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# Taxon diversity of butterflies in different habitat types in Royal Manas National Park

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**Abstract**
This study was carried out in Manas range of Royal Manas National Park for the period of three months in 2014. The aim of this research was to study taxon diversity of butterflies. The modified line transect of 1000 meters with five meters width on either side was used to record the butterfly communities. During the study 91 species belonging to five major families were recorded of which one species was new record for Bhutan. Nymphalidae was the most common (33%, n = 30), and the lowest was Hesperidae (12%, n = 11). Shannon's diversity index (H′ = 3.162) and Pielou's evenness index (*J′* = 0.85) indicated high butterfly diversity and Margalef's richness index (*Dmg* = 45.97) indicated rich species diversity in the study area. Study area hosts a unique diversity of butterflies, therefore underlining the importance for maintaining biodiversity within and outside the park area as a landscape conservation programme.

**Keywords:** Butterfly, diversity, evenness, habitat, Manas range, richness.

## 1. Introduction
Among all the insects, butterflies are planet's most majestic creature with brilliant colour and exquisitely patterned [16], and have always been most fascinating to humankind from the time immemorial [10]. Butterflies are taxonomically well studied group, which have received a reasonable amount of attention throughout the world [6], and around 18,000 species of butterflies are estimated to be there in the world and India alone has recorded 1,501 species [10]. Likewise Nepal has recorded 640 species [30] and the adjoining state of Sikkim has recorded 689 species [7].
A lots of study had found that habitats and butterfly diversity was positively related [12, 36]. Many butterflies are restricted to specific habitat types and some are highly mobile, so this study examined butterflies diversity in different types of habitat found in Manas. Very little is known about butterfly diversity in Bhutan despite being estimated to have 800-900 species of butterflies [38]. Likewise, there is no record of study done on butterfly diversity in Royal Manas National Park (RMNP). Therefore, the aims of the study were (i) to study butterfly diversity and composition in Manas range and (ii) to compare butterfly diversity and composition among different habitats.

## 2. Materials and Methods
### 2.1 Study area
Royal Manas National Park (RMNP) was established as Game Sanctuary in 1966 and later it was upgraded to National Park in 1993. RMNP is the first and oldest of all the protected areas and occupying 1057 km2 in the Himalaya kingdom of Bhutan. It is located in the southern foothills of the Bhutan (90° 35' 03.61" E to 91°13'28.51"E and 26° 46'16.16"N to 27° 08'38.70"
and borders with India's Manas Tiger Reserve (World heritage site), forming a trans-boundary landscape conservation.
Among the three ranges of RMNP, Manas range is located towards the east and river Manas runs through forming the lifeline of the park. It covers an area of 348.31 km 2 ranging from altitude 80 m [34] to 892 m above the sea level. Due to its diverse vegetation types and altitude ranges, Manas plays the most potential role as a source for the globally endangered species *viz.,* Bangle tiger, Asian elephant, Asiatic water buffalo, Binturong, Dhole, Golden langur.


**Fig 1:** Map of Bhutan showing protected areas and Biological Corridors network.

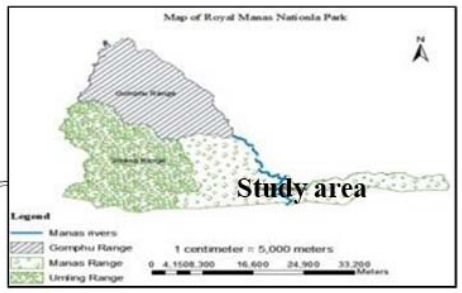


**Fig 2:** Map of RMNP showing study area

### 2.2 Sampling

"Pollard walk" method was adopted with a few modifications based mainly on geographical and climate considerations [18, 28, 29, 31]. 1000 meters transect [18, 22] were laid in each habitat types, *viz.*, closed canopy, shrub land, crop field, along the roads and river/stream beds. This method was used for estimating diversity, species richness, abundance, trends and threat status [20]. Transect counts provides an index of population size and therefore can be used to measure changes in abundance.

Butterfly sampling was carried out during 0900 to 1200 hours and 1400 to 1700 hours during the sunny days [22, 31] with uniform pace of 45-50 minutes in a transect [18, 23]. Each transect was visited once a month from January to March in 2014. Butterflies observed within five meters either side of transect line and five meters to the front of recorder were recorded [13, 16, 22, 31]. Every effort was made to avoid counting butterfly more than once. Stoppages were made along transect to resolve identification problems either by photograph or capture by butterfly sweep net for closer examination and recording was resumed from the point where the walk was interrupted. Butterfly capturing was done very safely by butterfly sweep net and release in the
same area immediately after the photograph was taken. Trends in the survey were evaluated over three months. Species which encountered a total abundance exceeding 100 individuals were described as very common, common (50-99 sighting); not rare (15-49); rare (3-5); very rare (1-2) [35].

### 2.3 Butterfly species identification

Identification of butterflies' species followed Haribal [7], Kehimkar [10] Singh [29], Smith [30] Venkataraman [39] in addition to Van der Poel, and Wangchuk, [38] Wangdi and Shrub [40, 41].

### 3. Statistical analysis

Shannon Weaver diversity index (H′) [27], Margalef's index (Dmg) [14], Pielou's Index (J′) [21] and Sørensen's similarity index were used to analyze the data [5, 9, 24, 28, 29]. Density of butterfly was expressed either in km2 or in hectare after obtaining total survey area.

Further correlation, one way ANOVA and non-parametric test were carried out for entire pooled data [2, 16, 22, 24, 25, 31, 32] and before conducting the above statistical analysis the data were tested for normality using SPSS, and non-normal data were either transformed or analyzed non- parametrically. Species accumulation curve was also plotted for the entire sampling to see the rate of species accumulation during each of the three successive sampling along with sampling efforts.

### 4. Results and Discussion

### 4.1 Butterfly diversity within whole study area

One new record of butterfly diversity for Bhutan was added from the current study, viz., Coon (Sancus folio – Mabille) (Figure 5). Besides, the all the butterfly recorded (annexure I) in the study is new record for the study area.

A total of 1319 individuals and 91 species were identified belonging to five major families in five different habitat types in Manas range. The individual density of butterfly in Manas range was 59 individuals per hectare. Shannon's diversity index of 3.162 indicates the high butterfly diversity for the study area [33] which is also supported by high value of Pielou's evenness index (J′ = 0.85). Besides, Margalef's richness index (Dmg = 45.97) indicated rich species diversity in the study area [8] Even though the indices are high, the current study would not have truly captured the richness of the area as increase in sampling efforts resulted in increased number of species and individuals recorded ($r = .569$; $p = .000$; $r = .491$, $p = .015$; $F(1,43) = 13.68$; $p = .001$ respectively), and high species richness was recorded in forest where the sampling efforts were higher in west Albertine rift forest [9]. The number of species recorded increased with the increase in the number of individuals encountered [18]. The Margalef's index and species number were significantly correlated ($r = .884$; $p = .000$) showing that if we encounter more individuals in sampling there are more chances of adding new species and thus species richness will increase.

Out of five families Nymphalidae was the most common (33%, n = 30), followed by Lycaenidae (23%, n = 21), Pieridae (19%), Papilionidae (13%) and the lowest was Hesperidae (12%, n = 11) in the study area. This could be due to Nymphalidae being largest family and Hesperidae being the lowest in species richness. Around 6000 and 3500 species of Nymphalidae and Hesperidae are found worldwide respectively [10]. Similar studies around the world found that Nymphalidae ranked the highest in species richness followed by Lycaenidae [9, 18, 24, 29, 31, 35]. While, the least common family varied in different studies, for instance Pieridae was the least common family in the study by Majumder, *et al*. [18], Papilionidae by Kasangaki, *et al*. [9] Tiple [35], and Hesperidae by Ramesh [22], Sarma [24], Singh [29].

### 4.2 Butterfly diversity among habitats

Habitats differed in the butterfly species diversity and the

shrub land had the highest diversity (H′ = 3.47), followed by river beds (H′ = 3.35), and the lowest along the roads (H′ = 2.74). The Shannon diversity index was significantly different among habitats $F(4, 40) = 4.126$; $p = .007$). Roads and closed canopy habitats had comparatively less diversity of butterfly as compared to forest patches exposed to direct sunlight [17, 22]. While, bush brown dominated the closed canopy as expected as they like shady habitats due to their cryptic canopy behaviors [7].

Many studies revealed that species diversity had strong relationship with habitat types [12, 36] Butterfly species are associated with flowers and host plant for adult and larva respectively, and sunlight to stimulate their body [5, 40]. Species richness in five different habitat types was found to be comparatively different. Shrub lands (*Dmg* = 63.62) recorded the highest, followed by river beds (*Dmg* = 61.57), and lowest along the roads (*Dmg* = 21.510). The highest species richness in shrub land could be due to edge effect [18]. Shrub land was found to have high species richness in previous studies [24, 31], while Majumder, *et al*. [18] found uniform species richness in different habitats.

Pielou's species evenness index (J′), which measures the evenness of species abundance is complimentary to the diversity index concept and it indicates how the individual of various species are distributed in the community [8].

The species was distributed evenly in all the habitats except for the closed canopy. The highest evenness was found in crop fields ($J'$ =.897), followed by river beds and roads ($J'$ = .886), and lowest in closed canopy ($J'$ = .778) (Table 1). This was because closed canopy forest was dominated by bush brown species, while it had lesser number of other species. However, for the whole study area the species were uniformly distributed among the habitats ($J'$ = .824) as Pielue's evenness ($J'$ =.824) lies between ($J'$ = .76) and ($J'$ = .94) which were considered highly even respectively by [18, 26].

Density differed in different habitats. Individuals and species density of butterfly was the highest in shrub lands 10 individuals and 2.84 species per hectare as also recorded by [24] and followed by closed canopy 9 individual's density per hectare. Whereas river beds was the second highest in species density 2.76 per hectare were also found by [4] in Katavi ecosystem of western Tanzania. The lowest was along the roads 3.12 and 0.98 per hectare respectively (Figure 3).

Individual and species density increased from January (first sampling) towards March (third sampling). Individuals and species density were the highest in March, 48 individuals and 19 species per hectare respectively. The lowest was found in January, 29 individuals and 9 species.

**Table 1:** List of butterfly species and its status over three months (January to March 2014)

| Sl. No. | Family/ Species | Scientific Name | Occurring months | | | No. of Individual | Status |
|---|---|---|---|---|---|---|---|
| | **Lycaenidea** | | **Jan** | **Feb** | **Mar** | | |
| 1. | Chocolate Royal | *Remelana jangala ravata* | | | * | 1 | VR |
| 2. | Common Acacia Blue | *Surendra quercetorum* | * | * | * | 22 | NR |
| 3. | Common Cerulean | *Jamides celeno* | * | * | * | 28 | NR |
| 4. | Common Gem | *Poritia hewitsoni hewitsoni* | * | * | * | 1 | VR |
| 5. | Common Line Blue | *Prosotas nora* | | | * | 8 | R |
| 6. | Common Pierrot | *Castalius rosimon* | | | * | 3 | R |
| | | *Neopithecops zalmora* | | | | | |
| 7. | Common Quaker | *zalmora* | * | * | * | 3 | R |
| 8. | Common Imperial | *Cheritra freja* | * | * | * | 4 | R |
| 9. | Fluffy Tit | *Zeltus amasa* | | * | * | 8 | R |
| 10. | Green Oak Blue | *Arhopala eumolphus* | | | * | 1 | VR |
| 11. | Indian Cupid | *Everes lacturnus* | | | * | 1 | VR |
| 12. | Large Oak Blue | *Arhopala amantes amantes* | | | * | 2 | VR |
| 13. | Malayan | *Megisba malaya* | | | * | 1 | VR |
| 14 | Margined Hedge Blue | *Celatoxia marginata* | | | * | 3 | R |
| 15. | Pale Grass Blue | *Maha maha* | * | * | * | 12 | NR |
| 16. | Pea Blue | *Lampides boeticus* | | | * | 30 | NR |
| 17. | Plump Judy | *Abisara echerius* | | | * | 1 | VR |
| 18. | Punchinello | *Zemeros flegyas indicus* | * | * | * | 47 | NR |
| 19. | Purple Sapphire | *Heliophorus epicles indicus* | | * | * | 17 | NR |
| | Transparent 6- | | | | | | |
| 20. | Lineblue | *Nacaduba kurava* | | | * | 14 | R |
| 21. | Western Centaur Oakblue | *Arhopala pseudocentaurus* | | * | * | 5 | R |
| | **Nymphalidae** | | | | | | |
| 1. | Banded Tree Brown | *Lethe confusa* | | | * | 2 | VR |
| 2 | Chestnut Tiger | *Parantica sita* | | | * | 1 | VR |
| 3 | Commander | *Moduza procris* | | | * | 1 | VR |
| 4 | Common Birdwing | *Troides helena* | | | * | 3 | R |
| 5 | Common Baron | *Euthalia aconthea* | | | * | 1 | VR |
| 6 | Common Castor | *Ariadne merione* | | | * | 1 | VR |
| 7 | Common Evening Brown | *Melanitis leda ismene* | * | * | * | 110 | VC |
| 8 | Common Fivering | *Ypthima baldus baldus* | | * | * | 103 | VC |
| 9 | Common Jester | *Symbrenthia lilaea khasiana* | * | * | * | 21 | NR |
| 10 | Common Lascar | *Pantoporia hordonia* | | | * | 5 | R |
| 11 | Common Sailer | *Neptis hylas varmona* | * | * | * | 50 | C |
| 12 | Common Tiger | *Danaus genutia* | | * | * | 5 | R |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 13 | Common windmill | *Byasa polyeuctes* | | | * | 10 | R |
| 14 | Circe | *Hestina nama* | * | * | * | 13 | R |
| 15 | Dark Blue Tiger | *Tirumala septentrioni* | * | | * | 9 | R |
| 16 | Dark Evening Brown | *Melanitis phedimebele bela* | * | * | * | 13 | R |
| 17 | Glassy Tiger | *Parantica aglea melanoides* | * | * | * | 30 | NR |
| 18 | Grey Count | *Taneaecia lepidea lepidea* | * | * | * | 7 | R |
| 19 | Jewel Fourring | *Ypthima avanta* | * | * | * | 14 | R |
| 20 | Knight | *Lebadea martha marrtha* | * | * | * | 5 | R |
| 21 | Large Yoeman | *Cirrochroa aoris aoris* | * | * | * | 5 | R |
| 22 | Leopard Lacewing | *Cethosia cyane* | | | * | 2 | VR |
| 23 | Lemon Pansy | *Precis lemonias lemonias* | * | * | * | 59 | C |
| 24 | Long Brand Bushbrown | *Visala visala* | * | * | * | 21 | NR |
| 25 | Nigger | *Orsotrioena medus medus* | * | * | * | 19 | NR |
| 26 | Orange Oakleaf | *Kallima inachus* | | * | | 2 | VR |
| 27 | Stright Banded Treebrown | *Neope verma sintica* | | * | * | 9 | R |
| 28 | Striped Blue crow | *Euploea mulciber mulciber* | * | * | * | 42 | NR |
| 29 | Tabby | *Pseudergolis wedah* | * | * | | 6 | R |
| 30 | Tawny Rajah | *Charaxesbernardus* | | | * | 2 | VR |
| | **Papilionidae** | | | | | | |
| | | *Graphium sarpedom* | | | | | |
| 1 | Common Blue Bottles | *sarpedom* | | * | * | 2 | VR |
| 2 | Common Mime | *Chilasa clytia* | | * | | 1 | VR |
| 3 | Common mormon | *Menelaides polytes* | * | * | * | 22 | NR |
| 4 | Common Raven | *Princeps castor polas* | * | * | * | 15 | NR |
| 5 | Glassy Blue Bottle | *Graphiumcloanthus* | * | | * | 4 | R |
| 6 | Great Mormon | *Papilio memnon* | | | * | 4 | R |
| 7 | Lime Butterfly | *Princeps demoleus* | | * | * | 4 | R |
| 8 | Paris Peacock | *Papilio paris* | | | * | 6 | R |
| 9 | Red Breast | *Papilio alcmenor* | | * | | 4 | R |
| 10 | Red Helen | *Papilo helenus* | | * | * | 9 | R |
| 11 | Tailed Jay | *Graphium agamemnon* | | | * | 1 | R |
| 12 | Yellow Helen | *Papilio nephelus* | | | * | 1 | R |
| | **Pieridae** | | | | | | |
| 1 | Chocolate Albatross | *Appias lyncida* | | | * | 4 | R |
| 2 | Common Emigrant | *Catopsilia pomona* | | * | * | 6 | R |
| 3 | Chocolate grass Yellow | *Eurema sari* | * | * | * | 10 | R |
| 4 | Chocolate Soldier | *Precis atlites* | * | * | * | 62 | C |
| 5 | Common Grass Yellow | *Eurema hecabe* | * | * | * | 4 | R |
| 6 | Common Gull | *Cepora nerissa* | | | * | 31 | NR |
| 7 | Great Orange tip | *Hebomoia glaucippe glaucipe* | | * | * | 13 | R |
| 8 | Indian Cabbage white | *Pieris canidia indica* | | * | * | 17 | NR |
| 9 | Large Cabbage White | *Pieris brassicae nepalensis* | * | * | * | 65 | C |
| 10 | Lesser Gull | *Cepora nadina* | * | * | * | 1 | VR |
| 11 | Mottled Emigrant | *Catopsilia pyranthe* | | | * | 5 | R |
| 12 | One Spot Grass yellow | *Eurema andersoni andersoni* | * | * | * | 23 | NR |
| 13 | Psyche | *Leptosia nina* | * | * | * | 19 | NR |
| 14 | Spotted Sawtooth | *Leptosia thestylis thestylis* | | * | * | 7 | R |
| 15 | Tree Yellow | *Gandaca harina asssamica* | * | * | * | 10 | R |
| 16 | Three Spot Grass Yellow | *Eurema blanda silhetana* | * | * | * | 61 | C |
| 17 | Yellow Orange Tip | *Ixias pyrene familiaris* | * | * | * | 88 | C |
| | **Hesperidae** | | | | | | |
| 1 | Brown Awl | *Badamia exclamationis* | | | * | 1 | VR |
| 2 | Chestnut Angle | *Odontoptilum angulata* | | | * | 1 | VR |
| 3 | Chestnut Bob | *Iambrix salsala* | | * | * | 4 | R |
| 4 | Coon | *Sancus fuligo* | | | * | 1 | VR |
| 5 | Common Banded Awl | *Hasora chromus* | | | * | 2 | VR |
| 6 | Common Spotted Flat | *Celaenorrhinus leucocera* | | * | * | 2 | VR |
| 7 | Fulvous Pied Flat | *Pseudocoladenia dan* | | | * | 11 | R |
| 8 | Himalayan Dart | *Potanthus Dara* | | * | * | 3 | R |
| 9 | Orange Awlet | *Bisasis jaina* | | | * | 4 | R |
| 10 | Tiger Hopper | *Ochus subvittatus* | | | * | 2 | R |
| 11 | Water Snow Flat | *Tagiades litigiosa* | | | * | 6 | R |

VC - very common (> 100 sightings); C - common (50–100); NR - not rare (15–50); R - rare (2-15) VR- very rare (1-2); * - presence in different months

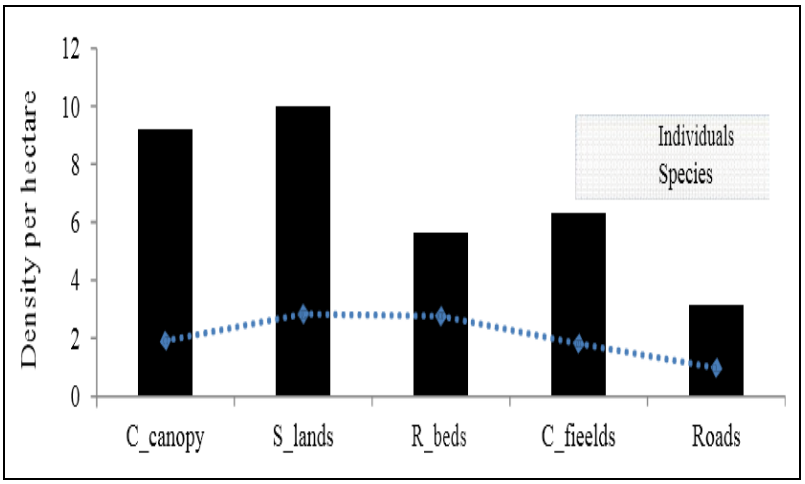


**Fig 3:** Density of individuals and species in different habitats respectively. The Kruskal Wallis test revealed significant effect of different months on individual and species density $H(2) = 7.81$, $p = .02$). Similar study conducted along Sunkos river catchment area in Bhutan, recorded first peak in March and lowest in January [29]. Not a single species of Hesperidae was found along transect during first sampling and it could be due to least species in family and/or due to cold weather.

### 4.2 Butterfly diversity and Environmental factors

The altitude of transects within the study area ranged from 121m at place called Revaling to 892 m at Tashibee. The species diversity decreased with increase in altitude ($r = -.815$; $p = .000$), and abundance also showed similar relationship with the altitude ($r = -.699$; $p = .004$). The relationship between species diversity and altitude and between abundance and altitude could be due to relationship between altitude and temperature as current study found both abundance and diversity increased from colder months to warmer months (Figure 4).

Butterflies communities avoid the low temperature and hibernate during winter, and also food plants availability depend on temperature and seasons.

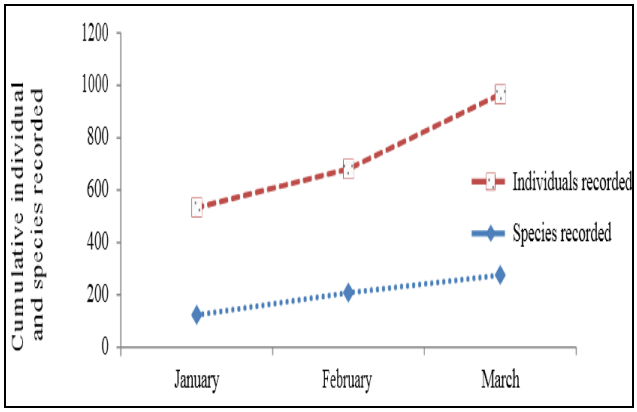


**Fig 4:** Species and individuals cumulative curve for pooled data over three months.

A study in Sunkos river catchment area in Bhutan recorded first peak in butterfly diversity in the month of March and the lowest in January [29]. Forest in the Himalaya region and elsewhere also harbor high diversity at low elevation which could provide diverse host plants for butterflies [19]. Similar study conducted along the altitudinal gradient of Sikkim also revealed that butterfly species richness, abundance and diversity peaked at low and decline towards mid to high elevations [1].

### 4.3 Beta diversity of butterfly within Manas range

Butterfly species composition during entire sampling had mean similarity values < 0.10 by Sørensen's similarity index of all the five different habitat types. The low value of the similarity index is an indicator of high beta (β) diversity [33]. High β diversity across different habitats suggests that entire study area hosts a unique diversity of butterflies [8]. Highest similarity was found in river beds - crop fields (0.128), and lowest in shrub land - roads (0.074). The highest similarity between river beds - crop fields could be due to both habitats being dry with less diverse food plants. Shrub land-roads hosted lowest similarity because it could be due to edge effects and exposure to direct sun light in case of shrub land. Whereas transect along the roads were opposite to sun direction and it was windy as compared to shrub lands. This study corresponds to the finding that different layers of canopy facilitate different sets of microclimates and complex vegetation made the habitat distinct for different butterfly species [18].

***Coon* (*Sancus folio*-Mabille)**

**Fig 5:** New record of butterfly for Bhutan

## 5. Conclusion

Study carried out only for three months revealed 1319 individuals and 91 species of five major families. One new species of Hesperiidae family were discovered which indicates possibilities of adding many more species. Further systematic research is essential for getting a detailed periodic estimate and

comparisons of the faunal diversity of butterflies in different seasons. β diversity in forest at low altitude is comparatively high which indicates the presence of diverse and unique species in study area. This underlines the importance for maintaining biodiversity within and outside the park area as a landscape conservation programme.

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