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Variation in butterfly diversity and unique species richness along different habitats in Trishna Wildlife Sanctuary, Tripura, northeast India

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Abstract: Quantification of butterfly diversity and species richness is of prime importance for evaluating the status of protected areas. Permanent line transect counts were used to record species richness and abundance of butterfly communities of different habitat types in Trishna wildlife sanctuary. A total of 1005 individuals representing 59 species in 48 genera belonging to five families were recorded in the present study. Of these, 23 species belonged to the family Nymphalidae and accounted for 38.98% of the total species and 45.20% of the total number of individuals. Mature secondary mixed moist deciduous forest showed the maximum diversity and species richness, while exotic grassland showed minimum diversity and species richness. Out of 59 species, 31 are new records for Tripura state, while 21 are unique species and nine are listed in the threatened category. This study revealed that mature secondary forests are more important for butterfly communities, while exotic grasslands have a negative impact on species composition.

Introduction

In the humid tropics, due to deforestation of primary forests, secondary forests and plantations are becoming increasingly widespread land-use systems in human dominated areas (Barlow *et al.* 2007). Despite their quick expansion and potential importance, the biodiversity conservation values of secondary and plantation forests remain poorly understood (Hartley 2002; Dunn 2004), especially in relation to butterfly diversity. Along with the availability of larval and adult food plants, habitat quality appeared to be one of the most important parameters that is used to determine butterfly community structure (Barlow *et al*. 2007). However, several studies (Bowman *et al*. 1990; Lawton *et al*. 1998; Ramos 2000) have discussed the potential of butterfly diversity in secondary forests, but diversity and species richness of butterflies across different secondary vegetation gradients were poorly understood.

Among insects, butterflies are ideal subject for ecological studies of landscapes (Thomas and Malorie 1985), and their value as indicators of biotope quality is being increasingly recognized because of their sensitivity to minor changes in micro-habitat, in particular, light levels (Kremen 1992). To a large extent, butterflies (being a pollinating agent) contribute to the growth, maintenance and expansion of flora in the tropical regions where these insects show high abundance and species diversity (Bonebrake *et al.* 2010).

The northeastern region of India is home to a rich diversity of butterflies and other insects, due to vegetative richness (Alfred *et al.* 2002; Majumder *et al.* 2011), and it is also globally recognized as one of 25 biodiversity hotspots (Myers *et al.* 2000). Nonetheless, its biodiversity is under threat due to deforestation and habitat modification. A perusal of the literature suggests that 76 species of butterflies were previously recorded from the state of Tripura (10,490 sq km), in northeastern India (Mandal *et al.* 2002; Agarwala *et al.* 2010; Majumder *et al.* 2011). Among other northeastern states, 104 species from Meghalaya (22429 sq. km), 695 species from Sikkim (7096 sq. km), 333 species from Nagaland (16579 sq. km), 96 species from Mizoram (21081 sq. km), 134 species from Arunachal Pradesh (83743 sq. km) and 962 species of butterflies from Assam (78438 sq. km) have been recorded (Evans 1932; Talbot 1939; Wynter-Blyth 1957; Haribal 1992; Gupta 2006; Gupta and Maulik 2006; Gupta and Majumder 2006; Ghosh and Majumder 2007; Gupta and Maulik 2007; Gupta 2007; Borang *et al.* 2008). At the time of this study, 22 common species were known from this sanctuary (Roy Choudhury *et al.* 2011) without regard to their abundances, community structure and habitat preferences. In this study, an attempt has been made to estimate the diversity and unique species richness of butterflies inhabiting the Trishna wildlife sanctuary along four different secondary habitat types.

Materials and Methods

Study site

The present study was conducted in Trishna wildlife sanctuary, (TWS). TWS is located in the south district of Tripura state (Figure 1), and encircled by Bangladesh on three sides. Geographically it lies between 23°26.137' N, 91°28.184' E with an altitudinal gradient of 31–82 m above sea level. The total sanctuary area is 194.71 km^2. The vegetation types of the sanctuary are classified mainly into: tropical semi-evergreen forest, East Himalayan lower Bhabar Sal, moist mixed deciduous forest, and savannah woodland. Trishna sanctuary is known to contain 230 tree species, 110 species of shrubs, 400 species of herbs, and 150 species of climbers (Economic review of Tripura, 2008-2009). The sanctuary has several perennial water rivulets. The area has a tropical climate, with cold weather

from November through February. Annual average rainfall is 255.89 mm. Temperatures vary from 6.8°C in January to 37.7°C in June. The sanctuary is well-known for its Asian population of Bison (*Bos garus* Smith) and migratory water birds in winter among many other wild animals. The present study is funded by Japan International Co-operation Agency (JICA).

Sampling regime

Field surveying of butterfly fauna was conducted from May 2010 to October 2010, following Modified Pollard Walk Method (MPWM) (Pollard 1977) in four distinct habitats of TWS. Four Permanent Line Transects (PLTs) (approx. 1 km long and 5 m wide) were laid based on floral composition in the four habitat types, namely: mature secondary mixed moist deciduous forest (TWS I); regenerated secondary mixed moist deciduous forest (TWS II); secondary mixed moist deciduous forest with bamboo patches (TWS III) and a grassland of exotic species (*Pennisetum purpureum* Schumach) (TWS IV) (Table 1). The degree of anthropogenic pressure is distinct among the four habitats in the study area. Butterflies were counted during sunny days at a constant speed in each transect from 8 am to 12 am local time for four consecutive days. This was repeated at 30 day intervals, maintaining the same spatial scale in each of the four sampling sites. Collected butterflies were identified using field guides (Haribal 1992; Kunte 2000; Kehimkar 2008), and followed the classification given by Ackery (1984). Vouchers of collected specimens are maintained in the Department of Zoology, Tripura University.

Data Analysis

The Shannon diversity index was applied to estimate butterfly species diversity along the habitats (Shannon and Wiener 1949). This index was calculated by the equation $H_s = -\sum p_i \ln p_i$. Where, p_i is the proportion of individuals found in the *i*th species and 'In' denotes the natural logarithm. Species dominance across habitats was estimated by Simpson's dominance index (Simpson 1949). This index was used to determine the proportion of more common species in a community or an area by the following formula $D_s = \sum^{s}_{i=1} [n_i (n_i-1)]/[N (N-1)]$ where, n_i is the population density of the *i*th species, and N is the total population density of all component species in each site. Comparisons of butterfly species composition between different forest habitats was estimated using single linkage cluster analysis based on Bray-Curtis similarity (McAleece 1998). Biodiversity Pro version 2 (Lambshead *et al.* 1997) was used for data analysis.

Results and Discussion

During the systematic survey, a total of 1005 individuals of 59 species of butterfly belonging to 48 genera and five families were recorded from the four habitat types at TWS (Table 2, 4). The 59 species recorded in the present study compared suitably with the 72 species recorded in another study of northeast India (Ali and Basistha 2000) that showed more or less similarity in habitats and climatic conditions. Among the families, Nymphalidae was dominant with 23 species followed by the Lycaenidae (13 species), Papilionidae (8 species), Hesperiidae (8 species) and Pieridae (7 species) (Table 2). Members of the Nymphalidae were always dominant in the tropical region because most of the species are polyphagous in nature, consequently helping them to live in all the habitats. Additionally, many species of this family are strong, active fliers that might help them in searching for resources in large areas (Eswaran and Pramod 2005; Krishna Kumar *et al.* 2007; Raut and Pendharkar 2010; Padhye *et al.* 2006).

A high proportion of nymphalid species indicates high host plant richness in the Trishna sanctuary area. Notwithstanding, all the recorded species are widely distributed in India (Wynter-Blyth 1957) and only *Troides helena* L. is listed as an endangered species in

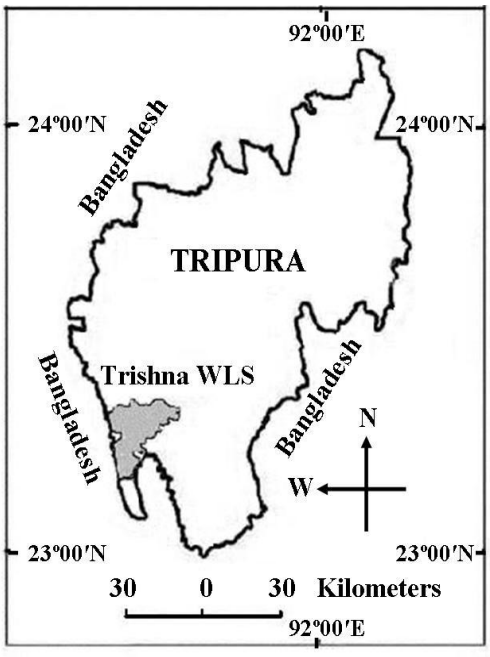

Figure 1. Location map of Trishna Wildlife Sanctuary.

Table 1. Characteristics of the four habitat types at Trishna Wildlife Sanctuary.

STUDY SITES	GEOGRAPHICAL POSITION	ALTITUDE (M) ABOVE SEA LEVEL	HABITAT TYPE AND DOMINANT PLANT
TWLS I	23°16′41.23'' N 91°24′08.4'' E	41 m	Mature secondary mixed moist deciduous forest dominated by *Shorea robusta* Roth, *Dipterocarpus turbinatus* C.F.Gaertn, and *Terminalia belliraca* (Gaertn.) Roxb. plants.
TWLS II	23°15′01.17'' N 91°23′22.45'' E	31 m	Regenerated secondary mixed moist deciduous forest dominated by *Toona ciliate* M. Roem., *Albizia procera* Durazz along with many herbs, shrubs and climbers
TWLS III	23°16′41.45'' N 91°22′32.93'' E	56 m	Secondary mixed moist deciduous forest with bamboo patches covered with sedges, long grasses and shrubs like *Microcos paniculata* L., *Chromolaena odorata* (L.) King and H.E.Robins, and *Lantana camera* L.
TWLS IV	23°16′33.29'' N 91°23′01.29'' E	52 m	Grassland of exotic species (*Pennisetum purpureum* Schumach) along with small Cashew nut plantation

CITES Appendix II (Collins and Morris 1985). However, 9 species: viz. *Lethe europa* (F.), *Cepora nerissa* (F.), *Castalius rosimon* (F.), *Narathura selta* (de Niceville), *Pantoporia hordonia* (stoll), *Megisba Malaya* (Horsfield), *Arhopala fulla* (Hewitson), *Elymnias malelas* (Hewitson) and *Baoris farri* (Moore) are listed in the Indian Wildlife Protection Act of 1972 as under Schedule I and II (Anonymous 2006). An aphidophagous butterfly, *Spalgis epius* Westwood (Kehimkar 2008), belonging to the family Lycaenidae is recorded from the sanctuary. Out of 59 species, 21 species (35.59%) have been recorded from only a single habitat type, and hence, referred to as unique species (Table 4). TWLS IV contain one of these [*Spalgis epius* (Westwood)], whereas TWLS I, TWLS II and TWLS III contain seven, five, and eight unique species, respectively. Results suggested that the structural complexity and vegetation diversity of each habitat type might facilitate a definite set of micro-habitats suitable for a particular species. Thirty one species (52.54%) were recorded for the first time in the state (Table 4).

High species richness of butterflies in secondary forest habitats was reported by earlier workers (Bowman *et al*. 1990; Lawton *et al*. 1998; Ramos 2000), and several studies revealed that habitat specificity is directly linked to the availability of host plants for larvae and adults (Grossmueller and Lederhouse 1987; Thomas 1995). In general, all four habitats showed high species richness and diversity index values. Particularly, among the study sites, TWS I ranked highest based on species richness and diversity indices (D_S; H_s) followed by TWS II, TWS III and TWS IV (Table 3, Table 4). Species richness and diversity of butterfly in the regenerated secondary forest (TWS II) is also high because of rapid vegetative succession that provides suitable foliage and nectar for larval and adult stages of butterflies. Moreover, some butterflies (*Papilio demoleus* Linnaeus, *Graphium agamemnon* Linnaeus, *Castalius rosimon* Fruhstofer; *Eurema hecabe* (Moore) were observed in the core area of TWS II, mudpuddling in the wild boar (*Sus scrofa* Linnaeus) inhabited sites. Pits created by wild boars serve as collection sites of mineral-rich feces and urine perfect for mudpuddler butterflies, especially females that require minerals for reproduction (Ramos 1996). TWS III showed moderate species richness and diversity due to half of the sampling area being rich in secondary vegetation, and the remaining half being dominated by bamboo patches. Most of the species recorded in TWS III are found in the secondary vegetation and only a few species *Lethe europa* (Fabricius), *Lethe mekera* (Moore) and *Mycalesis perseus* (Fabricius) were confined to bamboo patches because they prefer bamboo as a host plant (Kehimkar 2008). Comparatively, TWS IV (grassland of exotic species) showed poor species richness and diversity of butterflies. A similar impact of exotic species was found in the case of many native herbivores, particularly those species for which native plants serve as a potential food plant (Nagy *et al.* 1998). The cultivation of exotic grass species will largely create a problem for the host-specific butterfly species of the sanctuary that chiefly rely on locally available plant species for their survival. Among the four habitats, TWS I showed low dominance value (0.038) followed by TWS II (0.041), TWS III (0.045) and TWS IV (0.054), respectively (Table 3). The low dominance value of TWS I indicate that butterfly species are more or less evenly distributed in terms of abundance compared to TWS II, TWS III and TWS IV. The present results indicate an availability of host plants for each butterfly species and efficient resource sharing by each species recorded in the TWS I.

Table 2. Family wise composition of butterflies showing number of genera, species and individuals recorded from Trishna Wildlife Sanctuary.

FAMILY	GENERA	SPECIES	INDIVIDUALS
Nymphalidae	18	23	492
Lycaenidae	13	13	224
Papilionidae	4	8	116
Hesperiidae	8	8	58
Pieridae	5	7	115
Total	48	59	1005

Table 3. Diversity indices of butterfly communities in four habitats of Trishna Wildlife Sanctuary.

HABITAT TYPES	SHANNON DIVERSITY INDEX (H_s)	SIMPSON'S DOMINANCE INDEX (D_s)
TWS I	3.44	0.038
TWS II	3.38	0.041
TWS III	3.25	0.045
TWS IV	3.04	0.054

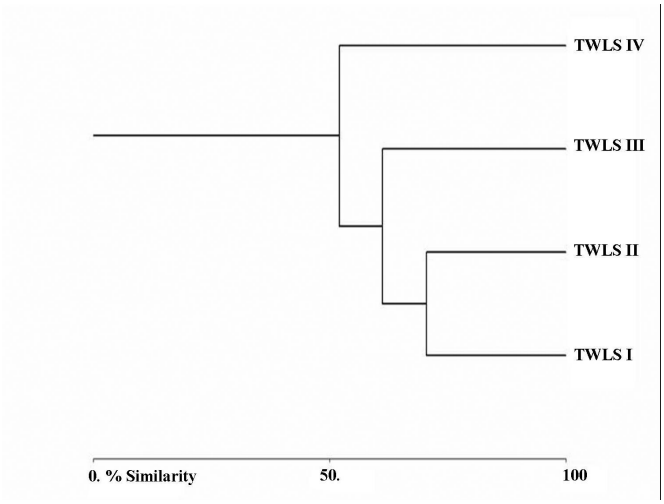

Figure 2. Single linkage cluster analysis between habitats based on Bray-Curtis similarity.

Cluster analysis based on the Bray-Curtis single linkage similarity value revealed the percent similarity between butterfly species composition across the four habitat types. The open habitat of long exotic grass (TWS IV) stood out clearly from the other three habitats and showed linkage at 50.86% (which represent lowest) similarity. Degraded forest habitat (TWS III) was linked at 58.16% similarity to the cluster of habitats of primary forest (TWS I) and regenerated forest (TWS II) which showed highest similarity in species composition (70.55%) (Figure 2). Results showed that more than 50% of the butterfly species recorded in all the sampling sites were the same despite differences in habitat characteristics. Study conducted by Novotny *et al.* (2007) in tropical forests showed low beta diversity of herbivorous insects. The high similarity value of butterfly fauna between different habitats of TWS is an indicator of low beta diversity in this small forest area which in turn indicates availability of more or less similar

niches in each of the studied habitats. This fact is also supported by Proctor (1986), who opined that tropical forests contain more microhabitats per unit ground area than their temperate counterparts. However, Klopfer and MacArthur (1961) suggested that in tropical forests species may reside not in the number of niches available, but in an increase in the similarity of coexisting species. The extent to which all these informal explanations apply is a matter of further study at micro-habitat level.

The present study confirmed the existence of a wide diversity of butterflies in the selected habitat types of Trishna Wildlife Sanctuary and indicates specifically that mature secondary and regenerated forests had the highest butterfly diversity and species richness, while exotic grasslands have negative influences on local butterfly community structure. However, to understand the influence of different landscape elements on butterfly community structure, long-term butterfly censusing and monitoring (both temporally and spatially) is required in Trishna Wildlife Sanctuary. Moreover, the presence of 9 threatened species and 21 unique butterfly species in the sanctuary makes it an important butterfly habitat in the state for future conservation and management programs.

Table 4. List of butterfly species and their abundance recorded in Trishna Wildlife Sanctuary.

SPECIES NAME	ABUNDANCE			
	TWS I	TWS II	TWS III	TWS IV
Arhopala pseudocentaurus (Doubleday) ++	22	28	18	0
Melanitis leda (Linnaeus)	16	13	21	9
Junonia almana (Linnaeus)	9	9	12	18
Orsotrioena medus Fabricius.	15	16	10	6
Ypthima baldus (Fabricius)	16	10	16	4
Catopsilia pomona (Fabricius)	8	9	13	14
Euploea core (Cramer)	6	8	19	10
Neptis hylas (Linnaeus)	5	10	15	12
Junonia atlites (Linnaeus)	15	11	0	13
Papilio polytes Linnaeus	8	10	10	11
Ypthima huebneri Kirby	9	12	12	6
Castalius rosimon (Fabricius) x	11	9	15	0
Narathura selta (deNiceville) x ++	20	13	0	0
Catopsilia pyranthe (Linnaeus)	7	7	9	4
Zizeeria karsandra (Moore) ++	5	6	8	7
Eurema hecabe (Linnaeus)	4	8	8	6
Papilio demoleus Linnaeus	15	7	0	6
Baoris farri (Moore) x	11	9	1	0
Pantoporia hordonia (Stoll) x	4	6	5	5
Lethe europa (Fabricius) x ++	8	0	11	0
Junonia hierta (Fabricius)	10	0	0	8
Zemeros flegyas (Cramer)	7	10	0	0
Atrophaneura aristolochiae (Fabricius)	6	6	0	5
Tanaecia lepidea (Butler)	4	7	4	0
Papilio nephelus Boisduval	3	0	5	7
Zizina otis (Fabricius)	8	0	0	5
Danaus genutia (Cramer)	3	9	0	0
Athyma perius (Linnaeus) ++	0	4	7	0
Mycalesis perseus (Fabricius)	0	2	5	3
Megisba malaya (Horsfield) x++	0	4	5	0
Iambrix salsala (Moore) ++ -	9	0	0	0

Table 4. *Continued.*

SPECIES NAME	ABUNDANCE			
	TWS I	TWS II	TWS III	TWS IV
Sarangesa dasahara Moore ++	5	0	3	0
Udaspes folus (Cramer) ++	0	4	0	3
Graphium sarpedon (Linnaeus)	0	3	4	0
Gandaca harina (Horsfield) ++ -	7	0	0	0
Graphium agamemnon (Linnaeus) -	0	0	7	0
Spalgis epius (Westwood) ++ -	0	0	0	7
Elymnias hypermnestra (Linnaeus)	3	3	0	0
Troides helena (Linnaeus) -	5	0	0	0
Eurema blanda (Boisduval)	2	0	0	3
Loxura atymnus (Stoll) ++ -	0	0	5	0
Parnara guttatus (Bremer and Grey) ++	0	1	2	2
Hypolimnas bolina (Linnaeus) -	0	4	0	0
Cepora nerissa (Fabricius) x -	0	4	0	0
Eraota timoleon (Stoll) ++ -	0	0	4	0
Arhopala fulla (Hewitson) x ++ -	0	28	4	0
Tagiades zapetus (Stoll)	2	2	0	0
Ancistroides nigrita (Latreille) ++ -	3	0	0	0
Lebadea martha (Fabricius) ++ -	3	0	0	0
Ariadnae ariadnae (Linnaeus) -	2	0	0	0
Discophora timora Westwood ++ -	0	0	2	0
Leptosia nina (Fabricius) -	0	0	2	0
Discolampa ethion (Westwood)	1	1	0	0
Elymnias malelas (Hewitson) x ++ -	0	2	0	0
Papilio memnon Linnaeus -	1	0	0	0
Uthalia aconthea (Cramer) -	0	1	0	0
Lethe mecara (Moore) ++ -	0	0	1	0
Catapaecilma elegans (Druce) ++ -	0	0	1	0
Suastus gremius (Fabricius) ++ -	0	1	0	0

Symbols following butterfly names denotes: x Threatened species, ++ new record for the state, - unique species

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