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Variation in butterfly species diversity and patterns of abundance in Manas wildlife sanctuary

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Abstract
Quantifying and monitoring invertebrate fauna is an important step in formulating conservation and management plans for different habitats. Butterflies, due to their potential as indicator species, their short life cycles and easy identifiability, are useful for studies on landscape ecology and habitat quality even in protected areas such as Manas Wildlife Sanctuary. The study, undertaken to understand how butterfly species composition and abundance vary in different landscape elements of Manas Wildlife Sanctuary, found that there is a high similarity between the woodland, grassland and edge landscape elements in the study site. But difference in vegetation composition along with natural habits of different species, led to the highest diversity being recorded in woodland LSE (H'=3.274), followed by edge LSE (H'= 3.117) and grassland LSE (H'= 2.891). Nymphalidae family was found to be the most abundant in the study site while individuals of Riodinidae were the least abundant.

Keywords: butterfly, landscape, diversity, variation, Manas wildlife sanctuary

Introduction

Butterflies are among several insect groups that respond rapidly to minor changes in local weather, climate, light levels, and other small changes in their habitat [1, 2]. Many authors have thus suggested the potential of butterflies to be used as early indicators of environmental change [3, 4]. Even in protected areas, butterflies are ideal subjects for ecological studies of landscapes because butterfly community structure is largely determined by habitat quality, along with the availability of larval and adult food plants. [5, 6]. An important step in the study and conservation of most butterfly species is understanding their dependence on the vegetation composition and structure that comprise their habitat and studying processes that influence the habitat and vegetation composition. Due to its location in the Indo-Myanmar biodiversity hotspot, Manas Wildlife Sanctuary, serves as a conservation area for many endemic, rare, endangered and charismatic species, including but not restricted to *Rhinocerous unicornis*, *Porcula salvania*, *Panthera tigris*, *Elephas maximus*, *Caprolagus hispidus*, *Houbarogsis bangalensis*, *Cairina scutulata*. Yet like most protected areas, in Manas Wildlife Sanctuary, emphasis is given on conservation of vertebrates, but emphasising conservation strategies with respect to vertebrates may lead to large gaps in the overall protection of biodiversity [7]. Though much work has been done in this region on different vertebrate species, still research on insects including butterflies is lacking. In recent years, notable works on butterflies have been undertaken by Singh, [8] Saikia and Saikia, [9] Choudhury *et al.* [10], Gogoi [11, 12] among others. But detailed studies on associations between landscape elements and butterfly communities and maintenance of vegetation for butterfly conservation are lacking. This study thus attempts to investigate patterns of butterfly species diversity and abundance in the three predominant landscape elements in Manas Wildlife Sanctuary. In doing so, the study can help identify landscape elements that support the diversity of resident butterfly species, which can help towards formulating plans for their management. This can also provide useful information to quantify the status of habitats present in the three landscape elements and associated with different animal taxa, and their management strategies.

2. Materials and methods

2.1. Study Site

The study was conducted in the Manas Wildlife Sanctuary (henceforth Manas), a UNESCO World Heritage Site. With a total area of 390 km^2, Manas Wildlife Sanctuary is a part of the core area of Manas Tiger Reserve.

Located in the north-eastern state of Assam, in the foothills of the Himalayas, the climate of the study area is meso-thermal humid climate, which is characteristic of Brahmaputra valley type.

Monsoon (June–September) is the hottest period with the most rainfall, while winter (December–February) is characterized by fog and cold weather.

The pre-monsoon season from March–May and the retreating monsoon from October–November, are both transitional periods. Annual rainfall ranges between 3000-4000mm [13] Broadly, the vegetation of Manas is classified as sub-Himalayan alluvial semi-evergreen forest, east Himalayan mixed moist and dry deciduous forests, the commonest type, and grasslands. [14] Manas is situated in one of the major biodiversity hotspots of the world and represents a highly diverse zone for flora and fauna, with records of 60 species of mammals, around 470 avian species, and 42 species of herpetofauna.

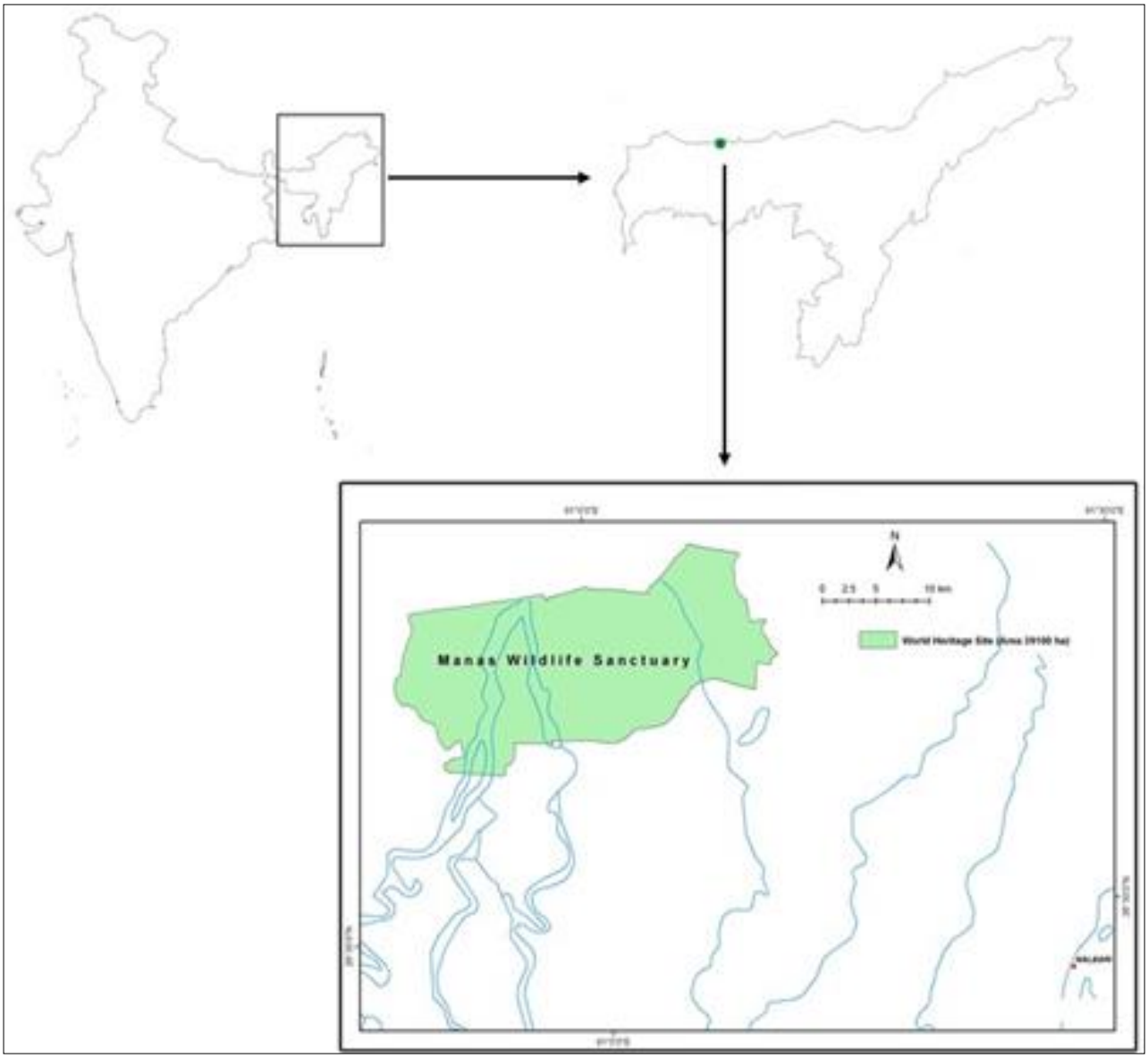

Fig 1: Location map of Manas Wildlife Sanctuary.

2.2. Sampling procedure

Field survey of butterflies was conducted for three consecutive years from 2015-2018. Depending on observed levels of habitat complexity and vegetation type, the study area was divided into three distinct landscape elements and a total of 17 transects were laid out covering each landscape element (Table 1). Butterflies were sampled using the Modified Pollard Walk method [15]. Sampling was carried out on days with less than 30% cloud cover as butterfly activity is more on sunny days [16]. In each transect, butterflies were recorded within 10 metres from the observer on either side. Each record was noted, and photographs of every new species encountered, including the commonest ones, were taken for reference. Since all butterflies could not be identified from only the upper-side or under-side of wings as seen in the field, many species were hand netted, photographed and released immediately with due permission of forest officials.

No specimens were collected during the process. Butterflies were identified using the identification keys of Watson, [17] Evans [18] Talbot [19], Haribal [20], and photographic guides of Kehimkar [21, 22].

Table 1: Characteristics of the Transects in the different landscape zones in Manas.

Landscape Elements (LSE)	Transect Number	Transect Length	Vegetation
Grassland LSE	T1 – T5	1000 metres each	Narenga porphyrocoma, Imperata cylindrica, Vetiveria zizaanioides, Arundo donax, Saccharum spontaneum, Saccharum procerum Phragmites karka, Themeda arundinacea, Bombax ceiba, Lagerstroemia flosreginae, Dillenia indica, etc.
Woodland LSE	T6– T10	1000 metres each	Bombax ceiba, Pterospermum acerifolium, Amoora wallichi, Lagerstroemia flosreginae, Terminalia bellerica, Careya arborea, Dysoxylum binectariferum, Phoebe goalparensis, etc.
Edge LSE	T11 – T16 T17	500 metres each 1000 metres	Lantana camara, Leea asiatica, Mimosa pudica, Ageratum conyzoides, Cynodon dactylon, Costus speciosus, Leucus aspera, Riccinus communis, Tridax procumbens, etc.

2.3. Data analysis

Butterfly diversity was estimated using the Shannon-Wiener index (H') which is given by the formula:

$$H' = -\sum_{i=1}^{s} Pi \ln Pi$$

Where *s* is the number of species, p_i is the proportion of the proportion of individuals found in the *i*th species and *ln* denotes the natural logarithm. Species dominance across the different landscape zones were estimated using the Simpson's dominance index to determine the proportion of more common species in a community or an area. It is calculated using the formula $D = \Sigma si=1$ [ni (ni-1)]/[N (N-1)] where, *ni* 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 across the different landscape zones were done using the single linkage cluster analysis based on Bray-Curtis similarity (Biodiversity Pro 2.0) [23, 24].

3. Results and Discussion

During the survey, 252 butterfly species of butterflies were recorded with a dominance of Nymphalidae family (101 species, 40.1%) followed by Lycaenidae (63 species, 25%), Hesperiidae (35 species, 13.9%), Pieridae (27 species, 10.7%), Papilionidae (24 species, 9.5%), and Riodinidae (2 species, 0.8%). This result represents 26.2% of total 962 species of butterflies recorded from North-East India.[18] The maximum number of genera were recorded under Nymphalidae family (35.6%) while the least were recorded under Riodinidae family (1.48%). 49 species of butterflies which are protected under the Wildlife Protection Act of 1972 [25] were also found in the study area.

Dominance of members of Nymphalidae family were reported by different authors from Manas Biosphere Reserve [26, 10] As documented by several studies, habitat specificity is directly linked to the availability of host plants, [27, 28] therefore dominance of Nymphalids may be due to the presence of plants of Apocynaceae, Anacardiaceae family which serve as host plants for butterflies of this family. Moreover most species under Nymphalidae are strong fliers and this attribute helps them to spread out and utilize resources in different landscape elements. [29][30] The study also recorded the presence of *Hasora taminatus* in the edge LSE and *Pontia daplidace* in both the grassland LSE and woodland LSE. Both species were previously recorded from West Arunachal Pradesh and are expected to have extended their range through Buxa-Manas. *Pontia daplidace* was previously recorded from Manas National Park only by Gogoi *et al.* in 2014. [8] Similarly, the skipper *Caprona agama* is known only from Khasi Hills in Northeastern India but it was recorded in the study area, from the grassland LSE.

The grassland LSE showed the lowest species richness but many species of butterflies were recorded mudpuddling in pits, created by wild boars and due to movement of vehicles. Most recorded mudpuddlers were different species of Lycaenidae and Pieridae such as *Castalius rosimon*, *Zeltus amasa*, *Catopsilia pomona*, *Cepora nandina*, *Appias Indra*, *Appias olferna.* Most Papilionidae were absent in this LSE and only a few species, *Papilio demoleus*, *Papilio helenus*, *Papilio polytes*, *Castalius rosimon* were recorded mudpuddling and nectaring. Individuals of these families obtain most of their nutritional requirement from flower nectar and most of them are canopy fliers. But especially males of these families have the habit of coming down to moist ground to take up water and nutrients which are subsequently required for reproduction. Thus high abundance of individuals of Pieridae in this LSE may be likely due to their preference for open areas and habit of nectar feeding which does not require them to penetrate dense forest understory [32]. Overall due to dominance of Poaceae family, and less abundance of nectaring plants, butterfly abundance in grassland LSE was lowest among the three.

Comparatively, butterfly diversity and recorded abundance was higher for edge LSE. Species representing all six families of butterflies were recorded from this LSE. This may be due to the presence of diverse vegetation in the area, including species such as *Lantana camara*, *Leucas aspera*, *Costus speciosus*, *Crotalaria mucronate*, *Heliotropicum indicum*, *Mimosa pudica*, among others, which provided suitable foliage and nectar resources for both larval and adult stages of butterflies. Many butterfly species such *Neptis hylas*, *Rohana parisatis Phalanta phalanta*, *Polyura athymas*, *Lampides boeticus*, *Megisba malaya*, *Zizina otis*, *Ypthima baldus*, *Caleta elna*, *Papilio polytes*, *Paplilio paris*, *Papilio polyctor*, *Graphium sarpedon*, etc. were recorded mudpuddling along the river sands, puddles along animal trails and animal feces in this LSE. The edge LSE also recorded a high abundance of Nymphalids, which can be explained by the presence of open areas and the preference of Nymphalids with strong flying activity to visit such sites. [9].

The woodland LSE on the other hand, recorded the highest number of individuals of species belonging to Papilionidae. This might be because most species of Papilionidae are confined to moist evergreen forests and are mostly fast fliers such as *Graphium agamemnon*, *Papilio demolus*, *Graphium antiphates*, etc, which sometimes settle down to mudpuddle.[21] Many individuals belonging to Nymphalidae family were also recorded in this LSE, including species such as *Symbrenthia hypselis*, *Kallima inachus*, *Doleschallia bisaltide*, *Lethe europa* etc, which gain most of their nutritional requirements by feeding on juices of rotting fruits and plant sap along with carrion, animal dung, etc.[33] and this LSE provided an ideal habitat for these species in terms of their feeding preferences. The transects in the woodland LSE were highly diverse in terms of butterfly species richness and abundances which may be due to the presence of mixed vegetation including large trees such as *Bombax ceiba*, *Pterospermum acerifolium*, *Lagerstroemia flosreginae*, *Terminalia sp.* etc, shrub species such as *Ipomea carnea*, *Phlogacanthus curviflorus*, *Costus speciosus* and herbs as *Tridax procumbens*, *Zinnia elegans*, etc. in this LSE. This provided better opportunity for different butterfly species and contributed to high diversity. The woodland LSE thus provided the most varied resource in terms of host plants and nectar plants along with mate location sites, which might have helped to avoid competition. This LSE also provided an ideal habitat for shade loving species such as *Lethe chandica*, *Mycalesis gotama*, *Orsotrioena medus*, *Badamia exclamationis*, *Hasora taminatus.*

All three landscape elements showed high species richness and diversity index values. Woodland LSE ranked highest in

terms of diversity (H'=3.274, D =0.007), followed closely by Edge LSE (H'= 3.117, D=0.008), while Grassland LSE showed the lowest values (H'= 2.891, D=0.01). Among the three LSE habitats, Woodland LSE showed lowest dominance value (0.007) which indicates that butterfly species were more or less evenly distributed in terms of abundance in this site as compared to the other two LSE.

Cluster analysis based on the Bray-Curtis single linkage similarity value revealed the percent similarity between butterfly species composition across the three landscape elements (Figure 2). The grassland LSE stood out clearly from the edge LSE and woodland LSE and showed lowest similarity at linkage value of 62.35%. Woodland LSE and Edge LSE showed higher similarity in species composition and were linked at 76.51% (Figure 2). Despite differences in vegetation composition, results showed that more than 50% of the butterfly species recorded in all the landscape elements were the same. The high similarity value of butterfly fauna between different habitats of Manas is an indicator of low beta diversity in the protected area. This indicates availability of more or less similar microhabitats for butterflies in each of the studied landscape. This is line with findings of other researchers such as a study by Proctor in 1986 and Novotny *et al.* in 2007, which showed that tropical forests contain more microhabitats per unit ground area than their temperate counterparts and that tropical forests showed low beta diversity of herbivorous insects. [34, 35]

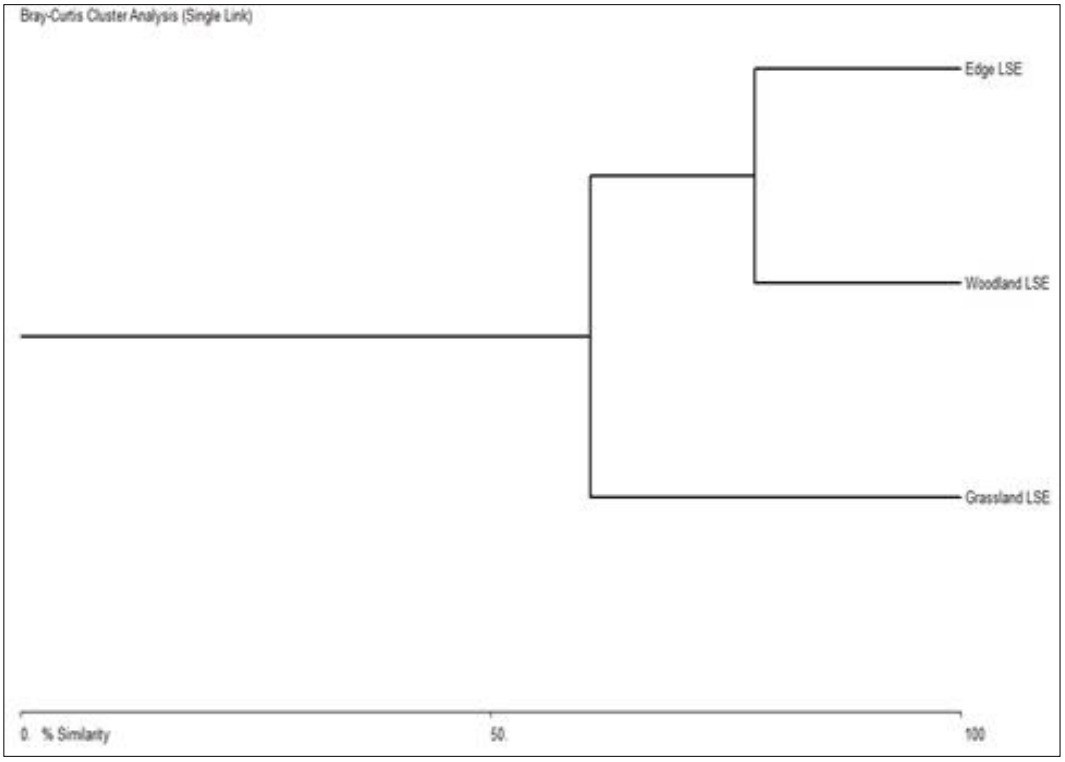

Fig 2: Single linkage cluster analysis between landscape zones in Manas based on Bray- Curtis similarity.

4. Conclusions

The present study confirmed the presence of a wide diversity of butterflies in Manas Wildlife Sanctuary and found high similarity values for butterfly fauna between different habitats of Manas Wildlife Sanctuary. Although in terms of species richness and diversity, Woodland LSE was more closely related to the Edge LSE than the Grassland LSE but overall, there was more than 50% similarity between all three landscape elements. This indicates availability of similar microhabitats for butterflies in each of the studied landscape even though each LSE might facilitate definite set of micro-habitats suitable for different species of butterflies. As such long-term studies and monitoring can help understand the influence of different landscape elements on butterfly community Moreover, due to its geographic position in the Indo-Myanmar biodiversity hotspot, presence of 252 species of butterflies including 49 species protected under Wildlife Protection Act of 1972, Manas Wildlife sanctuary is an important protected area in the state for future works on conservation and management programs and long term monitoring programs of butterfly fauna.

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