Conservation Science
Translating Knowledge into Actions

# Distribution of butterflies along a trekking corridor in the Khangchendzonga Biosphere Reserve, Sikkim, Eastern Himalayas

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## Summary

**Aim** The aim of the research was to understand the distribution pattern of butterflies along attitudinal and disturbance gradients in a trekking corridor in Sikkim, India.

**Location** Khangchendzonga Biosphere Reserve, West Sikkim, India.

**Material and Methods** The study focused on two sets of data, one on inventory of species along the trekking corridor and the other on butterfly species and their numbers along the 19 permanent plots measuring 30x40m. Among the 19 plots, four each was laid in degraded forests (canopy cover <40%) and undisturbed forests (canopy cover >40%) within the warm temperate broadleaf forest (1780–2350 m), and five and six in degraded and undisturbed forest respectively in cool temperate sub-alpine forest (2350–3600 m). The surveys were conducted thrice a season for two seasons. All individuals recorded from the 114 pseudo replicate plots (19 plots, 3 times a season for 2 seasons) and the casual observations were considered for preliminary analysis for dominant families.

**Key findings** Among the 189 species recorded, Nymphalidae family was dominant (44%) followed by Lycanidae (19%) and the least number of species was recorded from Riodinidae (1%). Likewise, 69% of the species recorded were found to be 'fairly common', 16% 'common' and 11% rare. The highest number of species per transect was recorded from the disturbed condition (7.1±0.7 Standard Error) at warm temperate broadleaf forest (WTBF) followed by undisturbed condition (6.7±0.8) and the least was recorded at the undisturbed condition (4.1±0.5) of cool temperate sub-alpine forest (CTSF). Similarly, the butterfly species diversity, its richness and evenness significantly differed between the forest types i.e. WTBF and CTSF and showed negative correlation along altitudinal gradients.

**Conservation implications** Study concludes that the human interventions and tourism enterprises are bringing subtle changes in butterfly habitat and may have major effects on some of the habitat specific species if they are not seriously considered in the management interventions.


**Keywords**: Butterfly, trekking corridor, forest types, altitude, distribution, management, Sikkim, Himalayas

## Original Article

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## Introduction

Sikkim, a small (7096 sq km) Indian state, lying between 27$^{0}$03’47” and 28$^{0}$07’34” N and 88$^{0}$03’40” and 88$^{0}$57’19” E, is widely acknowledged by scientists as India’s most critical and biodiversity rich areas (Myers et al. 2000, Mittermeier et al. 2004, CEPF 2005, Chettri et al. 2008, Arrawatia and Tambe, 2011). Though it was once a forbidden independent country, Sikkim has a rich history with many eminent naturalists visiting this biodiversity rich state. Among them were the noted entomologists like De Niceville (1881, 1882, 1883, 1885), Elwes (1882), Elwes and Moller (1888), Gammie (1877) and Sanders (1942) who have made extensive documentation of butterflies from Sikkim. However, the legacies of those pioneers were not taken forward and as a result the documentation of butterflies in Sikkim was very sporadic thereafter. The butterfly of Sikkim was brought in the limelight only recently through a book on butterfly (Haribal 1992) and thereafter the interests towards butterfly research in the state have increased (Chettri 2000, Kunte 2010, Acharya and Bijayan 2011, Rai et al. 2012).

Though, the state is rich in biodiversity, in the recent past, the forested habitats have witnessed immense human pressures in terms of resources extraction and habitat destruction (Chettri et al. 2002, Sundriyal and Sharma 1996, Sundriyal et al. 1994, Chettri and Sharma 2006). Other drivers of changes such as climate change (Chettri et al. 2010, Chaudhary et al 2011), land use and land cover changes (Tambe et al. 2012) are bringing additional challenges to conservation communities and management authorities in the state. Though butterflies are well known as surrogates for habitat and other biodiversity (Kremen 1992, Chettri 2010), so far, there has been very limited effort made on community ecology in relation to their habitats for butterfly in Sikkim (see Chettri 2000, Acharya and Bijayan 2011).

Yuksam–Dzongri trekking corridor in west Sikkim is an important tourist destination (Rai and Sundriyal 1997). The trail, which falls within Prek Chu watershed in west Sikkim, is an important repository of biodiversity including butterfly species (Chettri et al. 2001, 2005, Bhattacharya et al. 2010, 2012, Chettri 2010, Sathyakumar et al. 2011). However, disturbances such as firewood extraction, fodder lopping and cattle grazing are worldwide problem and have increased during the last two decades in this trekking corridor due to growth in tourism and population (Maharana et al. 2000, Chettri et al. 2002, Chettri and Sharma 2006). These have resulted in the fragmentation and deterioration of wildlife habitats (Chettri et al. 2005, Chettri 2010). Vegetation structure showed remarkable changes in species composition at human disturbed locations compared with relatively undisturbed areas along the corridor (Chettri 2000). However, so far, there has not been any attempt to understand the human induced disturbances on butterfly communities within this trekking corridor. Therefore, an exploratory monitoring of butterflies in the area that encompassed a wide range of altitude and diverse forest types is of special importance because of disturbances along the trek in recent years. The need for documentation on butterflies with their affinity to available habitats along a trekking corridor was realised. Thus, this study is focused on distribution of butterflies along the altitudinal and forest disturbance gradients along with seasonal differences in the Yuksam-Dzongri trekking corridor in the Khangchendzonga Biospehere Reserve in Sikkim, India.

## Materails and methods

### *Study area*

Yuksam-Dzongri trekking corridor (26 km long) encompasses elevation from 1780 m to 4000 m (**Figure 1**). The trail passes through Sachen, Bakhim and Tshoka in the south-western part of Khangchendzonga Biosphere Reserve in Sikkim, India. Yuksam is a trailhead for this corridor and leads to the Base Camp, Dzongri, Thangsing and Gocha La in the West Sikkim (**Figure 1**). According to classification by Champion and Seth (1968), the area broadly comes under the sub-type 11b of northern montane temperate forest type and the group 12 of Himalayan moist temperate forest, sub-alpine scrub and pasture land. The corridor broadly has three forest types viz., temperate forest (1780-2730 m amsl), mixed conifer forest/sub-alpine (2730-3650 m) and alpine scrub and grasses (above 3650 m).

### *Data collection*

Two sets of data were gathered on butterfly species from the study area. The first set was collected with casual observation while trekking along the corridor and a comprehensive checklist of butterflies was prepared. The second set of data were collected with butterfly species and their numbers along the 19 permanent plots measuring 30x40m for one year stretched over 1998-1999. These plots were established along the trekking corridor based on forest resources utilisation pattern by the local communities and tourism entrepreneurs to monitor tree species diversity, regeneration and woody biomass dynamics (see Chettri et al. 2002). Among the 19 plots, four each was laid in degraded forests (canopy cover <40%) and undisturbed forests (canopy cover >40%) within the warm temperate broadleaf forest (1780–2350 m), and five and six in degraded and undisturbed forest respectively in cool temperate sub-alpine forest (2350–3600 m).These degraded and undisturbed forests were categorized on the basis of additional disturbance indicators such as higher intensity of trampling by domestic cattle, higher firewood and fodder extraction, low regeneration etc. (see Chettri et al. 2005). Butterflies were monitored, both by visual and baited trap methods, in the 19 permanent plots, using 100m transects, cross-

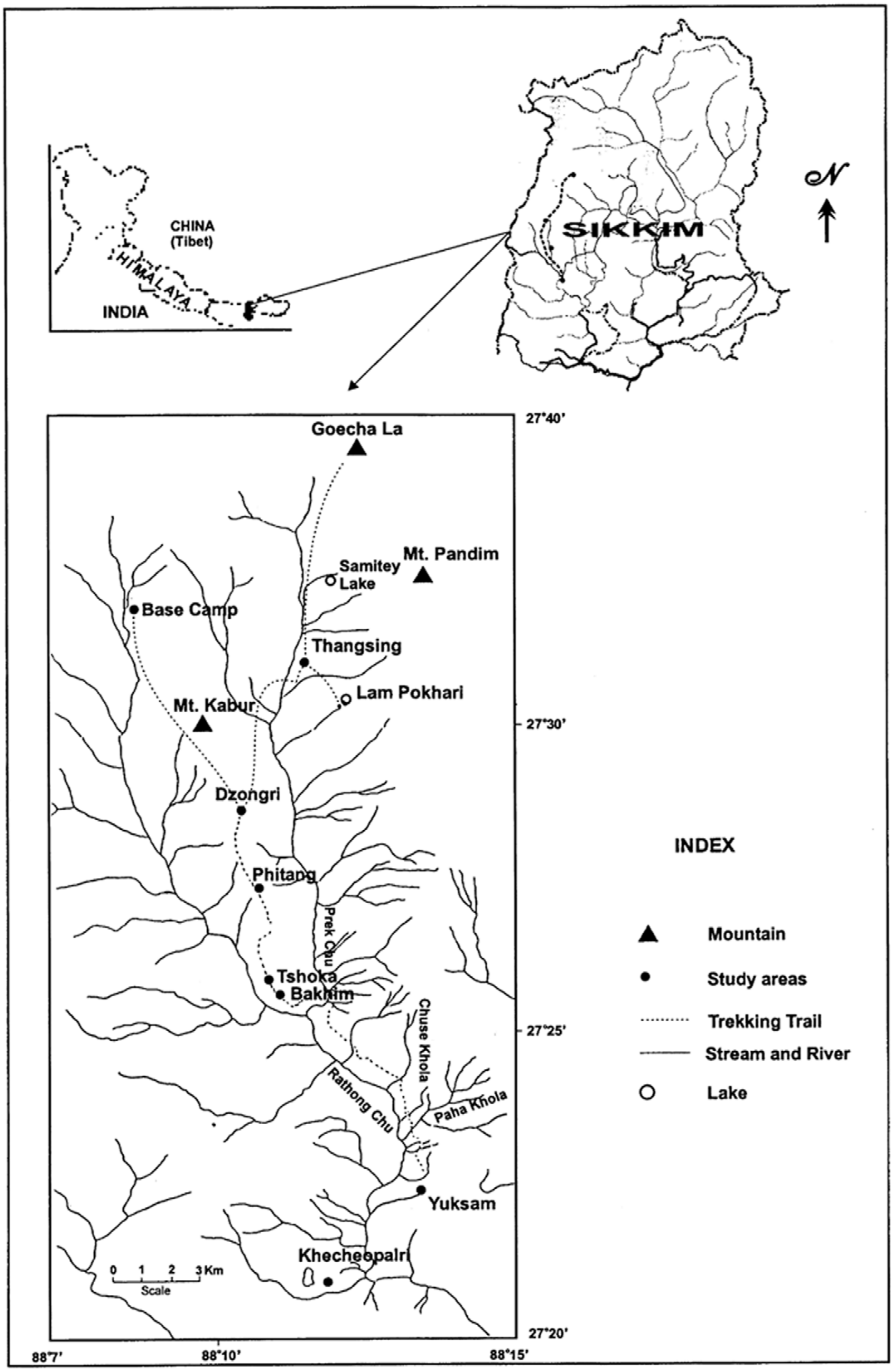


**Figure 1**: Map showing Yuksam-Dzongri trekking corridor in the Khangchendzonga Biosphere Reserve, Sikkim Himalayas.

ing each of the permanent plots through its center. The surveys were conducted thrice a season for two seasons (within the same 19 plots) during summer (May-August) and in winter (October-February) stretched over one year time during 1998 and 1999 following Pollard et al. (1975) and Pollard (1977). During each survey, visual observations were made by walking across each of the 100m transects twice a day (morning 11:00hr and afternoon 13:00hr) in good weather days and the species were recorded from 10m distance from both side of the transect. Canopy species and the species that were not easily recognised with bare eyes during their flight were identified with the help of fermented banana baits following De Vries (1988). Occasionally, the canopy foragers were also observed with the help of a binocular when there was difficulty in butterfly identification. Identifications of all the specimens to species were done refereeing photo-plates and description provided by Haribal (1992).

***Data analysis***

All individuals recorded from the 114 pseudo replicate plots (19 plots, 3 times a season for 2 seasons) and the casual observations were considered for preliminary analysis for dominant families. From the recorded list each species was categorised based on the individuals and species sighted and segregated to common (more than 10 sightings), fairly common (more than 5 sightings), uncommon (3-4 sightings) and rare (1-2 sightings). However, only the species and individuals recorded from transects were used for statistical analysis. Before the statistical analyses, all recorded species and their number were segregated in two categories (summer and winter). Then the species and individual number were combined together to an individual transect level based on their cumulative number of species and average number of individuals. Thus, the analysed data are based on 38 replicas (19 plots x 2 seasons). This helped me to minimise the error brought in by pseudo replicates where chances of repetition in counting the same species were avoided. The datasets were tested for normal distribution both for overall species distributions and the distributions between the two seasons. With these datasets, five different analyses were made to address different aspects of butterfly distribution along the trekking corridor as discussed below:

As an initial step towards understanding distributions of species, Sorensen Similarity Index (Sorensen 1948) was calculated between and within the degraded and undisturbed forests in warm temperate broadleaf forest (WTBF) and cool temperate sub-alpine forest (CTSF) as well as in between WTBF and CTSF. Secondly, using the species data composition, community structure of butterfly (Shannon diversity (*H*'), Margalef's species richness index (*S*) and Pielou's evenness index (*E*)) were analyzed using statistically formulae available from Hayek and Buzas (1997). This was followed by Analysis of Variance (ANOVA) in which seasonal variations on mean butterfly number between forest types, habitat conditions and the seasons were analysed. In the fourth analysis, effects of the forest types and habitat conditions on the diversity indices were tested using Mann-Whitney U test following Hill et al. (1995). In addition, Spearman correlation was also used to see the relationships between butterfly diversity indices and the altitudes (irrespective of habitat conditions and types). Statistical analysis was performed using the windows-based SYSTAT program (SYSTAT 1996).

## Results

***Butterfly species composition***

Among the 189 recorded species Nymphalidae were dominant (44%) followed by Lycanidae (19%) and Papilionidae (16%), Pieridae (14%), Hesperidae (5%) and the least number of species were recorded from Riodinidae (1%) (**Figure 2a**, Appendix A). Likewise, 69% of the species recorded were found to be 'fairly common', 16% 'common' and 11% rare (**Figure 2b**, Appendix 1).

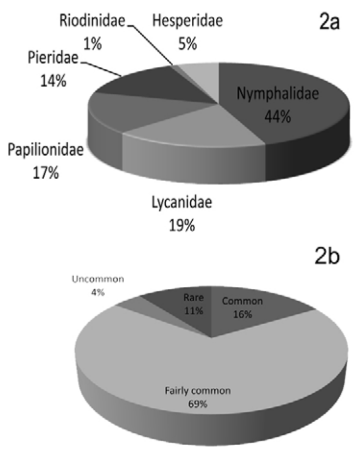


**Figure 2**: The representative families of butterflies recorded from the Yuksam-Dzongri trekking corridor (2a) and their status (2b) in the Khangchendzonga Biosphere Reserve, Sikkim Himalayas.

The mean number of species and their densities at different forests are presented in **Table 1**. The highest number of species per transect was recorded from the disturbed condition (7.1±0.7 Standard Error) at warm temperate broadleaf forest (WTBF) followed by undisturbed condition (6.7±0.8). The least mean number was recorded at the undisturbed condition (4.1±0.5) of cool temperate sub-alpine forest (CTSF). Similarly, butterfly diversity, richness and evenness were also high at the disturbed conditions of WTBL and CTSF except for diversity which was high in the undisturbed forest condition in CTSF (see **Table 1**). The result showed that the disturbed forest of the WTBL have higher number of species and diversity indices compared to undisturbed condition. Similar trend was also seen in the CTSF with an exception for diversity index in which high value was recorded from undisturbed forest condition. great orange tip (*Hebormoia glaucippe*) and plain tiger (*Danaus chrysippus*) were found only at the undisturbed condition of WTBF. Likewise chocolate demon (*Ancistroides nigrita*), common mormon (*Papilio polytes*) and yellow owl (*Neorina hilda*) were recorded only from the degraded condition of CTSF whereas only one species

**Table 1**: Sample size, composition and species diversity indices of butterfly in different habitat conditions and forest types at Yuksam-Dzongri trekking corridor.

| Parameters | Warm temperate broadleaf forest | | Cool temperate sub-alpine forest | |
|---|---|---|---|---|
| | Disturbed | Undisturbed | Disturbed | Undisturbed |
| Sampling plots (100 m transect) | 4 | 5 | 6 | 4 |
| Total species recorded | 36 | 44 | 22 | 27 |
| Species per transect (mean±SE) | 7.1±0.7 | 6.7±0.8 | 4.1±0.5 | 5.2±0.6 |
| Individuals per transect (mean±SE) | 20.6±1.4 | 24.2±1.2 | 16.8±1.3 | 18.1±0.8 |
| Shannon diversity (H') | 3.39 | 4.77 | 3.32 | 2.28 |
| Margalef's species richness | 10.91 | 11.29 | 10.58 | 9.87 |
| Pielou's evenness | 0.33 | 0.59 | 0.22 | 0.28 |

Some species were recorded only from specific habitat conditions reflecting their habitat specificities. Seven species, namely chestnut tiger (*Parantica sita*), dark judy (*Abisara fylla*), golden saphaire (*Heliophorus brahma*), great morman (*Papilio memnon*), orange staff seargeant (*Athyma cama*), red spot jezebel (*Delias descombesi*) and spectacle swardtail (*Pazala mandarinus*) were exclusively recorded from the degraded conditions of WTBF. Similarly, common albatross (*Appias albina*), common evening brown (*Melanitis leda*), common maplet (*Chersonesia risa*), dark cerulean (*Jamides bochus*), (hill jezebel (*Delias belladonna*)) was recorded as habitat specific species from the undisturbed condition of CTSF. The species similarity (Sorensen Similarity Index) between the degraded and undisturbed conditions in the WTBF was significantly higher (69%) than CTSF (31%). Interestingly, 40% of the species were also recorded as common between the WTFB and CTSF. However, the similarities between the two degraded forests (17%) and two undisturbed forests (7%) were notably less.

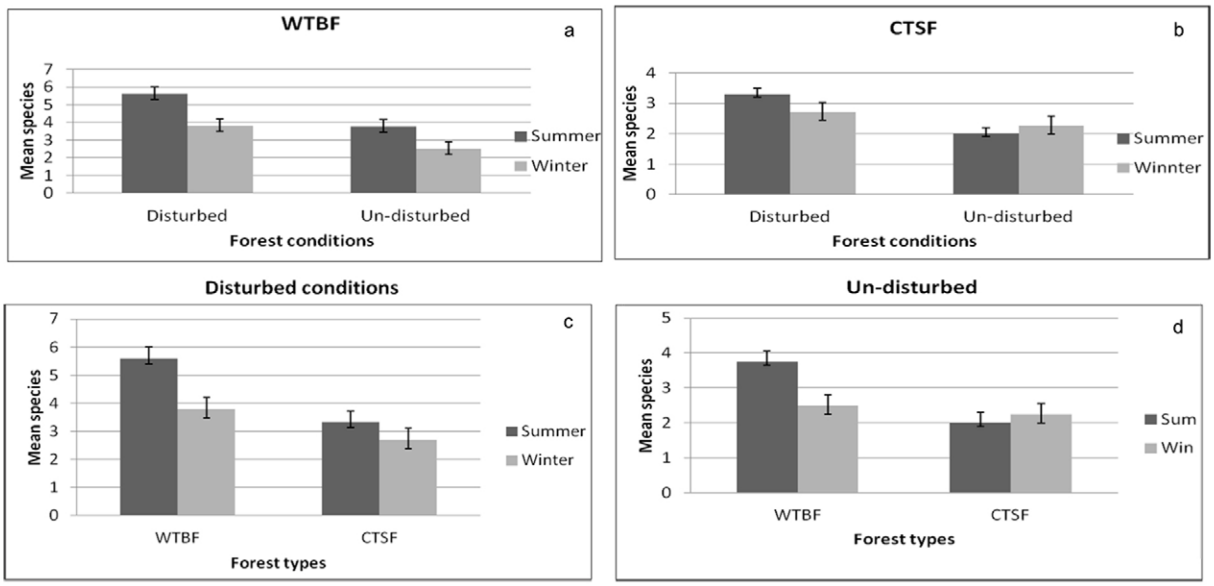


**Figure 3**: Figure 3: Mean number of butterfly species in the summer and winter seasons during 1998-1999 in the degraded and undisturbed conditions of warm temperate broadleaf forest (WTBF, 3a) and cool temperate sub-alpine forest (CTSF, 3b) and within degraded (3c) and un-disturbed condition (3d) between the forest types in Yuksam-Dzongri trekking corridor

***Spatial and seasonal variations in butterfly species***

The mean butterfly species number differed significantly between the habitat conditions, forest types and seasons (ANOVA: $F_{1,30}$= 16.8, $P$<0.001; $F_{1,30}$= 13.8, $P$<0.001; $F_{1,30}$= 6.9, $P$<0.003 respectively) (see Figure 3a,b,c and d). Significant interaction between the seasons and forest types ($F_{1,30}$= 4.0, $P$<0.005) indicates that they collectively have more influence in the variations. However, the other interactions were found insignificant.

Similarly, the butterfly species diversity, its richness and evenness significantly differed between the forest types i.e. WTBF and CTSF (Mann Whitney test values were $U$=290.0, P<0.001, $U$=282.5, P<0.003, $U$=283.0, $P$<0.003 respectively) (**Table 2**). However, except butterfly species richness ($U$=92.5, $P$<0.01), their diversity and evenness between the degraded and undisturbed conditions were insignificant (**Table 2**). Thus, the results suggest that the diversity indices significantly differ between forest types, but they showed weak and insignificant relations with habitat conditions except on the diversity. When the datasets (diversity, richness and evenness) were used for Spearman correlation with altitudes (irrespective of habitat condition and types), they showed significant negative relations with the increasing altitudes (**Table 3**). However, the overall distribution patterns on these diversity indices varied with the rise in altitudes (see **Figure 4**).

**Table 2**: Comparative assessment of butterfly community structure between forest conditions (open and closed canopy) and forest types (lower forest and upper forest) of Yuksam-Dzongri trekking corridor

| Variable | Forest condition effect | | | Forest type effect | | |
|---|---|---|---|---|---|---|
| | Mann-Whitney* U- value | $X^{2\#}$ | P | Mann-Whitney! U- value | $X^{2\#}$ | P |
| BSD | 154.5 | 4.0 | 0.51 | 290.0 | 10.4 | 0.001 |
| BSR | 92.5 | 6.1 | 0.01 | 282.5 | 8.9 | 0.003 |
| BEV | 109.0 | 3.9 | 0.04 | 283.0 | 9.1 | 0.003 |

(BSD = butterfly species diversity; BSR = butterfly species richness and BEV = butterfly evenness).
*Count number U 0.05(2),16,22; !Count number U 0.05(2),18,20; # chi-square approximation with df 1

**Table 3**: Spearman correlation coefficient for overall butterfly diversity indices and elevation along the Yuksam-Dzongri trekking corridor (n=19, d.f.=17)

| Variables | Elevation | H' | S | E |
|---|---|---|---|---|
| Elevation | 1 | | | |
| Shannon diversity (H') | -0.673** | 1 | | |
| Margalef's species richness (S) | -0.576** | 0.259 | 1 | |
| Pielou's evenness (E) | - 0.604** | 0.686** | 0.474* | 1 |

**P>0.001; *P>0.01

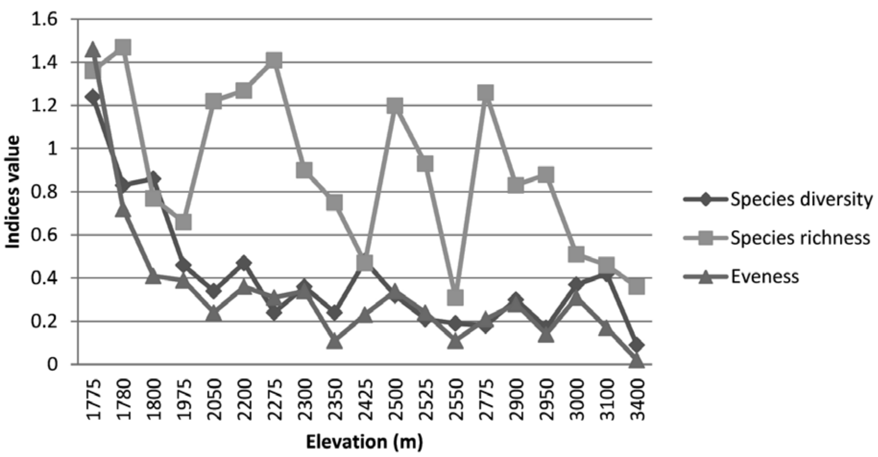


**Figure 4**: Relationship between butterfly diversity indices and elevation along Yuksam-Dzongri trekking corridor, Sikkim.

## Discussion

The butterfly diversity along the Yuksam-Dzongri trekking corridor is rich and the pattern of richness is similar as the bird richness reported by Chettri et al. (2001). The majority of species were occasionally sighted during the casual visits and they were mostly recorded from the lower elevations i.e. riverbanks. The most widely distributed and dominant species were the Nymphalidae as reported by Uniyal and Mathur (1998) in the western Himalayas, suggesting similar pattern of family distribution across the Himalayas. The higher number of butterfly species and their diversity at WTBF suggest that the lower altitude areas are much better habitat for butterfly species compared to CTSF. But, 31% dissimilarity between the degraded and undisturbed forest conditions in WTBF, 69% in CTSF and 40 % in between the WTBF and CTSF suggests that there is *Beta*-diversity effect on butterfly species between these forests. However, the similarities between the two degraded conditions and undisturbed forests were notably low. This could be as a result of differences in altitudes, phenology and the habitat requirements of certain species as explained by Negi and Gadgil (2002).

High number of species and diversity indices found in the degraded condition of WTBF supplements the findings of many other researchers (Cheverton and Thomas 1982; Devy and Davidar 2001). This could be related to higher number of host plants and nectar resources in the degraded conditions compared to undisturbed condition. It was observed that in the degraded conditions, there were higher plant diversity and productivity (Chettri et al. 2002). This could be as a result of enhanced photosynthesis due to availability of higher light intensity as a result of opening of crown cover (Davidar et al.1993). In addition, high relative humidity due to shade trees and dense canopy cover might have affected the number of butterfly species and their diversity in the undisturbed forest conditions. Because, at high relative humidity, that are normally observed in moist rainforests, the larvae are susceptible to viral and bacterial diseases leading to their death (Kremen, 1992, 1994). Furthermore, the low plant species diversity in undisturbed condition as reported in our earlier study (Chettri et al. 2005) could have limited the food resources for both larvae and adults. This finding is in contrary to the report of Hill et al. (1995). In their study, Hill and his co-workers stated that there was greater species richness in an unlogged forest due to greater vegetation cover with more shade. But, this could be due to the physical feature of habitat such as similar temperature, altitude and humidity between the two sites. This might have created microclimate in such habitat and the similarity is crucial for sensitive taxa like butterfly. But in present study, it showed contrasting habitat variations in terms of temperature and vegetation between the two forest conditions (degraded and undisturbed) and forest types (WTBF and CTSF), both in structure and composition (Chettri et al. 2002). However, this contrary finding could be related to the higher number of butterfly in the undisturbed forests in the CTSF. Here, the canopy cover was more open and humidity was low, even in the undisturbed condition, than the WTBL.

Interestingly, there was significant variation among the number of species, diversity, richness and evenness in butterflies when they were treated against the two prevailing seasons, forest conditions and forest types as reported elsewhere (Pearman and Weber 2007). Such variation on diversity indices, which reflects the community composition and distribution pattern, is an important indication in community assessment and habitat management (Helmus et al. 2007). Higher diversity at the degraded conditions suggests that the butterflies use open canopy forest where the diversity of tree species is higher as reflected in our earlier study (Chettri et al. 2002). As discussed in our earlier research (Chettri et al. 2001, 2002, 2005), degraded forests were diverse in their vegetation composition and stratification and butterfly also used these habitat conditions more extensively than the undisturbed forests. Some previous studies have also demonstrated such increase in diversity following forest disturbance (Holloway et al. 1992; Sparks and Parish, 1995). Raguso and Llorente-Bousquets (1990) found an apparent increase in butterfly diversity following fragmentation in the habitats due to selective logging. The significant higher butterfly diversity indices in disturbed forests compared to undisturbed one were found where tree diversity indices were also higher (see Chettri et al. 2002). This suggests that there is strong interaction between the two groups (Hill et al. 1995, Croxton et al. 2005). Moreover, some of the habitat specific species, as discussed in the result section, does have implications on their habitat specificity and need cautious interventions to conserve them as they could be sensitive to even subtle changes in their habitat due to their food habit (Krauss et al. 2004). This relationship is expected because butterfly species diversity is a function of plant species diversity as butterflies and their food plants are the product of coevolution (Ehrlich and Raven 1964, Loertscer 1995, Singh and Singh 1998). However, the population dynamism found in this study could also be subject to their habits as majority of butterfly species uses one habitat condition for feeding and other for basking. Therefore, it was assumed that differences in tree structure, climatic variables, season and other factors along the trekking corridor forest might have brought about such variations.

The Spearman correlations revealed that the differences in butterfly species diversity in the different habitat conditions and forest types, though differed due to human interventions, have maintained normal trend of diversity along the altitudinal gradient. The significant negative correlations with altitudes suggest that there is a normal trend of butterfly diversity as seen for birds and other biodiversity (Chettri et al. 2005). Such decrease of butterfly along the increasing altitude is obviously due to remarkable decrease in temperature along the trail (Chettri 2000), which is an important factor for survival of butterflies (Brakefield 1982). However, the variation in diversity indices, as some of them were not linear along the altitudinal gradients, suggest that there is a serious need to have better understanding on the impact of human disturbances on the level of habitat change and its implication in gradient scale analysis (Nogues-Bravo et al. 2008).

To conclude the results, the Yuksam-Dzongri trekking corridor is rich in butterfly but habitat disturbances through human interventions such as firewood collection, fodder lopping and grazing including tourism pressure are bringing subtle changes in the habitat (Chettri el al. 2001, 2002, 2005, Chettri and Sharma 2006). Although, the area is rich in butterfly species, the discussion so forth has cleared that the disturbance in natural areas brings about changes in biological diversity. Higher diversities in the degraded conditions have reflected that the disturbance is within the intermediate level (Fox 1979). Information on organisms and their response to habitat change due to human disturbance provides important clue in planning and increases conservation efficacy in the protected area management, especially where tourism enterprises are allowed. Therefore, there is an urgent need to address these issues through innovative managerial interventions, both for human pressure and pressure embarking from tourism activities.

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## Biography

Dr Chettri joined ICIMOD in 2002 as a Project Coordinator for Transboundary Biodiversity Conservation and Management and was subsequently promoted to Action Area Team Leader for Biodiversity Conservation and Management in the Environmental Change and Ecosystem Services (ECES) Programme. In this role he was responsible for facilitating stakeholders to formulate strategic plans for conservation and landscape management and for promoting regional cooperation in conservation through participatory conservation planning, policy analysis, and the development of a new policy framework at the landscape level in the Hindu Kush-Himalayas. Dr Chettri has an MSc (1995) and a PhD in Zoology (2000) from North Bengal University, India. Since January 2013, Dr Chettri is leading a team of multidisciplinary professionals working on climate change science, the economic valuation of ecosystem services, biodiversity informatics, and the up-scaling and promotion of transboundary landscapes and trans-Himalayan transects in Kangchenjunga Landscape. Before joining ICIMOD, Dr Chettri served as a Fellow at the Ashoka Trust for Research in Ecology and the Environment in its Eastern Himalayan Programme.

**Appendix A**: List of butterfly showing common name, Latin name, family and status (C-common, FC-fairly common, U-uncommon and R-rare) recorded during the survey.