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Full Length Research Paper

Impact of tropical forest degradation on nymphalid butterflies: A case study in Chandubi tropical forest, Assam, India

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Study examines the hypothesis, whether the diversity of Nymphalid butterflies in tropical primary forest of Chandubi is associated with vegetation structure and canopy openness and that this relationship differs between butterfly taxa in relation to phylogenetic differences in light and shade preferences. Study has emphasized whether the increasing diversity of butterflies in degraded tropical forest is associated with the loss of species with restricted geographical distribution. Study considered altogether eight habitat variables and the t-test using equal variance, Spearman rank correlation and multiple regressions were also used for statistical analyses. Species diversity was analyzed using Margalef's D indices that indicate both the species richness and abundance. Bootstrap method was used to compare the diversity among samples. PCA was done to examine the relationship between vegetation structure and species diversity in primary and degraded forest. The relationship between vegetation factor scores and species diversity in each sampling station in primary and degraded forest was analyzed using stepwise multiple regression. Results indicates that the butterflies species sampled in closed canopy forest had more restricted geographical distribution than those being sampled in disturbed forest. The species with greater light preference had significantly wider geographical distribution, whereas the species with greater shade preferences had significantly narrower geographical range. The stepwise analysis of multiple regressions between the diversity indices of shade groups of butterflies and vegetation density (PRIN 1) of closed forest shows a significant positive relationship, but the relationship was negative when similar analysis was carried out between species diversity indices of light preferred groups and vegetation density. Majority of closed canopy forest butterflies are sensitive to changes in moisture availability and humidity. Thus, changes in canopy cover and light penetration through microclimatic effects on adult and larval survival does have an impact on butterfly distributions and abundance. While the species richness and diversity are higher in degraded forest, the conservation value of primary forest lies more in the presence of species with restricted ranges. Owing to loss of diverse vegetation in degraded forest, the dense canopy cover and transparent ground cover has been reduced and thus leading to decline of forest butterflies species. Study has clearly indicated the strong and significant relationship that exists between the species of narrow range of geographical distribution and species shade preference. The restricted ranges species are affected due to forest degradation. Thus, clearly bringing into light, that increasing diversity in degraded forest is associated with the loss of species with restricted geographical distribution.

Key words: Nymphalid butterflies, forest degradation, primary forests, conservation value, endemic species, geographic distribution range, light and shade groups, phylogeny, tropical forests.

INTRODUCTION

Globally, tropical primary forests reclaimed one sixth of all primary forests that were clear-cut in the 1990s (Wright, 2005) and are likely to be a dominant feature of tropical forest landscapes in the future (Wright and Muller-landau, 2006). Tropical forests which contain much of the Earth's remaining biological diversity are also experiencing unprecedented rates of deforestation (Laurance, 1999; Brooks et al., 2002; Koh, 2007). Again, the South-east Asia has the highest relative rate of net forest loss (0.7%) and degradation (0.4%) in the humid tropics (Achard et al., 2002) and could close up to three-quarters of its original forests and almost half its species by 2100 (Brooks et al., 2003; Koh 2007). Although the effects of deforestation on the vertebrate fauna (for example avian fauna) of south-east Asia have been well reported (Brooks et al., 1997; Sodhi et al., 2005); the responses of less charismatic groups such as insects to habitat disturbance remain relatively poorly understood (Sayer and Whitemore, 1991; Dunn, 2005). This is alarming, considering the global dominance of insects among animal communities in terms of species richness, abundance and biomass (Wilson, 1987; Koh, 2007), as well as the overarching importance of insects in providing ecosystem services for human societies in a variety of viewpoint such as pollination of crops (Nabhan and Buchmann, 1997) predators of crop pest, biological control agent important components of food chain in ecosystem etc. Among all the insects, butterflies are the highly sensitive to habitat disturbance and have been used commonly as an indicator taxon for ecological research (Kremen, 1994; Koh and Sodhi, 2004). Again, many South-east Asian butterflies are endemic to the region and face the grim prospects of global extinction if current levels of deforestation are to continue (Koh, 2007). From a conservation perspective, forest butterfly species (that is those previously only from primary forests) deserve the highest conservation and research attention (Koh, 2007). Mittermeier et al. (2004) identified 34 biodiversity hotspots in the world as areas containing high concentrations of endemic species and undergoing immense habitat loss. South and South-east Asian country overlaps with six of these hotspots (that is Indo-Burma, Sundaland, Wallacea, the Philippines, Western Ghat and Eastern Himalayas). Each of these hotspots has a unique and a complex geological history that probably influenced the contemporary geographical range and local distribution of its species (Sodhi et al., 2004; Koh, 2007). Furthermore, the state of Assam within Northeast India has an overlap of two of its important biodiversity hotspots (for example Eastern Himalaya and Indo-Burma Biodiversity hot-spots), and again, according to Evans (1932) and Talbot (1939 to 1947), it is one of the most interesting and richest butterfly areas in the world that harbours above 962 butterflies species. Among nymphalids, Northeast India harboured above 343 species and subspecies of which 96 (27% of total) species are endemic to this region in which nearly 43 species are reported from Assam (Evans, 1932). According to Willott et al. (2000), Hill et al. *(*2001) and Saikia et al. (2009), the conservation of biological diversity in tropical forest ecosystem is under threat throughout South and Southeast Asia owing to various anthropogenic problems. Thus, there is an urgent need to understand the impacts of anthropogenic habitat disturbance on biodiversity in tropical forests, but no consensus has yet emerged (Hill and Hamer, 2004).

Since, these forest fragmentations and canopy openness of the forest ecosystem changes the microclimatic condition of ground zones and leads to impoverishment of soils, resulting in changes of butterflies community compositions and species structures. Amongst all the biota, the butterflies are very sensitive to modification of habitat, humidity and moisture conditions and thus, most specialized and native butterflies have disappeared from culturally modified habitat of tropical forest ecosystems (Hill et al., 2001). Moreover, the under story butterflies of tropical forest are highly habitat specific, steno-topic and relatively narrow geographical ranged species, often endemic and nearly endemic in particular bio-geographic forest environment (Leps and Spitzer, 1990; Spitzer et al., 1993). In recent habitat modification in tropical forests, the potential role of sunlight in determining plant species assemblages, structures and diversity have been given more importance for ecological studies by various authors (Denslow, 1987; Brokow and Busing, 2000). Again, the comparable studies on the relationships between habitat modification and insect's species within undisturbed tropical forests have been made by Hamer et al. (2003) and Saikia (2008). Hence, the examination of these relationships in primary forests will be an important prerequisite for understanding the process causing changes in distribution patterns and species composition of butterflies following forest degradation (Hamer et al., 2003; Kremen, 1992; Davis et al., 2001; Saikia et al., 2009, 2010a, b). The present study highlights Assam as a region urgently in need of butterfly conservation and requiring research and review of empirical studies of the community level response of eastern Himalayan biodiversity hotspots to land use changes. Study also emphasizes the importance of identifying the ecological correlates of sensitivity of butterfly species to forest modification and the potential biological mechanisms underlying their responses to land use change. Owing to the high proportion of endemic species in Tropical forests of eastern Himalayan biodiversity hotspots area, the loss of these threatened species would probably result in global extinctions. For examples 27% of the Nymphalid butterfly species occurs here are endemic (Evans, 1932; Saikia, 2008) and are confined to primary forest habitat. The primary aim of this study was to add to the knowledge of the value of primary forest and degraded forest for fruit feeding butterflies (Nymphalids). Study examined the fruit feeding butterfly (Nymphalids) as these are the easiest family of butterflies to sample using a standardized methodology. Thus, the study on the Nymphalid butterflies has been emphasizing the effects of anthropogenic problems on butterflies habitat associated with various environmental factors such as light penetration into the forest floor and vegetation

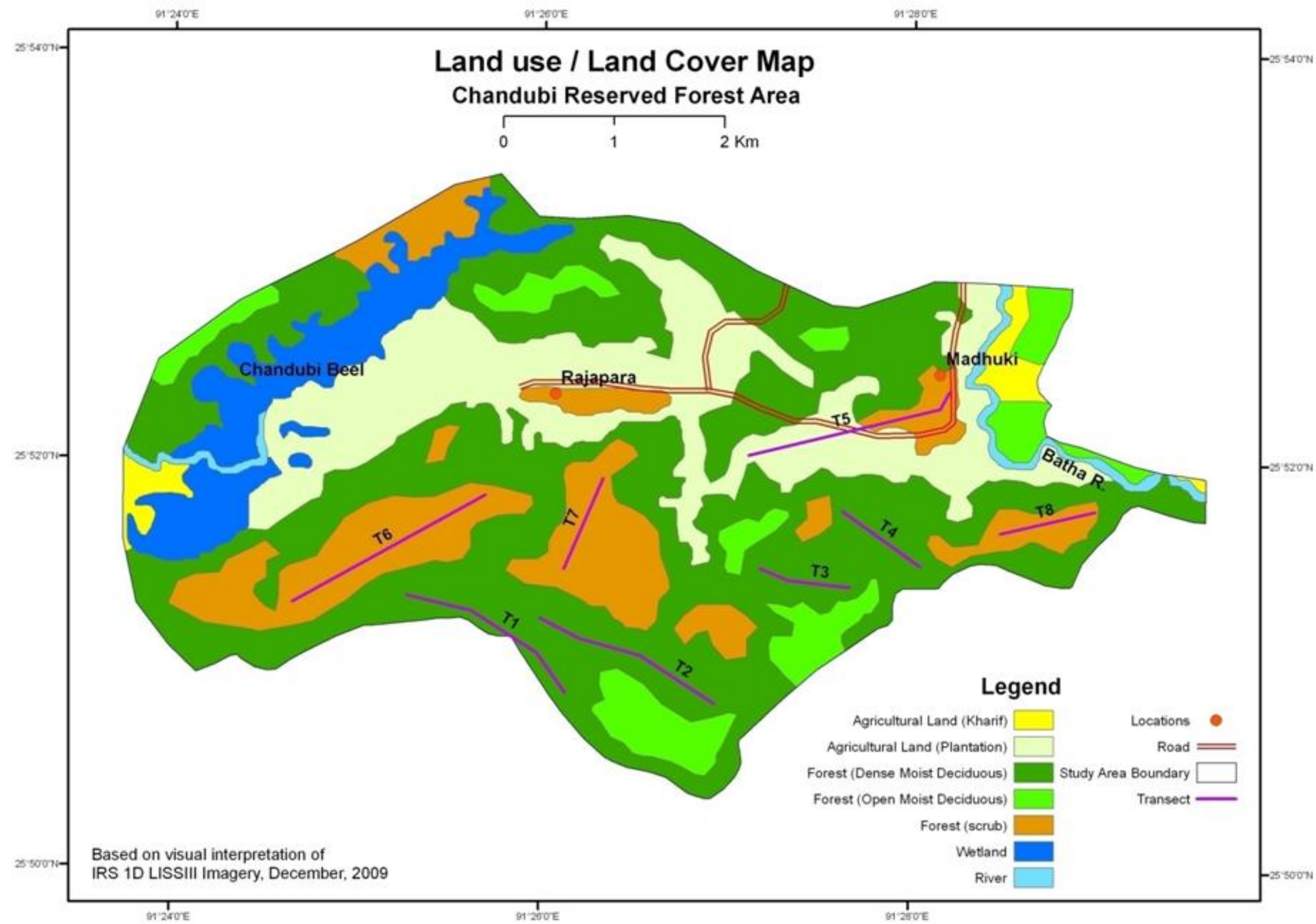

Figure 1. Map of Chandubi Reserve Forest, Kamrup, Assam, India.

growth, canopy cover and canopy openness in different topographic situation within the Chandubi Tropical Forest of Assam as suggested by various authors (Huston, 1994; Rosenzweig, 1995; Hill et al., 2001). One of the major environmental gradients in tropical forests ecosystem is the amount of sunlight below the canopy level and this varies in relation to gap dynamics caused by illegal tree felling.

The present study tests the hypothesis that the degraded habitat or forest gaps can cause more changes in Nymphalid diversity than the closed canopy or dense forests owing to increasing abundance of habitat generalized species. Changes in diversity in degraded forest is associated with the loss of habitat specialized species in restricted ranges or endemic category. Again, the diversity of butterfly is related to vegetation structure and canopy openness and that this relationship differs between butterfly taxa in relation to phylogenetic differences in degraded and primary forest habitat use.

MATERIALS AND METHODS

Study area

Study has been carried out in Chandubi Tropical Forest (Coordinates: 26° 50' to 26° 55' N and 91° 20' to 91° 30'; altitude: 40 to 200 m MSL) with covering an area of 166 km^2 in Kamrup District, Assam, India (Figure 1). It is basically located in the hilly terrain covering a small-extended plain in the down slopes of the hills. The hills are actually continuation in the form of spurs of Khasi hill ranges of Eastern Himalayan biodiversity hotspot. The habitat is an undulating hilly terrain, the forests are located in alluvial tarries and undulating terrain and these are cut up by numerous narrow water channels and streams. The study area has unique geologic and physiographic make up of the state and is composed of special habitat mosaic. The Meghalaya hill ranges on the North-west and North-east, and the Chandubi Tectonic Lake on the west. The climate of study area is mesothermal humid climate, gets heavy rainfall (300 to 450 cm) in addition to periodic wind, storm and thunders (Borthakur, 1986). On the basis of temperature, humidity and precipitation pattern, the climate of Chandubi could be divided into four distinct seasons namely: pre-monsoon, monsoon, re-

Plate 1. Clearance of forest habitat in peripheral and central zones: (a) Burning for shifting agriculture, (b) Forest clearance plains to construct tourist hub construction, (c) Illegally sowing tree inside forest and (d) Forest destruction in central zones at study site.

treating monsoon and winter. The rainfall, fogs and temperature were found to change in relation to different seasons and in different physiographic areas within it. A forest type of study area is tropical wet evergreen, tropical semi-evergreen and tropical moist deciduous types with presence of occasional sub-tropical broad-leafed hill forest. With respect to the degree of degradation of forest, owing to illegal tree felling since last 5 to 10 years, the habitat has experienced gap dynamics and sun light availability on the forest floor and under story in both the peripheral region and central parts. Thus, the habitat could be distinguished into two distinct zones: degraded forest or logged forest (DF) and primary or closed canopy forest (CF).

Degraded forest (DF)

Degraded forests or logged forests consists of a variety of scrubs, tree saplings, burning zones for shifting agriculture, remnants of raged trees, climbers and various grass species etc. The same can be seen along the vast extended parts of the forest habitat in Chandubi Reserve Tropical Reserve Forest. The overall configuration in canopy coverage of individual tree species in degraded forest could not satisfy the criteria of closed canopy or primary forest that permit sufficient sunlight to enter into the forest floor. Yet again, in either side of the regular roads and trails of Chandubi Reserve forest, very less tree densities has been found and thus the forest floors are occupied by heterogeneous vegetation. These areas could be categorized as degraded or disturbed forest. The accessibility of various larval host plants exists in those areas has attracted the butterflies in disturbed forest habitat. This type of categorization of DF habitat in study site was primarily based on the anthropogenic forest disturbances and as well as natural tree fall gaps. Consequently, the comparison of butterfly diversity both in degraded or disturbed forest and primary or closed canopy forest would help us to analyze the anthropogenic forest disturbances in the study site (Plate 1).

Closed canopy forest (CF)

The primary of closed canopy forest (CF) of Chandubi Chandubi Reserve forest has been characterized on the basis of the forest that has maintained an average of 75 to 85% canopy cover where artificial or natural tree fall gaps are partial. The habitat is distinguished by the existence of less dense under story, less herbs, shrubs and climbers. The area is very dense at canopy level and less or almost no canopy gaps are present for sunlight to enter into the forest floor. The top-soil of the forest ground zone is characterized by high humus and leaf litter deposition (Plate 2).

Methods of samplings

Transect design

The samplings were made between November 2009 and April 2011

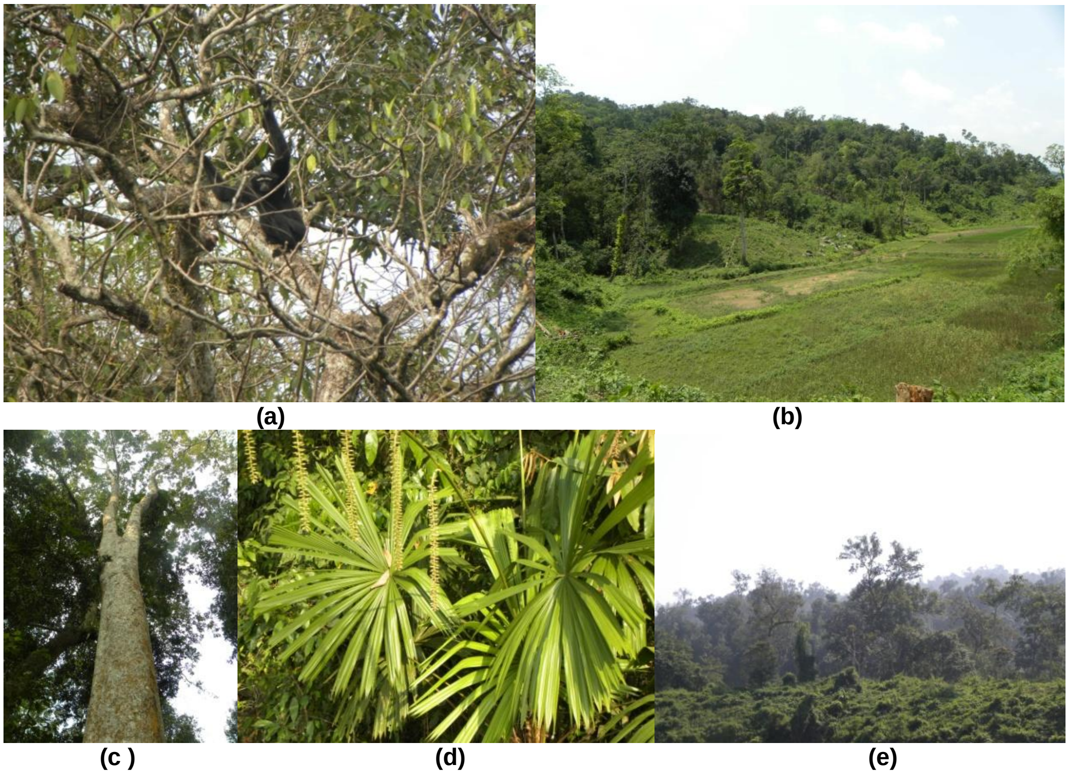

Plate 2. Part of primary forest during winter in Chandubi Reserve Forests: (a) Western Hoolock Gibbon, (b) Forest edge showing closed forest, (c) and (d) showing fig trees/host plants for mammals, birds and butterflies, and (e) part of left out dense forest at study site.

to collect the butterfly data using transect methods described by Pollard et al. (1975) and Pollard (1977) with some modifications described in the text. Overall eight randomly selected permanent line transects (T_1 to T_8, for line and point transect, Table 1) were established 1.5 to 2.0 km apart from each other. The line transects were situated 500 m inside the forest from the edge to reduce β diversity and edge effects respectively. Four line transects were in logged or degraded forest (DF) and four were in unlogged or primary closed forests (CF) in Chandubi Tropical Forest of Assam. There were altogether 36 point transects established on aforesaid line transact after a gap of 200 m from each point (Table 1) to collect the butterflies and habitat data of the sampling zones. The forest zones Chandubi east and west (Table 1) were categorized in a gap of nearly 5 km and they are separated from each other by a gap of human inhabited area. The east zone was less degraded than west, thus, more samplings of closed forests have been chosen from eastern zone than from western zone and verse versa. In point transacts, altogether 18 points (in a gap of 200 m between two point as described earlier) were selected at Chandubi reserve forest east and 18 points at Chandubi Reserve Forest west zone during study period (Table 1).

Trap design

It is difficult to identify butterflies when they are in flight and therefore the study focused on the guild of fruit feeding Nymphalid butterflies that could be caught in traps baited with rotting fruits (Hill et al., 2001; Hamer et al., 2003; Saikia, 2008; Saikia et al., 2009). During this study, traps were used and baited with fresh and rotten bananas and jackfruits (De Vries, 1987; Daily and Ehrlich, 1995; Saikia, 2008; Saikia et al., 2009). This guild comprises approximately 75% of all Nymphalid butterflies recorded by Hill et al. (2001). 20 bait traps were hung at 200-m intervals along 4 km of transects at closed forest and degraded forest and sampled butterflies for 7 consecutive days on two occasions covering both winter and summer seasons [to account for seasonal variation in species abundance (Hamer et al., 2005)] at each site (280 trap days in total). All traps were >250 m inside the forest from the periphery so that data were unlikely to have been influenced by edge effects (Benedick, 2005). Bait was placed in traps on the day prior to the first sampling day and was left in the trap for the rest of the sampling period. Fresh bait was added to each trap every second day, thus ensuring that all traps contained a mixture ranging from fresh to well-rotted bait. During each sampling period, traps were emptied daily and all trapped butterflies were identified where possible in the field (Evans, 1932; Haribal, 1992; Kehimkar, 2008) marked with a felt-tipped pen and released to avoid double count. The unidentified butterflies were collected and carried to the laboratory for study and preserved in the Gauhati University Biodiversity Museum. Data for each of the two sampling periods at each site were combined for analysis.

Data collection

The data were collected using transect methods described by Pollard et al. (1975) and Pollard (1977) with some modifications described in sampling design. In line transacts, the survey walked was performed along each transect at the speed of approximately 10 m per 10 min and recorded or collected all butterflies that were seen using butterfly swiping net in a belt of 10 m width in each side

Table 1. Design of randomly selected line and point transacts in the study area (points were established after 200 m interval within the line transact laid and the point transact data were collected within 30 m radius).

Transact no.	Chandubi east		Transact no.	Chandubi west	
	Length in closed forest (m)	Length in degraded (m)		Length in closed forest (m)	Length in degraded (m)
T1	1200 (6, points)	-----	T3	600 (3, points)	----------
T5	-------	600 (3, points)	T7		1200 (6, points)
T2	1200 (6, points)	----------	T4	600 (3, points)	---------
T6		600 (3, points)	T8		1200 (6, points)

of the transect. All butterflies and habitats data were collected in point transects within 30 m radius. After collection of butterfly data within a period of 30 min time in one point, the habitat data were also collected from each point. The butterfly data from traps and transact were used to determine the shade and light preference of each Nymphalid butterflies species. Before each data collection at point, at least 5 min time was spent quite silently to reduce disturbance factor. The unlogged forest or primary forest (CF) and logged or degraded forest (DF) data were recorded in separate data sheets for analyses. The butterflies and the habitat data were collected (as per the methods of Torquebiau (1986), Hill et al. (2001), Hamer et al. (2003), Saikia (2008) and Saikia et al. (2009) from eight line transacts and 36 aforesaid observation points along each transect from T_1 to T_8 (Table 1). The parameters used for habitat data collections were: 1) height of the trees, 2) circumference at breast height, 3) distance of 10 nearest trees from the station (circumference, ≥ 0.6 m) (Torquebiau, 1986), 4) estimated vegetation cover (%): i) at ground, ii) low (2 m above ground), iii) under story and (iv) canopy levels.

Identification and geographic range

The identification of butterflies and knowledge of their geographic ranges were based on the information of Antram (1924), Evans (1932), Haribal (1992), Kehimkar (2008), Tsukada (1982) and Wynter -Blyth (1957). The geographic distribution ranges were categorized on a scale of 1 to 5 (smaller to larger) as used by Spitzer et al. (1997) and Saikia et al. (2009) with some minor modifications to fit with the study area: 1) Eastern Himalayas (Sikkim to Assam), 2) Northeastern India and northern Indochina (up to Northern Burma), 3) Indo-Malayan region (India, including Andaman Island and Burma), 4) Indo-Australian region or Australasian tropics (all India, Burma and up to Sri Lanka etc.) and 5) Paleotropic (up to Baluchistan). For analysis, all the surveyed butterfly species were numerically categorized in to aforesaid five ranks according to their geographical distribution ranges.

Data analysis

The diversity of species was estimated in terms of species evenness (or equitability), using Margalef's D index and bootstrap method was used to calculate 95% confidence intervals (Hurlbert, 1971; Magurran, 1988). Evenness or equitability refers to the pattern of distribution of the individuals between the species. In order to test the differences in diversity between habitats (CF and DF), pair-wise randomization tests were carried out based on 10,000 re-samples of species abundance data following Solow (1993). Species richness was estimated using rarefaction (Heck et al., 1975). Percentage of cumulative abundance was plotted (K dominance) against log species rank (Lambshead et al., 1983) for comparing diversity between samples. The log normal distribution has been analyzed as per the method of May (1975) using species diversity and richness software version 3.0 (Pisces conservation Ltd., UK). For each Nymphalid species, the proportion of individuals recorded in closed forest or shade (CF) [using formulae for shade preference, (cf)/(cf + df), where cf + df ≥3] to indicate shade preference (value of '1' for species only in 'CF', value of '0' for species only in 'DF' or gap) and proportion of individuals in disturbed forest (DF) or gap [using formulae for light preference, (df)/(df + cf), where df + cf ≥ 3] to indicate the light preference (value of '1' for species only in 'DF' or gap sites, value of '0' for species only in 'CF' or shade sites) of the butterflies were calculated. To reduce sampling error, it included only those species for analysis where in the total number of individuals sampled was n ≥ 3, which was more appropriate than Davis et al. (2001) and Ribera et al. (2001) who considered that n ≥ 2 was sufficient for inclusion. Data were arcsine transformed for analysis and only selected data (cf + df ≥ 3) were used. For statistical analysis of data, t-test using equal variance, Spearman rank correlation and multiple regressions were used as per Hamer et al. (2003). All statistical analyses were done using SPSS, statistical software, version 17.0.1 (Dytham, 1999). The species diversity was analyzed using species diversity and richness software as per Magurran (1988) and Solow (1993). Although, the vegetation measurement data were taken at 36 sampling stations in Chandubi reserve forest, only 28 sampling data were considered at the time of analysis (14 stations at DF and 14 stations at CF). To examine the relationship between vegetation structure and species diversity in both the habitat, the vegetation measurements were used to calculate 7 variables (Table 3) to analyze the principal component factors (PCA) (Hamer et al., 1997; Pearman, 2002).

The PCA factors allowed ordination of differences among stations in vegetation structure by generating a number of independent factors comprising sums of weighted variables. The relationship between vegetation factor scores and species diversity at each sampling station in close canopy forest and degraded forest was analyzed using stepwise multiple regression (using SPSS version 17.0.1) as per Dytham (1999).

RESULTS

Diversity and abundance

A total of 1634 individuals referable to 106 Nymphalid butterfly species and seven subfamilies, counted in closed forest (CF) and degraded forest (DF) (Table 2) of Chandubi Tropical Forest formed the basis of calculations. The highest number of species have sampled in DF (N = 98 species) compared to CF (N = 75

Table 2. Species richness, abundance and diversity of butterfly fauna sampled in DF and CF of Chandubi (Margalef's D means followed by the different letter are significantly different at the 5% level; rarefaction estimate was done for species richness based on present absent data of each of the transact in CF and DF; also see text).

Variables estimate	Habitat studied	
	CF	DF
Species (Total = 106)	75	98
Individuals (Total =1634)	441	1193
Richness (SE)	101.6 (±1.90)	105.2 (± 0.81)
Margalef's D (SD)	12. 15a (±1.15)	13. 69b (±1.27)

*Margalef's D; DF vs. CF: P< 0.01 at 5% level; *DF is more diverse than CF.

Table 3. Proportional abundance of butterflies species (Arcsine transformed data) in closed canopy forest and degraded forest in Chandubi RF (mean value in bold are significantly higher in each habitat).

Subfamilies	Proportion to closed forest (CF)		Proportion to degraded forest or forest gap (DF)		N
	Mean	± SD	Mean	± SD	
Amathusiinae	**0.72**	0.23	0.36	0.17	3
Satyrinae	**0.76**	0.50	0.46	0.44	30
Nymphalinae	0.37	0.38	**0.89**	0.56	45
Heliconiinae	0.00	0.00	**1.57**	0.00	2
Apaturinae	0.**76**	0.61	0.54	0.64	5
Charaxinae	0.13	0.29	**1.31**	0.49	6
Danainae	0.16	0.17	**1.17**	0.43	12

species) habitat. Comparison of significant difference of diversity between CF and DF showed that the species richness was different among the habitats. The species richness (rarefaction) of CF habitat was 101.6 species, whereas, it was 105.2 species in DF habitat (Table 2). Margalef's D index of diversity was significantly higher in DF habitat than CF habitat at 5% level [Table 2; DF vs. CF randomization test, Δ = 1.0028, P < 0.02 (DF: H' = 13.7; CF: H' = 12.15); pair wise randomized test based on 10,000 random samples], where DF was more diverse than CF which proved the proposed hypothesis that the degraded forest supports higher diversity than closed canopy forests. The sampled data of CF and DF fit the truncated log normal distribution (for DF, χ^2 = 5.51, df = 6; P = 0.47 with predicted species in the community was 103.49, species behind the veil line = 4.29; λ = 174.36; for CF: χ^2 = 0.88, d.f. = 3; P = 0.829, with predicted species in the community was 75.86, species behind the veil line = 0.86; λ = 216.89). But the data sets of DF and CF habitat did not fit the log series model (for CF; x = 0.913, $\propto$ = 30.66, χ^2 = 19.24, d.f. = 3, p = 0.00024; for DF: x = 0.979, $\propto$ = 25.56, χ^2 = 11.55, d.f. = 5, p = 0.04, distributions are significantly different at 5% level).

The log-ranked proportional abundance of the species in DF was also higher than CF with most abundance species in each habitat category comprising around 10% of the total species scores (Figure 2). The percentage cumulative abundance plotted against log species rank for comparing diversity between samples (CF and DF) also indicating the differences of diversity.

Shade preferences of butterflies

Study encountered 1634 individuals of Nymphalid butterflies belongs to 106 species at degraded forest (DF) and closed canopy forest (CF) of Chandubi Tropical Forest. The survey revealed that, of the total 106 species recorded in study area, the individual counts and proportional abundance of 66 species were found to be higher in degraded forest (or gap), whereas, in close canopy forest, the individual counts or proportional abundance were higher for 38 species. Again, out of 66 abundance species in gap, 31 were found only in degraded forest and out of 38 abundance species in 'closed forest' (shade site), eight were found only in shade sites. The species *Mycalesis heri, Adolias Khasiana khasiana and Cethosia biblis tisamena* belonging to the subfamilies Satyrinae, Nymphalinae and Heliconiinae respectively, had sampled less than three individuals each, so, those three species were being excluded from the statistical analysis (methods in data selection for analysis). On the basis of the proportional abundance of the butterfly species (where n ≥ 3) both in

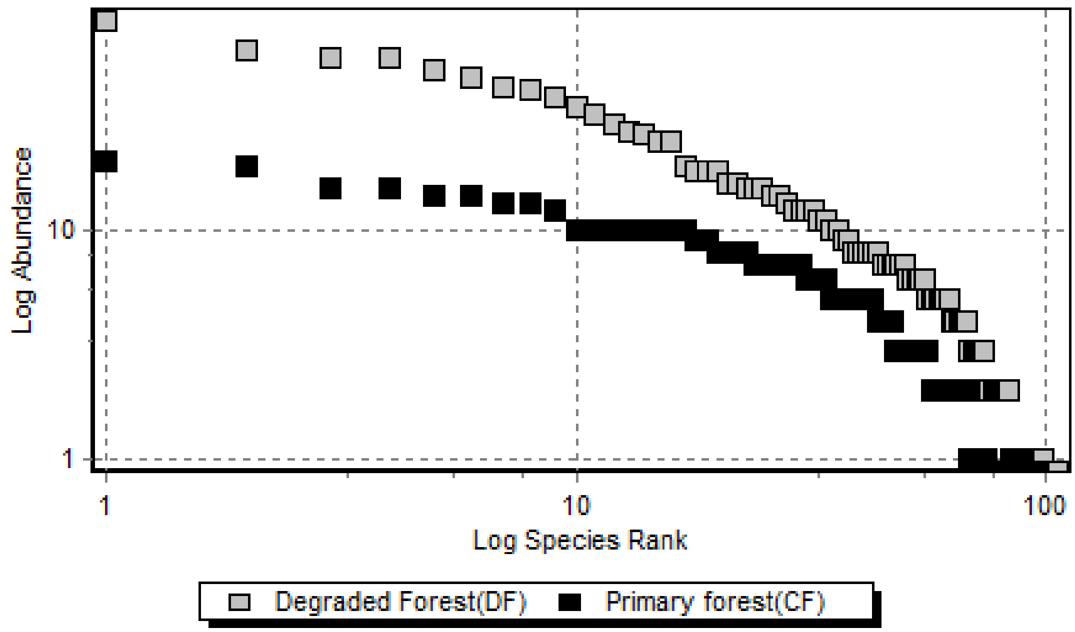

Figure 2. Log ranked proportional abundance of butterflies in CF and DF habitat of Chandubi shows that DF habitat has higher abundance than CF habitat (Gap = DF; primary forest = CF).

gaps (light) and shade sites, the species were differentiated into two groups (shade and light groups). Analysis showed that the mean proportion of butterflies in shade sites were higher in sub-families Amathusiinae, Satyrinae and Apaturinae (shade group) than that in the sub-families of Nymphalinae, Charaxinae, Heliconiinae and Danainae (in shade site: for shade group mean = 0.75, n = 38 species, SD = 0.023; for light group mean = 0.45, n = 73, SD = 0.23; t-test using equal variance estimate with arcsine transformed data; t_{101} = 5.65, P<0.001; Figure 3; Table 3).

On the contrary, the proportion of individuals of each species of butterflies occurring at gap sites or degraded forest were significantly higher in Nymphalinae, Charaxinae, Heliconiinae and Danainae subfamilies (light group) (in gap site: light group mean = 1.01, n = 65 species, SD = 0.54; t-test using equal variance estimate with arcsine transformed data; t_{101} = -5.22, P<0.001) than that in Amathusiinae, Satyrinae and Apaturinae (in gap site: shade group mean = 0.45, n = 38, SD = 0.44; Figure 4), indicating the phylogenic relationship of shade and light preferences of Nymphalid butterflies that proof the proposed hypothesis of phylogenetic differences in degraded and primary forest habitat use by the Nymhalid butterflies.

Geographic distribution of butterflies

Study revealed that the butterflies species sampled in relatively undisturbed closed canopy forest had more restricted geographical distribution than those sampled in disturbed forest (Appendix 1). The analysis of variance between species ranked range of geographic distribution and species shade and light preferences showed that the species with greater light preference or species sampled in degraded forest had significantly wider geographical distribution (one way ANOVA: dependant variables: proportion to DF; independent variables: species ranked range; $F_{4, 102}$ = 46.73, P< 0.001). Again, the species sampled in degraded forest or forest gap sites had significant positive relation with wide range of geographical distribution (Spearman rank correlation, where n ≥ 3; r^s = 0.82, P<0.01, n= 103; median range = 3.00 ± 1.01 SD), whereas, the species with greater shade preferences had significantly narrower geographical distributions (ANOVA performed; where n ≥ 3; dependant variable: proportion to CF; independent variable: species ranked range; $F_{4, 102}$ = 72.09, P< 0.001). Again, the species sampled in closed canopy forest or shade sites had significant negative relation with wide range of geographical distribution (Spearman rank correlation, where n ≥ 3; r^s = -0.82, P<0.01; median range = 2.47 ± 0.86 SD). Figure 5 also distinctly shows that in closed canopy forest, the value of proportional abundance of butterflies increases in case of narrow geographical distribution range species and the value reduces when distribution range of the species increases, whereas, opposite was the result shown in the Figure 6, where in degraded forest, the values of proportional abundance of butterflies were declined in case of narrow or restricted distribution range species and the value gradually

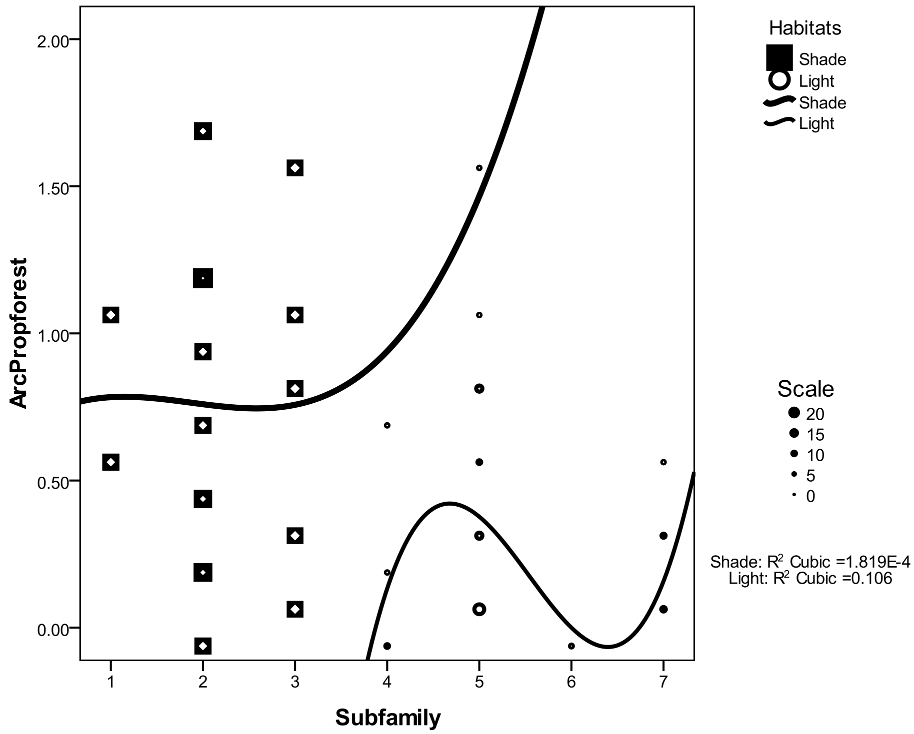

Figure 3. Shade preference of butterflies sampled in DF and CF habitat (black solid square and solid line: Amathusiinae, Satyrinae and Apaturinae; open circles and thin line: Nymphalinae, Charaxinae, Heliconiinae and Danainae subfamilies).

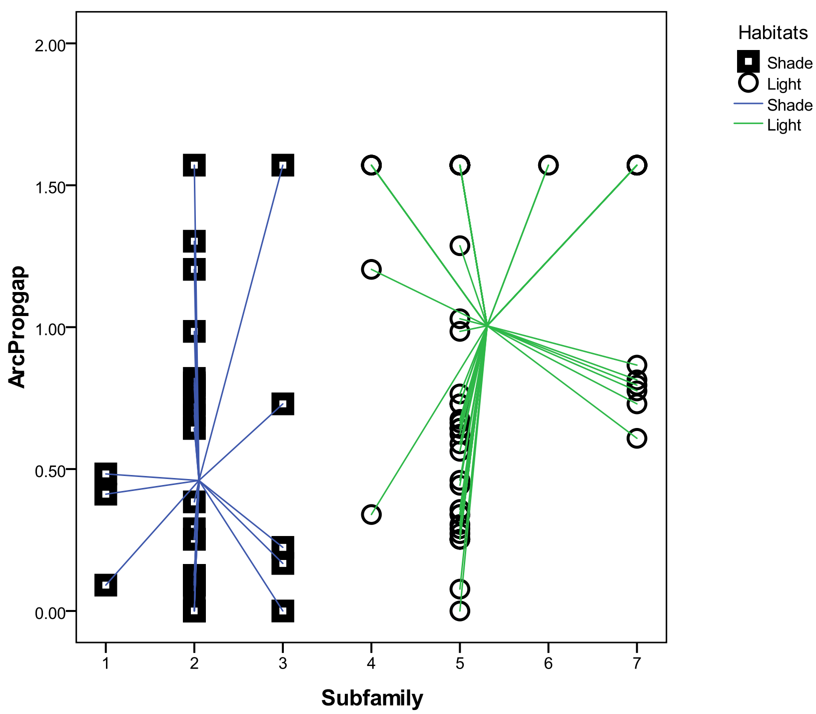

Figure 4. Light preference of butterflies sampled in DF and CF habitat (black open circled centroid: Nymphalinae, Charaxinae, Heliconiinae and Danainae subfamilies and black solid square centroid: Amathusiinae, Satyrinae and Apaturinae subfamilies).

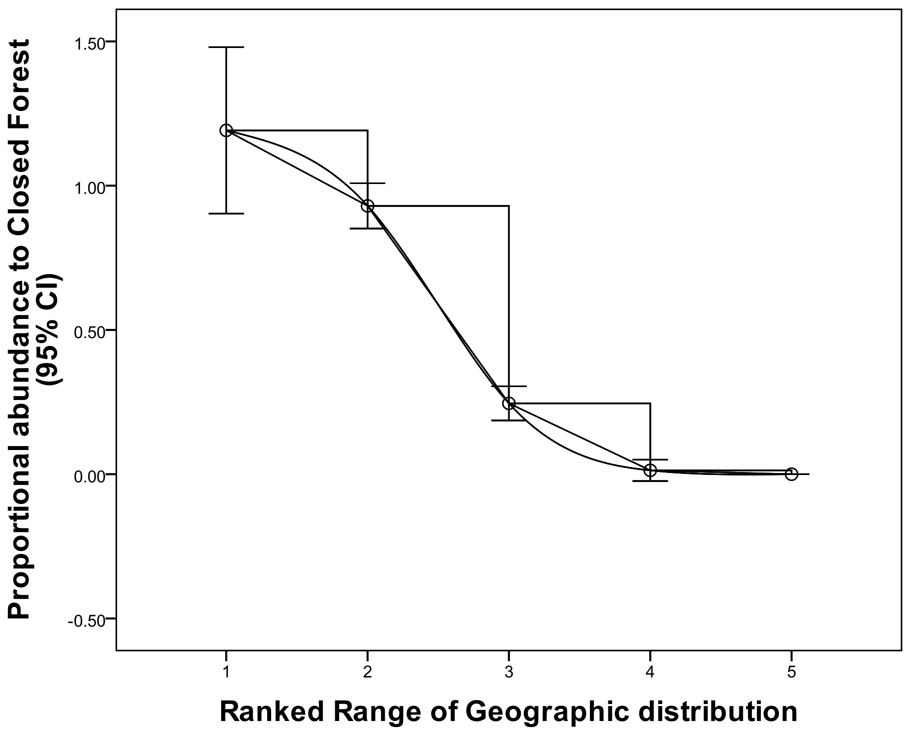

Figure 5. Arcsine proportions of individuals in butterflies species at closed forest areas and species ranked range of geographical distribution in RGRF (one way ANOVA results: $F_{4,\,102} = 72.09$, $P < 0.001$).

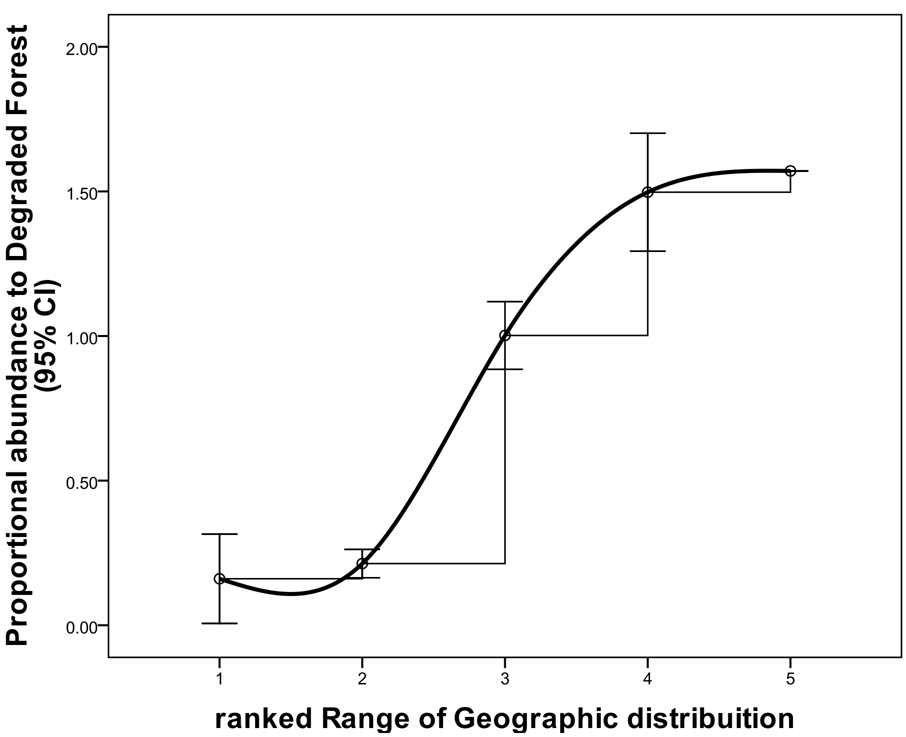

Figure 6. Arcsine proportion of individuals in butterfly species at degraded forest or canopy gap areas and species ranked range of geographical distribution in RGRF (one way ANOVA results; $F_{4,\,102} = 23.32$ $P < 0.001$).

Table 4. Contribution of different variables to two principal components (PRIN 1 and 2) of variation in vegetation structures. Variables making main contributions to each principal components are in bold.

Variables	Weighing			
	PRIN1		PRIN2	
	Primary forest	Degraded forest	Primary forest	Degraded forest
Trees				
Mean Height	**0.74**	0.39	**0.84**	**0.53**
Mean girth	**0.73**	0.24	**0.79**	**0.70**
Density	**0.53**	**0.86**	-0.51	-0.28
Percentage cover				
Ground cover	-0.41	**0.77**	-0.55	0.06
Low cover	-0.43	**0.80**	-0.36	0.31
Under story	**0.88**	**0.63**	-0.67	0.61
Canopy cover	**0.95**	-0.10	-0.36	0.67

increases with the increase of species geographical distribution range. Thus, the result supports the hypothesis that the increasing diversity of butterflies in degraded tropical forest is associated with the loss of species with restricted geographical distributions or endemic species.

Impact of forest destruction on individual species

The result shows that majority of narrow ranges species belong to Amathusiinae, Satyrinae and Apaturinae, whereas, the majority of wide ranges species belong to Nymphalinae, Charaxinae, Heliconiinae and Danainae. In Amathusiinae, Satyrinae, and Apaturinae, there was a significant and strong negative relationship between shade preference and impact of forest destruction (Spearman correlation; r^s = -0.825, n = 103 species, p<0.001) which means that the shade preferred species (or local and regional endemic species) are most adversely affected by forest destruction. However, there is a positive relationship between light preference and impact of forest destruction witnessed in Nymphalinae, Heliconiinae and Danainae (Spearman correlation r^s = 0.825, n = 103 species, P<0.001).

Vegetation structure and butterfly diversity

The principal component analysis (PCA) of vegetation data such as tree height, tree density and vegetation covers of the study area extracted two components of variations in closed canopy forests (PRIN 1 and 2) that explained 55 and 24% variability in the vegetation data, respectively. The first factor (PRIN 1) increases with increasing vegetation cover in canopy and under-storey, decreasing vegetation cover at ground level and low cover and increasing density of trees and mean height and girth (Table 4). A high PRIN 1 (PCA Factor 1) score thus represents dense forest with closely spaced trees with broad canopy diameter of individual trees and a relatively poor field layer. The PRIN 2 (PCA Factor 2) score increases with increasing height and girth of the trees. Thus, PRIN 1 primarily reflects density of forest, whereas PRIN 2 primarily represented sizes and architecture of trees in undisturbed closed canopy forest of study site. Again, PCA extracted 2 components of variation in degraded forests (PRIN 1 and 2) that accounted for 36 and 22% of the variability in the vegetation data, respectively. The first factor increases with increase of vegetation cover at ground, low (above 2 m), and under-story and decreasing canopy cover, mean height and girth of trees. A high PRIN 1 score thus represents vegetation structure with widely spaced trees with canopy openness and relatively high field layer. The decreasing girth of the trees in degraded forest accounted for the selective logging of tall trees (Table 4). The PRIN 2 score increased with increasing girth and height of the trees. Thus, PRIN 1 primarily does not reflect the overall dense forest covers, whereas, PRIN 2 primarily represented sizes and architecture of trees.

The stepwise analysis of multiple regressions between the diversity (Margalef's D index) of Amathusiinae, Satyrinae and Apaturinae butterflies and vegetation density (PRIN 1) of closed forest showed the significant positive relationship ($F_{2, 24}$ = 7.5, p<0.02; r^2 = 0.52; Figure 7), but the relationship was found to be negative when the similar types of analysis was performed between the diversity of Nymphalinae, Heliconiinae, Charaxinae and Danainae butterflies with vegetation density ($F_{2, 24}$ = 7.3, p<0.02, r^2 = -0.49; Figure 8).

DISCUSSION

Diversity of Nymphalid butterflies

Study observed that the species diversity is higher in the

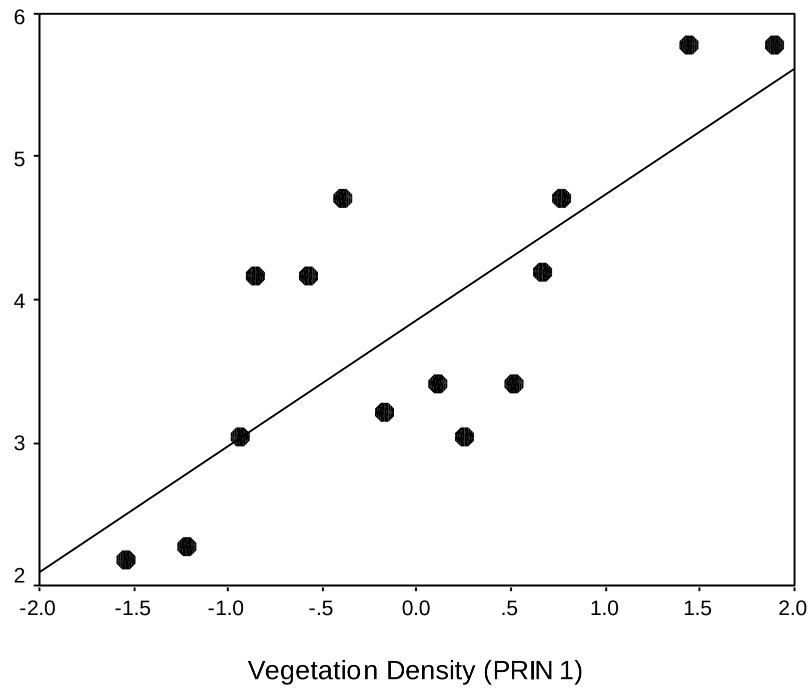

Figure 7. Diversity of Amathusiinae, Satyrinae and Apaturinae in relation to vegetation density and canopy closeness.

degraded forest (DF) or canopy gap area (Margalef's D index = 13.69; n = 98 species) than the primary or closed canopy forest (CF) (Margalef's D index = 12.16; n = 75 species) of Chandubi reserve forest. This finding is in conformity with the other studies, comparing disturbed and undisturbed habitats which show that the increased light was associated with increased butterfly diversity (Pinheiro and Ortiz, 1992;, Sparrow et al., 1994; Willott et al., 2000). The disturbed forest of Chandubi reserve forest was logged 5 to 10 years prior to undertaking the present study. Thereafter, the earlier closed canopy forests has replaced by secondary vegetations as well as weed species like *Melastoma malabathricum, Lantana camera, Eupatorium odoratum* various other climbers, grasses and scrub species etc. These secondary vegetations and weed species attracted the light-loving and generalized species of butterflies owing to availability of flower nectars and host plants almost throughout the year. In disturbed habitat of Chandubi reserve forest, the large numbers of formerly abundant local endemic and regional endemic (short geographical range species), Nymhalid butterflies species have vanished from this modified habitat and were being replaced by wide-range or generalized butterfly species. Ghazoul (2002) suggested that the increase in species richness is often due to invasion of disturbed areas by generalist and widespread species and the resulting homogenization of the world's biological communities is an important threat to the global biodiversity conservation. The present study shows that the abundance and diversity is higher in disturbed forest than in undisturbed primary forest habitat. This point has been proved from the various analyses such as log-ranked proportional abundance, log normal distribution and K-dominance curve [K dominance curve of closed canopy forest (CF) and degraded forest (DF)] crosses each other, indicating differences of diversity (Lambshead et al., 1983). Again, the Margalef's D index of diversity is significantly higher in disturbed forest than in closed canopy or undisturbed forest (P <0.01 at 5% level), these findings support the hypothesis that disturbed habitat or forest gaps have higher butterfly diversity than in closed canopy or primary forests. Spitzer et al. (1993), Hill et al. (1995), Hamer et al. (1997) and Wood and Gillman (1998), using similar census methods recorded higher butterfly diversity and abundance in disturbed sites than in undisturbed closed canopy sites. While, the diversity increases in disturbed habitat, it results in the reduction of the local and regional endemic nymphalid butterflies faunas, those are specialized in habitat use. These endemic species mostly prefer low or moderate sunlight compared to wide range species. Again, these species are low and week fliers and hide under dense shades during various stress situations.

The endemic species usually come out from the dense forest to the nearby forest edge where shade and dampness are available. The primary forest or undisturbed forests are inhabited by greater numbers of specialized butterflies and lesser numbers of generalized species and hence harbours less butterfly diversity in contrast to that in disturbed habitat. In fact, the butterfly

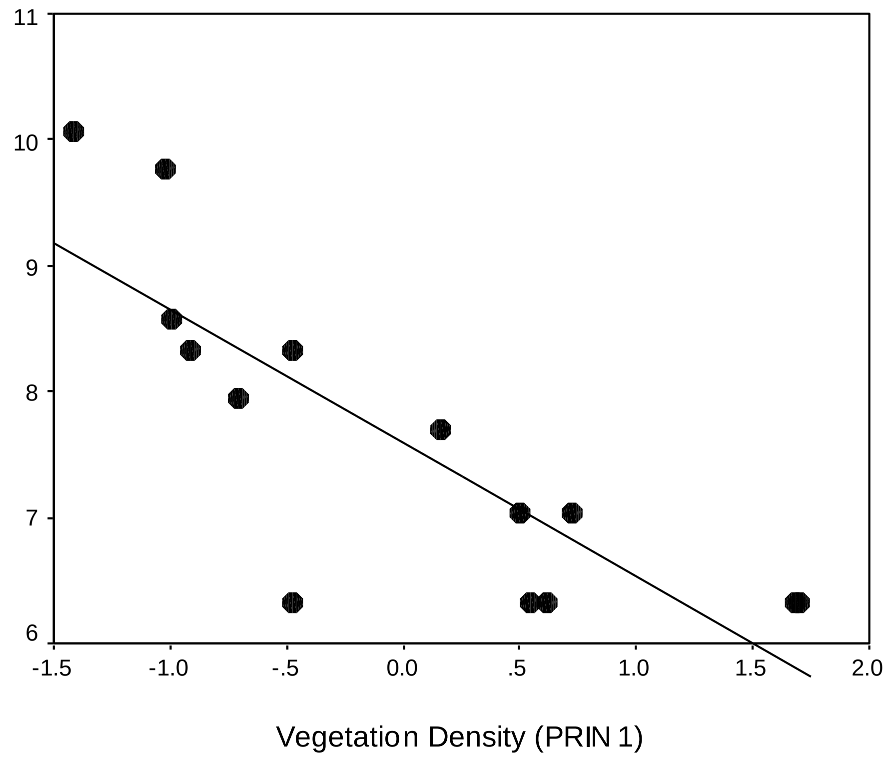

Figure 8. Diversity of Nymphalinae, Charaxinae, Heliconiinae and Danainae in relation to vegetation density and canopy openness.

diversity is reduced in modified habitat, immediately after logging in the tropical countries, but with the increased growth of weed species and secondary vegetation along with the reduction of human interference, the diversity increases in a progressive way.

Distribution and abundance

The present study indicated that the species abundance data for butterflies, fitted with log normal distributions in both undisturbed and disturbed habitat and the log series model does not fit in both habitats. Thus, it indicates that, although the habitat has been modified due to logging, the habitat heterogeneity might not be changed so much. May (1975), Putman (1994), Ghazoul (2002) and Hill and Hamer (1998) suggested that lognormal and log series models do not necessarily reflect biological conditions, log series model imply a structurally simplified habitat. Hill et al. (1995) concluded that species abundance and distributions of butterflies might be used as indicators of forest disturbance. But in case of Chandubi Tropical Forest, the significant differences of diversity and abundance were observed across the sites; yet log normal distributions fitted well in both the sites and log series model did not fit in both habitats. Ghazoul (2002) also supported the present findings and remarked that lognormals and log series models alone are not sufficiently sensitive to be used as disturbance indicators. Chandubi Tropical Forest is extremely rich in butterfly diversity especially Nymphalidae family. The existence of 106 butterfly species belong to a particular family in a definite area of 254.85 km^2 has indicates the habitat heterogeneity of Chandubi Tropical Forest. Most of the forest degradation has occurred at the peripheral region, whereas the core area of the habitat has still sustained dense close canopy forest. The higher density of the vegetation (Table 4) at ground level, under storey and low canopy cover in degraded part of the forest took place owing to destruction of primary forest that occurs about 5 to 10 years prior. Most of the bulky tall trees had been selectively felled and subsequently, the gap areas are being occupied by different invasive plants species like *L. camera, E. odoratum, Mymosa sp., Adatoda sp., Mikania* sp. etc. In addition, the forest department also planted monoculture plantation of exotic species namely: *Tectona grandis*. Thus, the habitat of study site forms a mixture of both pioneer and climax vegetation.

The availability of high butterfly diversity in degraded forest of Chandubi Tropical Forest also indicates that the habitat is mostly suitable for butterflies species assemblages and diversity. The study findings also supported the earlier results of Horn (1975), Connell (1978) and Basset et al. (2001) who suggested that the highest diversity occurs in situations of intermediate disturbance when both climax and pioneer species co-exist.

Conservation needs of primary forest

Out of seven subfamilies of Nymphalidae, the greatest numbers of species belonging to four subfamilies have been found to occur in degraded forest or forest gaps, whereas the rest three subfamilies are being found in closed canopy forest. Nymphalinae, Charaxinae, Heliconiinae and Danainae are those five subfamilies that prefers light or open areas rather than shade sites. The butterflies of Charaxinae and Nymphalinae (not all) are having strong flying activity, thus they prefers mostly in open areas than close canopy forest. According to Hill et al. (2001), the species of Charaxinae and Nymphalinae subfamilies have broad thorax and small abdomen and thus, they are frequently flying from ground zone to top canopy level. Consequently, they prefer to stay in open area or forest gaps rather than canopy closed forest areas. In contrary, the Satyrinae, Amathusiinae and Apaturinae are the three subfamilies that prefer shade sites. Spitzer et al. (1993, 1997), Hamer et al. (1997), Hill and Hamer (1998) and Wood and Gillman (1998) also suggested that most of the Satyrinae are restricted to undisturbed under storey habitats and are sensitive to canopy opening. The statistical analysis also found highly significant results between the association of species phylogeny (subfamily level) and butterfly shade and light preference (Figures 5 and 6) which shows that the diversity of butterfly is related to vegetation structure and canopy openness and that this relationship differs in different butterfly taxa. Again, there is a strong positive relationship between species shade preference and narrow geographical distribution and that of light preference with wide range of geographical distributions indicating that gaps or degraded forests are mostly used by opportunistic and wide range species and on the other hand, shades or closed canopy forests (primary forests) are harboured by habitat specialist butterflies or local and regional endemic species. This finding is in conformity with the opinion of Thomas (1991), Spitzer et al. (1997), Hill et al. (2001) and Hamer et al. (2003).

The endemic or habitat specialist species are mostly confined in close canopy forest. The species such as: *Elymnias pealii*, *Neorina hilda Mycalesis heri*, *Raphicera* s. *satricus*, *Mycalesis malsara*, *Yapthima nareda newara*, *Cirrochroa aoris aoris*, *Kallima inachus inachus*, *Neptis yerburi sikkima*, *Lebadea martha ismene*, *Adolias khasiana*, *Tanaecia julii appiades*, *Herona marthus marthus* and *Euploea diocletiana ramsayi* are endemic, and *Melanitis phedima bela*, *Elymnias hypermnestra undularis*, *Elymnias malelas malelas*, *E. patna patna*, *Lethe mekara zuchara*, *L. chandica flanona*, *Neope confusa gambara*, *Neope confusa confusa*, *Yapthima sakra austeni*, *Ethope himachala*, *Charexes pleistonax*, *Sephisa chandra*, *Ariadne merione assama*, *Neptis hylas adara*, *Neptis mahendra*, *Adolias cyanipardus*, *Tanacea lepidea lepidea* and *Tanaecia jahnu jahnu* are nearly endemic (Spitzer et al., 1997) to this region. Again, there is a strong positive relationship between canopy openness of habitat and the butterflies of Nymphalinae, Charaxinae, Heliconiinae and Danainae (gap preferred group) subfamilies that includes majority of wide geographical distribution range species. However, these subfamilies has also includes a number of narrow range species that confined only in close canopy forest. Among gap preferred group, 19 species belong to Nymphalinae and one species under Danainae subfamily shows strong affinity to shade sites (Appendix 1) of which the species *C. aoris aoris, K. inachus inachus, Neptis hylas adara, Neptis mahendra, N. yerburi sikkima, L. martha ismene, A. cyanipardus, A. khasiana, T. lepidea lepidea, T. julii appiades, T. jahnu jahnu, Euthalia jama jamaida* and *E. diocletiana ramsayi* are narrow geographic distribution range species. This finding clearly indicates that there is a strong and significant positive relationship between the species of narrow range of geographical distribution and shade preference of the species which supported the findings of Hamer et al. (2003) in Tropical Rain Forest of Northern Borneo. Thus, it is clear that most of the restricted distribution range species are affected owing to forest degradation.

According to Evans (1932), habitat of Eastern Himalayas houses 96 endemic butterfly species of which 45 species have reported from Assam. There were altogether 13 endemic species recorded in close canopy forest of Chandubi Tropical Forest and only one endemic species was in degraded forest during present study. But the butterfly diversity was found to be low in closed canopy forest than degraded forest (Saikia, 2008; Saikia et al., 2009). These findings have clearly brought into light that the increasing diversity in degraded forest is associated with the loss of species with restricted geographical distribution. Yet again, amongst shade-preferred butterfly subfamilies group (Amathusiinae, Satyrinae and Apaturinae), five species of Satyrinae and two species of Apaturinae have higher population abundance in gap sites than closed canopy forests. These are *Melanitis leda ismene, Mycalesis perseus blasius, Ypthima baldus baldus, Ypthima hubneri hubneri* and *Ypthima asterope maharatta* from Satyrinae and *Euripus halitherses* and *Dichorragia nesimachus* from Apaturinae subfamilies. Hamer et al. (2003) reported that the Satyrinae include some cosmopolitan species (for example *Melanitis leda, Mycalesis horsfield* and *Mycalesis orseis*) who prefers gap area within the forest. Willott et al. (2000) also reported the same findings with an increase in the abundance of several Satyrinae species in Bornean logged forest. Out of these seven gap preferred species, two have wide geographical distribution and other five are medium range species. The present study revealed that there may be some possibilities of phylogenetic relationship between the genera of light preferred shade loving group of butterflies and the butterflies of light loving group and also between shades preferred light loving group of butterflies and the butterflies of shade loving group. As the phylogenetic study of Southeast Asian butterflies have not been done beyond subfamilies level (Corbert and Pendlebury, 1992; Parsons, 1999), it is not possible to confer the ultimate conclusion for those species showing opposite behaviour. Thus, detailed study is necessary in future to establish the relationship among various butterfly groups. However, the study carried out across the globe emphasizes the importance of environmental heterogeneity for generating and maintaining species diversity in tropical logged forest (Huston, 1994; Rosenzweig, 1995).

Ganzhorn et al. (1990) and Hill et al. (1995) reported that the degraded forest vegetation is more homogeneous than primary forest. The present study also revealed greater heterogeneity in forest structure within undisturbed forest than degraded forests of Chandubi Tropical Forest. Dense shade or closed canopy forest of Chandubi Tropical Forest is formed by large patches of bamboo growths and assemblages of huge *Ficus* ssp., *Michelia* sp., *Shorea* ssp., *Artocarpus chapasha*, *Lagerstroemia parviflora, Gmelina arborea, Phyllanthus aficinalis, Bauhinia variegata, Terminalia belarica*, *Phoebe goalparaensis*, *Amoora wallichii, Cassia fistula* species etc. The studies of DeVries (1987) and Beccaloni (1997) emphasizes that butterflies distributions are expected to depend on the heavy growth and abundance of their host plants even at smaller area within forest stands and changes in stratification and type of forest vegetation may reflect differences in the composition of butterfly community. The forest disturbances that had caused increased canopy openness and light penetration leads to increase of the abundance of herbaceous growth and vines and favours the species normally frequenting tree fall gaps and streams (Ghazoul, 2002). He also emphasizes that in Amathusiinae, Satyrinae and Apaturinae subfamilies, those species with higher shade preference with narrower geographical distribution were most adversely affected by forest degradation, whereas, cosmopolitan species with low shade preference benefited from forest degradation. The study in Chandubi Reserve Forest also revealed that there is a significant difference in the faunal composition of butterfly assemblages in undisturbed and disturbed forest which is strongly associated with species light and shade preference and geographical distribution. Due to loss of heterogeneous vegetation in degraded forest of Chandubi Tropical Forest, the dense canopy cover and transparent ground cover has been reduced, ultimately leading to the declination of the forest butterfly species. PCA analysis also shows that in case of undisturbed forest, the principle component factor 1 (PRIN 1) increased with the increasing value of canopy cover, under story and tree density and the decreasing value of ground cover and low cover represented the dense forest with closely spaced trees, whereas, the principle component factor 1 (PRIN 1) of degraded forest is increasing with the increase of ground cover, low cover, underscore and tree density and decreasing canopy cover which represented the widely spaced trees with canopy openness. The principle component factor 2 (PRIN 2) represented the overall size and architecture of the forest which has no major variation in both the primary and degraded forest due to the presence of monoculture plantations and medium sized trees in degraded forest (Table 4).

The comparison between vegetation structure and the diversity of Nymphalinae, Charaxinae, Heliconiinae and Danainae in undisturbed forest shows the significant negative correlation between vegetation density (PRIN 1) and butterfly diversity in which the diversity of butterfly is decreasing with increasing (PRIN 1 factor) canopy cover or shade sites (Figure 8). On the contrary, diversity of Amathusiinae, Satyrinae and Apaturinae shows significant positive correlation with increased canopy cover (Figure 7).

Threats to endemic and native butterflies

The creation of gaps by local tree fellers at Chandubi Tropical Forest changes the natural disturbance regime and causes a threat to biota confined to the closed canopy forest. According to Blau (1980), Schulze and Fielder (1998) and Hill (1999) and Hamer et al. (2003), the majority of close canopy forest butterflies especially Amathusiinae, Satyrinae and Apaturinae are sensitive to changes in moisture availability and humidity; hence the changes in canopy cover and light penetration have impact on native butterfly distributions through microclimatic effects on adult and larval survival as well as indirectly through effects on host plant quality. This has also observed in the present study of butterflies at Chandubi Reserve Forest. While the species richness and diversity are higher in gaps or degraded forest, the conservation value of close canopy forest lies in the presence of species with restricted ranges or local or regional endemics. Thus, the conservation value of a biological community is determined not only by its richness and diversity, but also by the rarity and endemicity of its constituent species and the ability of species to maintain viable population in the face of disturbance pressure which is also suggested by Ghazoul (2002). Thus, it could be concluded that the butterflies are thus appropriate subjects for the study of logging impacts on biotic communities and have been widely used to assess patterns of tropical insect diversity in forest conservation studies (Brown, 1991; De Vries et al., 1997; Ghazoul, 2002). The change of butterfly species composition and community structure in tropical forest ecosystem is an important threat for the future biodiversity conservation; so, the ultimate solution lies on the conservation of butterfly species as well as the protection, preservation and restoration of close canopy of primary forest and the plant species, especially the native or indigenous ones.

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Appendix 1. Diversity and abundance of Nymphalid butterflies in forest gaps (DF) and primary forests (CF) of Chandubi Tropical Forest, Kamrup, Assam.

Species/subfamily	CF	DF	Ranked range
Amathusiinae			
Thaumantis diores diores (Doubleday, 1845).	20	2	2
Discophora sondiaca zal (Westwood, 1851).	9	6	3
Discophora timora timora (Westwood).	15	13	3
Satyrinae			
Melanitis leda ismene (Cramer, 1775).	4	56	4
Melanitis phedima bela (Moore, 1875).	10	6	2
Melanitis zitenius zitenius (Herbst).	5	10	3
Elymnias hypermnestra undularis (Drury, 1773)	10	4	2
Elymnias patna patna (Westwood).	6	2	2
Elymnias malelas malelas (Hewitson).	3	1	2
Elymnias pealii Wood Mason.	5	0	1
Lethe mekara zuchara (Fruhstorfer, 1857).	8	1	2
Lethe chandica flanona (Fruhstorfer, 1857).	10	1	2
Lethe distans (Butler, 1870).	13	1	2
Lethe europa niladana (*Fruhstorfer*).	10	15	3
Lethe rhoria rhoria (Fabricius, 1707).	5	12	3
Neope confusa confusa gambara (Fruhstorfer, 1857).	9	1	2
Neope confusa confusa confusa (Fruhstorfer, 1857).	10	1	2
Ethope himachala (Moore, 1865).	14	2	2
Neorina hilda (Westwood).	15	0	1
Mycalesis perseus blasius (Fabricius, 1798).	1	27	3
Macalesis visala (Moore, 1857).	4	7	3
Mycalesis mineus mineus (Linnaeus, 1765).	6	9	3
Mycalesis malsara (Moore, 1857).	10	1	1
Mycalesis franscica santana (Moore, 1857).	2	5	3
Mycalesis heri (Moore, 1857).	1	0	1
Mycalesis anaxias oemate (Fruhstorfer, 1911).	1	5	3
Mycalesis gotoma charaka (Moore).	14	2	2
Orsotrioena medus medus (Fabricius, 1775).	7	19	3
Raphicera satricus satricus (Doubleday, 1849).	5	0	1
Ypthima baldus baldus (Fabricius, 1775).	8	15	3
Ypthima sakra austeni (Moore).	7	1	2
Y. nareda newara (Moore).	5	0	1
Yapthima hubneri hubneri (Kirby, 1871).	7	18	3
Ypthima asterope maharatta (Moore, 1884).	0	32	5
Apaturinae			
Dichorragia nesimachus, (Boisduval, 1836).	2	4	3
Herona marathus marathus (Doubleday, 1848).	8	0	1
Euripus halitheres (Doubleday and Hewitson, 1848).	0	6	3
Sephisa chandra (Moore).	10	2	2
Stibochina nicea nicea (Grey, 1833).	7	2	2
Charaxinae			
Polyura athamas athamas (Drury, 1770).	0	18	3
Polyura arja (Felder and Felder, 1867).	0	8	3
Charaxes marmax (Westwood, 1848).	0	11	3
Charexes polyxena hierax (Felder, 1867).	1	14	3

Appendix 1. Contd.

Charaxes pleistonax (Felder).	2	1	2
Charexes aristigiton aristigiton Fd.	0	4	3
Nymphalinae			
Ariadne merione assama (Evans).	13	7	2
Ariadne ariadne pallidior (Frusthorfer).	1	24	3
Cirrochroa aoris aoris (Doubleday, 1847 to 1848).	5	2	1
Cirrochroa tyche mithila (Moore, 1872).	7	3	3
Issoria singha singha (Kollar, 1844).	0	7	3
Precis hierta magna	0	24	3
Precis lemonias lemonias (Linnaeus, 1758).	0	42	3
Precis almana almana (Linnaeus, 1758).	0	81	4
Precis atlites atlites (Johanssen, 1764).	0	56	4
Precis iphita iphita (Cramer, 1779).	8	18	3
Symbrenthia lilaea khasiana (Moore, 1874).	0	12	3
Kallima inachus inachus (Boisduval, 1836).	4	3	1
Doleschallia bisaltidae indica (Moore).	1	5	3
Neptis hylas varmona (Moore, 1872).	0	60	4
Neptis sapho astola (Moore, 1872).	10	8	2
Neptis soma soma (Moore, 1858).	5	8	3
Neptis sankara quilta (Moore).	3	6	3
Neptis yerburi sikkima (Evans).	7	0	1
Neptis clinia susruta (Moore, 1872).	2	3	3
Parthenos sylvia (Cramer).	2	3	3
Lassipa viraja viraja (Moore, 1872).	0	5	3
Pantoporia hordonia hordonia (Stoll, 1791).	7	8	3
Moduza procris (Cramer, 1877).	6	3	3
Lebadea martha ismene (Doubleday and Hewtson).	12	1	1
*Tanaecia lepidea lepidea (*Butler, 1868).	19	7	2
Tanaecia lepidea miyana (Fruhstorfer).	5	7	3
Tanaecia jahnu jahnu (Moore).	3	1	2
Tanaecia julii appiades (Menetries, 1857).	3	1	1
Parathyma perius (Linnaeus, 1758).	0	9	3
Parathyma cama (Moore, 1857).	0	5	3
Parathyma zeroca (Moore, 1872).	3	1	2
Parathyma ranga ranga (Moore, 1857).	0	15	3
Parathyma asura asura (Moore, 1857).	0	14	3
Parathyma nefte inara (Doubleday and Hewtson, 1850).	0	16	3
Cyrestis thyodamas thyodamas (Boisduval, 1836).	6	10	3
Chersonesia risa risa (Doubleday and Hewtson, 1850).	4	5	3
Euthalia aconthea suddhodana (Frusthorfer).	2	12	3
Euthelia phemius (Doubleday and Hewtson, 1850).	1	2	3
Limanitis danava (Moore, 1857).	2	3	3
Adolias cyanipardus (Butler).	3	1	2
Adolias Khasiana khasiana (Swinhoe).	2	0	1
Euthalia evelina derma (Kollar).	2	1	3
Cupha erymanthis lotis (Sulz, 1776).	2	4	3
Phalanta phalantha (Drury, 1770).	0	34	5
Hypolimnas misippus (Linnaeus, 1764).	0	46	5
Hypolimnas bolina (Linnaeus, 1758).	0	49	5
Heliconiinae			

Appendix 1. Contd.

Cethosia cyane (Drury, 1770).	0	6	3
Cethosia biblis tisamena	0	2	3
Vindula erota erota (*fabricius*).	0	29	4
Danainae			
Parantica aglea melanoides (Moore, 1883).	5	16	3
Danaus (*Salathura*) *genutia* (Cramer, 1779).	0	41	5
Danaus(Anosia) chrysippus (Linnaeus, 1758).	0	38	5
Parantica melaneus platiniston (Fruhstorfer, 1910).	2	4	3
Tirumala limniace leopardus (Butler, 1866).	0	26	5
Euploea mulciber mulciber (Cramer, 1777).	0	11	3
Euploea core core (Cramer, 1790).	3	4	3
Euploea radmanthus (Fabricius, 1973).	3	7	1
Euploea klugii klugii (Moore, 1858).	0	8	3
Euploea midamus rogenhoferi (Linnaeus, 1758).	2	5	3
Tirumala septentrionis (Butler, 1874).	0	12	5
Euploea aglea deione (Fruhstorfer, 1910).	3	8	3