; Isaac et al. 2011). Considering the sloppy difficult terrain of the study area, these methods were not feasible because counting the butterflies while walking along the transect was not possible. Hence, we used point count method (a modified form of transect method) where we halted at permanent points along the transects to record the butterflies. Transect walk or point count method may have some disadvantages (e.g., ascertaining identification of butterflies at the wing; see Walpole and Sheldon 1999). However, it is considered most suitable method in butterfly sampling across range of habitats (Caldas and Robbins 2003; Posa and Sodhi 2006) and commonly used in the Himalayas (Uniyal 2007; Chettri 2010b; Bhardwaj et al. 2012) and elsewhere (Spitzer et al. 1997; Vu and Yuan 2003; Vu 2009; Isaac et al. 2011; Ilian et al. 2012).

Depending upon the availability of suitable plots and accessibility in the sloppy terrain, a total of 23 transects were established covering various elevation and vegeta-

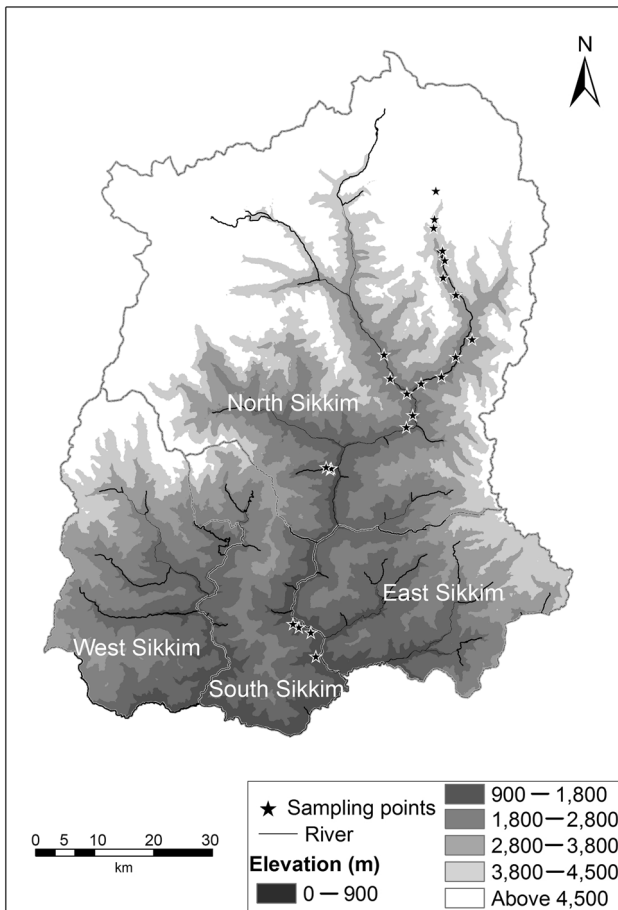


Fig. 1 Map of Sikkim showing sampling locations of butterflies. The map is classified at 900 m elevation interval corresponding to major vegetation types of the study area

tion types (Fig. 1; Table 1). Along the transects, we established permanent points each of which spaced 50–100 m apart. We conducted 5 min count within the 5 m radius plot observing butterfly species and their abundances. Prior to data collection, one of us (BKA) spent considerable amount of time in the field familiarizing with the butterfly identification (it was possible because the researcher worked on birds in the same study area for almost 4 years) and subsequent data collection was done by single observer (BKA). We identified butterflies at the wing with the help of photo plates and identifying characters provided in Haribal (1992) and Wynter-Blyth (1957). In cases where instant identification based on wing characteristics was not possible, the butterflies were caught using insect net, matched with the photo plates and identification characters of the book mentioned above, and released them back into the forest after taking photographs. Identification in such cases was ascertained by both the authors with careful examination of photographs and characters noted in the field. No collection of specimen was done during this study in Sikkim. We sampled each point uniformly covering three major seasons viz., pre-mon-

soon (Mar–May), monsoon (June–August) and post-monsoon (September–November).

Data analysis

We considered species richness as total number of species observed, and abundance as total butterflies counted during the sampling. We computed butterfly species richness from pooled data from all seasons for all elevation sites along the gradient. Additionally we also estimated species richness for three major seasons (pre-monsoon, monsoon and post-monsoon). We obtained weather data (temperature and precipitation) of seven locations in the study area from Indian Meteorological Department and Indian Army. Based on these data, we estimated MAT, MAP, MI and AET for all study transect using standard equations (see Acharya et al. 2011a, b for details). Similarly, we used quadrat sampling method for enumeration of trees and shrubs (the details of the sampling procedure and estimation of various community parameters of vegetation are available in Acharya et al. 2011a, b).

We used ordinary least square regression (OLS) to assess the relationship between butterflies species richness and elevation. We evaluated the effect of environmental factors (MAT, MAP, MI and AET) and habitat variables (TSR, TD, SSR and SD) on butterfly species richness and abundance using Pearson correlation coefficient. We then used multiple stepwise regressions, considering only the significantly correlated factors, to figure out the most determinant variables for butterfly richness pattern. Using software ‘R’ version 2.11.0, we generated regression model [total butterfly species richness (TBSR) \sim TSR + SSR + MAT + MAP + MI + AET] using butterfly species richness as response variables and habitat variables and environmental factors as predictor variables. In each step, we then dropped one factor with lowest AIC and sums of squares until we found no significant difference between the model with or without the predictor variable in consideration.

We examined pattern of species turnover rate between two consecutive elevational transects using Whittaker’s beta index following Rahbek (1997). Beta index (β) = $S/\alpha - 1$, where S is the total number of species in two consecutive transects and α is the average species richness of pair of transects. We used Pearson correlation analysis to establish the relation between turnover rate and mean elevation between the two transects.

We estimated the range of each butterfly species 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 as done in other studies (e.g., Brehm et al. 2007). We then generated the range profile of butterflies using lower and upper elevation limits.

Table 1 Details of sampling locations of butterflies along the elevation gradient in Sikkim, Eastern Himalaya

Transect	Elevation (m)	Location	Latitude (° 'N)	Longitude (° 'E)
T1	300	Bardang	27 12.1	88 28.9
T2	450	Reshep Dalep	27 14.8	88 27.2
T3	600	Namphing	27 14.3	88 28.4
T4	750	Pabong	27 15.1	88 26.6
T5	900	Sankalang Dzongu	27 29.3	88 30.6
T6	1050	Sankalang Toong	27 29.4	88 30.7
T7	1200	Barphok (Dzongu)	27 29.5	88 30.2
T8	1350	Toong	27 33.1	88 38.5
T9	1500	Theeng	27 34.2	88 39.2
T10	1650	Chungthang	27 36.2	88 38.6
T11	1800	Bop	27 37.1	88 40.1
T12	1900	Menshithang	27 37.6	88 36.9
T13	2150	Khedum	27 37.7	88 42.2
T14	2400	Rabum	27 39.8	88 36.3
T15	2650	Bitchu	27 39.5	88 43.7
T16	2850	Lachung	27 41.1	88 45.4
T17	3050	Phuni	27 45.2	88 43.8
T18	3250	Singba	27 46.8	88 42.5
T19	3450	Yumthang	27 48.4	88 42.7
T20	3650	Yumthang	27 49.3	88 42.5
T21	4000	Shivmandir	27 51.4	88 41.6
T22	4350	Yumesamdong (S)	27 52.2	88 41.7
T23	4700	Yumesamdong (N)	27 54.8	88 41.9

Results

Species richness along elevation gradient

We observed a total of 2749 butterflies representing 161 species and six families (see supplementary material) after the completion of 1014 point counts during this study in Sikkim. Familywise richness and abundance of butterflies are provided in Table 2. Species richness pattern followed declining trend along the elevation gradient ($R^2 = 0.835$; $P \leq 0.01$; Fig. 2). With a hump at 1000 m, species declined sharply up to 3000 m with no apparent change beyond this elevation. Elevational pattern of species was similar among all three seasons; richness showed negative trend with elevation during pre-monsoon ($R^2 = 0.783$; $P \leq 0.01$), monsoon ($R^2 = 0.818$; $P \leq 0.01$) and post-monsoon ($R^2 = 0.664$; $P \leq 0.01$) (Fig. 2).

Analysis at the family level showed that representatives of only three families (Nymphalidae, Papilionidae and Pieridae) occurred all along the gradient. Families Hesperidae, Lycaenidae and Riodinidae restricted be-

Table 2 Familywise species richness and abundance of butterflies observed along the elevation gradient in Sikkim, Eastern Himalaya

Family	Species richness	Abundance
Hesperidae	6	78
Lycaenidae	22	359
Nymphalidae	85	1314
Papilionidae	26	386
Pieridae	18	537
Riodinidae	4	75
Total	161	2749

low 2400, 2800 and 2500 m, respectively (Fig. 3). Species richness pattern of four butterfly families followed declining trend along the gradient (Fig. 3). No apparent pattern was observed in Hesperidae and Riodinidae families, which might be due to lesser number of species detected in these families (Table 2).

Determinants of butterfly richness and abundance along the elevation gradient

Butterflies showed close association with various habitat variables and environmental factors. Total butterfly species richness and abundance correlated positively and significantly with tree species richness (TSR), shrub species richness (SSR), mean annual temperature (MAT), mean annual precipitation (MAP), MI (moisture index) and actual evapotranspiration (AET) (Table 3). Similar trend was observed in butterfly species richness and abundance among various seasons. In the stepwise multiple regression model, among the set of correlated variables, MAT and AET remained the most important determinants for butterfly species richness pattern in the Eastern Himalayan elevation gradient (Table 4).

Species turnover along the elevation gradient

The rate of butterfly species turnover ranged from 0.11 to 0.75 with the highest value (0.75) between 3650 and 4000 m. We observed two major peaks of turnover i.e., between 1650 and 1800 m, and 3650 and 4000 m (Fig. 4). Species turnover between two consecutive ele-

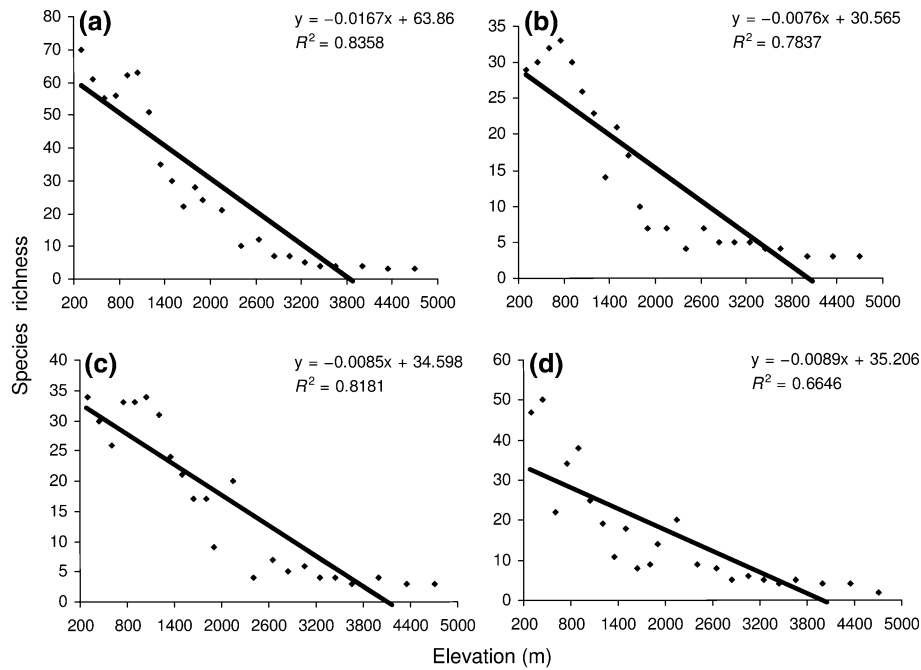


Fig. 2 Species richness pattern of butterflies along the elevation gradient of Sikkim, Eastern Himalaya. Total species richness (a), species richness during pre-monsoon (b), monsoon (c) and post-monsoon (d). All R^2 values are significant at $P \leq 0.01$

vational transects tended to increase with elevation but the relationship was not statistically significant ($P > 0.05$). That is, butterfly communities along transects at high elevations tended to differ more from one another than did butterflies at lower elevations.

Species range size distribution

Most butterfly species had narrow distribution range along the Eastern Himalayan elevation gradient. Number of species sharply declined with increasing range size. Of the total, 49 % species had < 500 m range with 25 % species restricted to single elevation site. Similarly, 38.5 % species restricted below 2000 m elevation, whereas only 3 % species occurred specifically above 2000 m (Fig. 5). Dark Clouded Yellow (*Colias fieldii fieldii*) was the most widely distributed species (range size > 3500 m) and none of the butterfly species occurred all along the elevation gradient in Sikkim, Eastern Himalaya.

Discussion

Butterfly species richness followed declining trend along the elevation gradient in Sikkim, Eastern Himalaya. With a hump at 1000 m, species sharply declined along the elevation gradient. Compilation of secondary information on elevation range of butterflies based on Haribal (1992) reflected high richness below 1800 m with peak at 900–1800 m elevation band (see Acharya and

Vijayan 2011). While we report pattern based on 161 species only but our study confirms that peak lies within 900–1800 m band (as reported in literature). As elevation band considered in this study was far lesser (150–350 m) compared to 900 m band (in literature), we infer more specifically that maximum species occur at around 1000 m elevation with declining ends. Chettri (2000, 2010b) also reported decrease in butterfly species richness with increasing elevation in the Western part of Sikkim Himalaya but the lowest elevation of the study area was 1800 m. There is a possibility of missing species detection and/or mis-identification during sampling (as it is likely in all ecological monitoring) which might alter the observed pattern. But considering the similarity in richness pattern in this study with available data (i.e., Haribal 1992), it appears that overall elevational pattern of butterflies in Sikkim might not change significantly with addition of those likely missed species.

The elevational pattern reported for butterflies in the present study has similarity with the pattern for Himalayan fishes (Bhatt et al. 2012) but slightly different from plants and other vertebrates groups from the same region (Chettri 2010a; Chettri et al. 2010; Acharya et al. 2011a, b). Since all these fauna and flora showed peak within 1000–2000 m elevation, the slight differences in elevation for richness peak among taxonomic unit might be due to differences in physiological requirements of each group of organisms (Jankowski et al. 2013) or availability of suitable habitats and/or variability in distribution of resources specific to the organism.

Decline in species richness along elevation gradient is observed in 25 % of the cases among various taxonomic

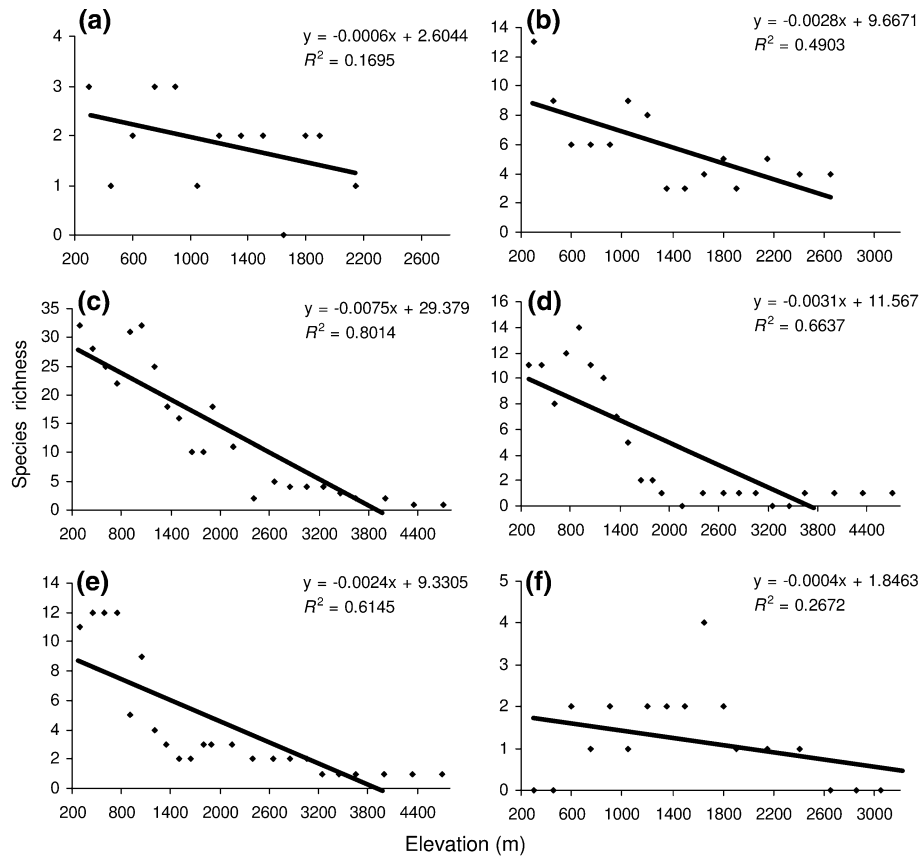


Fig. 3 Familywise species richness pattern of butterflies along the elevation gradient of Sikkim, Eastern Himalaya. HesperIIDae (a), Lycaenidae (b), Nymphalidae (c), Papilionidae (d), Pieridae (e) and Riodinidae (f). All R^2 values are significant at $P \leq 0.01$

Table 3 Correlation analysis between butterfly species richness and abundance with habitat variables and environmental factors

	TSR	TD	SSR	SD	MAT	MAP	MI	AET
TBSR	0.651**	-0.37	0.587**	-0.147	0.914**	0.914**	0.542**	0.961**
TBSA	0.547**	-0.087	0.422*	-0.082	0.856**	0.856**	0.491*	0.918**
PMBSR	0.613**	-0.079	0.519*	-0.158	0.885**	0.885**	0.514*	0.939**
PMBSA	0.637**	-0.064	0.482*	-0.127	0.855**	0.855**	0.497*	0.898**
MBSR	0.712**	0.056	0.666**	-0.091	0.904**	0.904**	0.553**	0.932**
MBSA	0.692**	-0.04	0.568**	-0.033	0.874**	0.874**	0.527**	0.905**
POMBSR	0.510*	-0.03	0.419*	-0.163	0.815**	0.815**	0.477*	0.884**
POMBSA	0.348	-0.124	0.253	-0.085	0.738**	0.738**	0.404	0.822**

TSR tree species richness, TD tree density, SSR shrub species richness, SD shrub density, MAT mean annual temperature, MAP mean annual precipitation, MI moisture index, AET actual evapotranspiration, TBSR total butterfly species richness, TBSA total butterfly species abundance, PMBSR pre-monsoon butterfly species richness, PMBSA pre-monsoon butterfly species abundance, MBSR monsoon butterfly species richness, MBSA monsoon butterfly species abundance, POMBSR post-monsoon butterfly species richness, POMBSA post-monsoon butterfly species abundance

** $P \leq 0.01$

* $P \leq 0.05$

groups (see Rahbek 2005). In general, this study confirms the findings of most previous studies on insects including butterflies. Bhardwaj et al. (2012) found negative trend of butterfly diversity in the western Himalayan elevation gradient. Similarly, declining trend of butterfly species richness with elevation was reported from Great Basin of USA (Fleishman et al. 1998), Spain (Sanchez-Rodriguez and Baz 1995) and Vietnam (Vu

and Yuan 2003). 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 spatial gradients (Fleishman et al. 1998; Vu and Yuan 2003; Vu 2009; Foristera et al. 2010).

The declining trend observed in this study might be attributed to decrease in temperature and rainfall to-

Table 4 Regression coefficients of stepwise multiple regression analysis [final model (total butterfly species richness \sim MAT + AET)] with butterfly richness as response and various environmental factors and habitat variables as predictor variables generated using software 'R' version 2.11.0

	Estimate	Std. Error	t value
(Intercept)	-17.65573	2.94365	5.998***
MAT	-1.89888	0.79747	2.381*
AET	0.07802	0.01329	5.870***

MAT mean annual temperature, AET actual evapotranspiration

*** $P \leq 0.001$

* $P \leq 0.05$

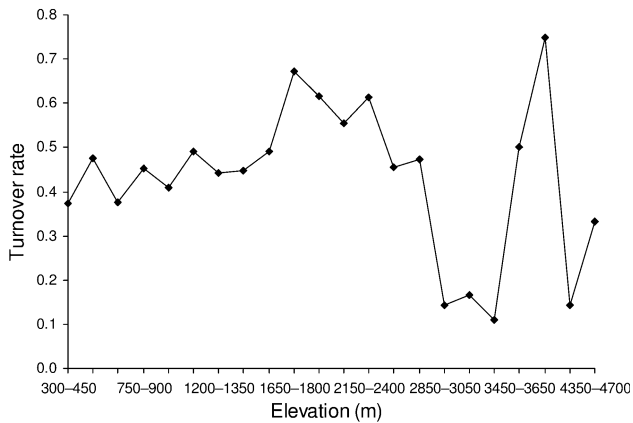


Fig. 4 Butterfly species turnover rate between consecutive elevational transects in Sikkim, Eastern Himalaya. Data points represents turnover rate between two consecutive elevational transects, calculated using Whittaker's beta index (β) = $S/\alpha - 1$, where S is the total number of species in two consecutive transects and α is the average species richness of pair of transects

wards higher elevation. The rate of temperature decline in Sikkim Himalaya was reported as -0.62 °C at every 100 m rise in elevation (Acharya et al. 2011b) but the rate of decline increases above 2400 m (-1 °C at every 100 m rise in elevation; see Chettri et al. 2010). Butterfly species showed positive correlation with MAT and MAP in Sikkim. Temperature surrogates thermal energy availability of an ecosystem and has largely determined global patterns in plant and animal diversity (Clarke and Gaston 2006; Craig and Klaver 2013; Wu et al. 2013). The so called *metabolic niche hypothesis* argues that temperature allows a greater range of energetic lifestyles at warmer sites and thus influences diversity of organisms (see Clarke and Gaston 2006). The thermal energy-diversity contention appears true for butterfly richness in Western Himalaya (Bhardwaj et al. 2012), biogeographical patterns of butterflies in boreal regions (Luoto et al. 2006) and the ant species richness along the Western Himalayan elevation gradient (Bharti et al. 2013). Butterflies need certain level of temperature (thermal energy) and moisture for their activity, and hence, unable to cope up with the extreme cold and dry climatic conditions prevalent at higher elevations (Haribal 1992; Fleishman et al. 1998; Kehimkar 2008; Ilian et al. 2012).

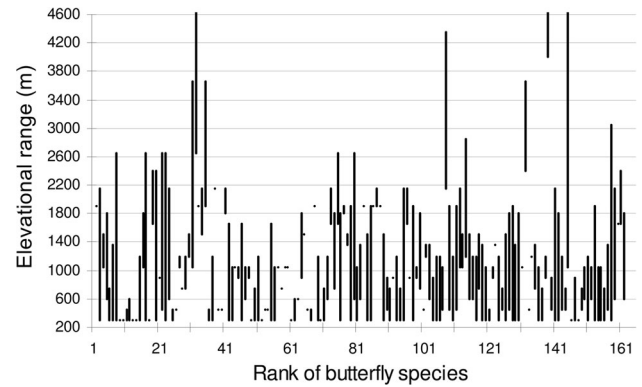


Fig. 5 Elevational range profile of butterflies in Sikkim, Eastern Himalaya. Rank to the butterfly species are assigned in ascending order as per the list of species provided in the supplementary material

Here we found strong support for productivity (AET surrogates productivity; see Chong et al. 1993; Rahbek 1997) and habitat variables (TSR and SSR) for butterfly species richness pattern. Habitat heterogeneity, and thus productivity, decreases with elevation mostly due to declining trend of plant species richness (Lieberman et al. 1996; Grytnes and Beaman 2006) or lesser leaf size and specific leaf area of plants (Garibaldi et al. 2011) resulting in the concomitant decline of insects. Contemporary climate, productivity and habitat heterogeneity have been considered as the major drivers of elevational distribution of species (Rosenzweig 1995; Kluge et al. 2006; Brehm et al. 2007; Whittaker 2010; Yu et al. 2013). High climatic stratification and narrow thermal tolerances of tropical species leads to the high rate of speciation in the tropical region causing declining trend of species towards temperate zone (see Cadena et al. 2012).

Other potential mechanisms such as area, geometric constraints and historical events might be important for the elevational pattern of butterflies. While we have not evaluated the role of historical factors, the effect of area and geometric constraints have been ruled out considering the large Tibetan plateau located at the higher elevation areas of Sikkim (see Acharya et al. 2011a) and little applicability of geometric constraints along smaller geographical scales (Dunn et al. 2007). Additionally, geometric constraints theory found no support for other taxonomic groups (trees, amphibians, reptiles and birds) along the Eastern Himalayan elevation gradient (Chettri 2010a; Chettri et al. 2010; Acharya et al. 2011a, b), and species richness pattern globally (Hawkins and Diniz-Filho 2002; Dunn et al. 2007; McCain 2009) because it does not provide biological explanations for the resultant patterns (McCain 2003).

Butterflies depicted high turnover in species composition along the elevation gradient of Eastern Himalaya. High turnover is the indication of diverse regions where species composition among sites and vegetation types differs significantly (Harrison et al. 1992; Gaston and

Blackburn 2000; Aynekulu et al. 2012). Distinct zonation of vegetation in our study area might have caused high species turnover of butterfly community composition. The turnover rate was high especially at vegetation transition zones with maximum value between 3650 and 4000 m. At these elevations, forests are largely replaced by shrubby vegetation and alpine meadows. The other peak of turnover was observed at 1650–1800 m, where tropical and sub-tropical forests transits to temperate forests. Similar turnover patterns have been found at ecotonal boundaries for butterflies (Despland et al. 2012), birds (Navarro 1992; Koh et al. 2006) and mammals (Nor 2001). Species compositional turnover among sites along the gradients are also caused by changes in the sizes of species pool (Kraft et al. 2011).

Narrow range size of most species reflects that butterflies are sensitive to changes in environmental parameters caused by changes in elevation and physiography (Levanoni et al. 2011). The data shows that around 50 % of the species found at one elevation/vegetation type does not occur at other sites (Fig. 5). 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. The host plant specificity might interplay in range size determinations as small range-sized lepidopterans are host specialists, whereas large range-sized species are generally polyphagous (Brehm et al. 2007). In addition to environmental factors, the physiology and biotic interactions are key determinants of elevational ranges of organisms (e.g., Jankowski et al. 2013).

There are reports that the butterfly ranges are also affected by the global climate change (Parmesan et al. 1999; Foristera et al. 2010; Acharya and Chettri 2012). In response to changing climate, butterflies have shifted their elevational or latitudinal ranges upwards leading to reduced range sizes (Walther et al. 2002; Hickling et al. 2006; White and Kerr 2006; Wilson et al. 2007; González-Megías et al. 2008; Foristera et al. 2010; Eskildsen et al. 2013). The elevational range shifts signify the reduction of habitable area of species threatening their long term chances of survival (Wilson et al. 2005; Chen et al. 2009). Systematic studies in the Himalayan region are necessary for better understanding of such global phenomenon.

In conclusion, butterfly species richness pattern followed declining trend along the elevation in Eastern Himalaya with most species having narrow range sizes. We also observed that 38.5 % species restricted below 2000 m elevation (tropical and sub-tropical forests) but only 3 % restricted above 2000 m elevation indicating the prime importance of low elevation areas (mostly below 2000 m) for conservation of butterflies. It is pertinent to mention here that most of the protected areas in Sikkim are restricted at mid to high elevations but maximum biodiversity occur below 2000 m (trees, butterflies, fishes, amphibians, reptiles and birds peaked below 2000 m). Hence, conservation of butterflies (and also other floral and faunal groups) restricted at lower elevation (outside protected areas) can be achieved only with the conserva-

tion of habitats in the cultivated systems and adjoining community owned forests patch and/or small reserve forests. Considering high diversity coupled with distinct community assemblages, low elevation areas in the human dominated landscapes are very important for conservation of biodiversity including butterflies in the Eastern Himalaya although entire elevation gradient is crucial especially for small range-sized species.

While a few explorative and empirical elevational pattern studies on fauna and flora are undertaken in the Sikkim region of the Eastern Himalaya, detail ecological study of individual species (especially endemics and threatened) are lacking. Additionally, understanding responses of flora and fauna to the global climate change is urgently needed. Most of the low elevation areas (that are rich in species) falls in the human dominated landscapes/cultivated systems. Hence, assessment of the potentiality of these areas in biodiversity conservation would probably be the most significant way forward.

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