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Seasonal species diversity and abundance of Butterflies around Mukutmanipur Dam and its surrounding areas of Bankura District, Bankura, West Bengal, India

Mizanur Rahman[1], Motinur Rahman[1], Ujjwal Mollah[2] and Biplob Kumar Modak*[1]

[1]*Department of Zoology, Sidho Kanho Birsha University, Purulia, West Bengal, India*
[2]*Natural and Applied Science Research Centre, Raja N.L. Khan Women's College, Midnapore, West Bengal, India*

ABSTRACT

Butterflies are beautiful as well as an important part of nature. Butterflies are good indicators of a healthy ecosystem and act as good pollinator agents, increasing the productivity of plants by promoting fertilisation. The objectives of the present survey are focused on the assessment of the diversity and seasonal variation of butterflies and their host plants found at Mukutmanipur. Mukutmanipur is known for its green forest, dam, birding hotspot, and habitat of chital deer. This survey was carried out from February 2024 to January 2025 and divided into four seasons- pre-monsoon, monsoon, post-monsoon and winter. Species diversity of butterflies was measured by using relative density, relative abundance, relative frequency, Shannon index, Simpson's diversity index, Margalef index etc. Analysis of season-wise distribution of species diversity indices was done through single-factor ANOVA. Individual rarefaction analysis was conducted study seasonal variation. Hierarchical classical clustering was done between seasons through the Jaccard similarity index through UPGMA. 42 species of butterflies were reported under five families. The current study indicates abundant butterflies belonging to the Nymphalidae family with 18 species. The highest count of butterflies was observed during the monsoon season and this reflection is also evident in individual rarefaction analysis. Season-based hierarchical cluster analysis shows higher similarity of butterflies between the monsoon and post-monsoon seasons. A checklist of the butterflies found in this region is also prepared. Lantana, Imperata and Calotropis were found to be the most favoured host plants of the butterflies of the study area.

Keywords: *Single factor ANOVA, Individual rarefaction, Hierarchical cluster analysis, Nymphalidae, Jaccard similarity index, Monsoon*

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Corresponding Author: *Biplob Kumar Modak*

E-mail Address: *bkmodak09@gmail.com*

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Introduction

Due to the unique ecology of Mukutmanipur, various types of plants and animals can be seen here. Although it is not a recognized biodiversity hotspot like the Himalayas or the Western Ghats. The large and beautiful water reservoir and the green forests surrounding it are habitats of various small and large aquatic and wild animals. They are essential for ecological balance and their existence depends on the abundance of host and nectar plants. As primary consumers in the food chain and masterful pollinators, they not only sustain biodiversity but also enhance plant fertilisation and boost the productivity of flourishing landscapes. The diversity and richness of butterflies within a region provide information regarding the health of the ecosystem and its functioning [1]. Plants in particular locations exhibit a close relationship with the life cycle of butterflies [4]. Environmental factors such as temperature, photoperiod, rainfall, humidity, food availability, and vegetation cover, including bushes and herbs, can be the root cause of seasonal variations. Certain species of butterflies depend on specific host plants to lay eggs and complete their life cycle.

The population dynamics of various species were significantly impacted by environmental influences [4]. Approximately 90% of the world's 19,238 butterfly species are found in tropical regions [1,3]. About 1,504 butterfly species can be observed on the Indian subcontinent; it has a diverse topography, climate, and vegetation [7].

The expansion of human settlements and urbanization has led to widespread habitat destruction to accommodate new infrastructure such as residential colonies, offices, roads, apartments, and market complexes. Consequently, green vegetation, open fields, and roadside bushes are frequently removed. The loss of natural habitats has an adverse impact on butterflies, various insects, and birds, ultimately reducing the area's biodiversity. Mukutmanipur is a beautiful region in West Bengal, India, famous for its beautiful landscape, rich flora, and it is also India's second-largest earthen dam. This place is not being recognized as a place of biodiversity hot spot, much like the Western Ghats. The rare ecology in this place provides a place for various plants and animals. Birds, butterflies, tiny creatures of many types are regularly seen in the forests, hills and lakes of this region.

Its ecological balance is at risk due to increasing urbanisation and tourism; that's why conservation measures are crucial for maintaining its biodiversity. Maintaining a list of the different species in this area is essential in the current situation. Assessing the diversity and abundance of butterfly species in Mukutmanipur and the surrounding area was the objective of the present study.

Materials and Methods

Study area:

The Mukutmanipur Dam is an earthen gravity dam. It was constructed at the crossing point of the Kangsabati and Kumari rivers in the Bankura district of West Bengal, India. (Fig. 1) The approximate coordinates of this dam are 86.7818° E longitude and 22.9639° N latitude. Including dykes and hillocks, the dam spans 11.27 km (7 miles) in length and reaches to a maximum height of 41.15 meters (135 feet) above the riverbed. It encompasses a catchment area of 3,625 square kilometres (1,400 square miles). Mukutmanipur experiences a diverse range of temperatures throughout the year. During the Summer (March to June), temperatures are generally high. Average high temperatures in July are about 32°C (90°F), and average low temperatures are about 25°C (78°F). This period also sees significant humidity and precipitation. The cooler and more pleasant months are November to February. January is the coldest month, having an average high temperature of 24°C (75°F) and lows around 9°C (48°F). The study area is home to a variety of nectar and host plants that offer an ideal habitat to numerous pollinators. These nectar plants provide an adequate and regular supply of nectar, it attracted bees, butterflies, and other beneficial insects. The host plants that they feed on (which also provide them with an excellent habitat for egg laying) are therefore able to support a complete life cycle for butterflies and other species, not only supporting it but also maintaining the overall biodiversity thus making it an ideal place for them. Massive trees offer lots of shade and places for living, while the landscape is large, serene water basins surrounded by lush greenery offer an ideal place for butterflies. The entire ecological health of the region has improved, and this balanced environment supports biodiversity.

Data Collection

This butterfly survey was carried out over four seasons between February 2024 and January 2025 to understand how butterfly diversity changes throughout the year. The four seasons included in the study were Pre-monsoon (March–May), Monsoon (June–August), Post-monsoon (September–November), and Winter (December–February). To keep the conditions consistent and avoid environmental changes affecting the results, observations were done only on bright, sunny days. During these times, the average temperature was about 32°C, and the humidity was around 80%. These weather conditions are ideal for butterfly activity. To spot as many butterfly species as possible, field observations were planned during two key times of day. The first was in the morning, from 8:00 AM to 11:00 AM, when butterflies are most active because of the light and temperature. The second session was in the afternoon, from 1:00 PM to 3:00 PM, which is another time when many butterflies are still active. The survey was done in eight selected locations for 24 days using fixed paths known as linear transects. Observers used the modified Pollard Walk Technique [14], slowly walking along each route and noting every butterfly seen in an imaginary area of 5 × 5 × 5 metres.

The preferred host plants of butterflies have also been documented using direct observation in the field and secondary data [5,6,11,17,18,19,21]. In the field, butterflies were systematically observed, identified, and counted. Photographic documentation was done using a Nikon D90 with a 72–300 mm lens. Preliminary identification was done on-site during the survey, generally by direct observation and photography and typically by manual collection, using conventional field guides. Common English names follow the conventions of Wynter-Blyth's (1957) [20]. The scientific nomenclature used in this study aligns with Varshney's (1983) [21]. Through precise and seasonally representative data collection, this strategy enhanced our understanding of the patterns of butterfly diversity in the year.

Statistical analysis

I. Measurement of dominance

In order to calculate the Importance Value Index (IVI), species dominance is measured through parameters such as density, relative density, abundance, relative abundance, frequency, and relative frequency [16].

(a) Density per Day (D)$=\frac{\text{Number of Individual of the species in all the day}}{\text{Number of day surveyed}}$

(b) Relative Density(RD)$=\frac{\text{Density of the species}}{\text{Total density of all species}}\times 100$

(c) Frequency (F%)$=\frac{\text{Number of days in which species occurred}}{\text{Total number of days studied}}\times 100$

(d) Relative frequency (RF)$=\frac{\text{Frequency of the species}}{\text{Total frequency of all the species}}\times 100$

(e) Abundance (A)$=\frac{\text{Total number of individuals of the species in all the sampling days}}{\text{Number of sampling days in which species occurred}}$

(f) Relative Abundance (RA)$=\frac{\text{Abundance of the species}}{\text{Total abundance of all the species}}\times 100$

(g) Importance Value Index (IVI) = *Relative Density + Relative frequency + Relative Abundance*

II. Measurement of biodiversity indices

a. Shannon_H

$$H=\sum_{n=1}^{s}\left(p_i \ln p_i\right)$$

where p_i is the proportion of individuals found in the i^{th} species and it denotes natural logarithm.

b. Simpson's Index of Diversity *(D)*

$$D = 1 - \Sigma\left(\frac{n}{N}\right)2$$

where n is the total number of individuals of each species in an area and N is the total number of said species living in the same area.

c. Margalef index *(D_{Mg})*

$$D_{Mg}=\frac{S-1}{\ln N}$$

where S is the number of species and N is the total number of individuals in the sample.

d. Evenness *(E)*

$$\text{Evenness } E=\frac{e^{H}}{S}$$

Where H = Shannon index and S = number of Species.

e. Brillouin Index *(HB)*

$$HB = \ln(N!) - \frac{\Sigma \ln(n!)}{N}$$

Where *n* represents the number of individuals of each species in an area, and *N* is the total number of all species in that same area.

f. Berger-Parker index *(D_{BP})*

$$D_{BP} = \frac{N_{max}}{N}$$

Where N_{max} is the number of individuals of the most abundant species, and N is the total number of individuals in the community.

g. Menhinick's Index (D_{MN})

$$D_{MN} = \frac{S}{\sqrt{N}}$$

Where S represents the number of species, and N is the total number of individuals in the sample.

Data interpretation

Ecological indices data of four distinct seasons were compared through one-way ANOVA. Rarefaction analysis was done to assess the species richness in each season individually. The Jaccard similarity index was used for hierarchical classical clustering. PAST software (Version 4.03), developed by Øyvind Hammer at the Natural History Museum, University of Oslo, has been used for statistical analyses.

Result

The present study is based on an extensive assessment of Mukutmanipur's butterfly biodiversity. Ecological richness of this region was made apparent by the study's impressive diversity, comprising 42 species representing 31 genera and five distinct families [1]. The butterflies are classified under 9 genera and 10 species of the Lycaenidae family, 10 Genera and 18 species of the Nymphalidae family, 2 genera and 3 species of the Papilionidae family, 6 genera and 7 species of the Pieridae family, and 4 genera and 4 species of the Hesperidae family. A total of 1097 butterflies were noted during four sampling seasons. With 378 individuals recorded, the Nymphalidae family exhibited the most abundance, peaking at 81 in a single monsoon sample. Also well-represented were the Lycaenidae and Pieridae families, with 328 and 294 butterflies, respectively. Hesperidae and Papilionidae were less abundant, with 36 and 61 individuals noticed, respectively. Compared to other seasons, most butterflies were found during the monsoon season [4]. A total of 382 individual butterflies and 39 species were recorded in Table 1. Fig. 2 illustrates the number of individual butterflies recorded for each family across different seasons.

Different ecological indices based on the observed butterfly species diversity are shown in Table 2. *Eurema hecabe* recorded the highest values, with a density of 4.4167, a relative density of 9.6624, an abundance of 4.4167, and the highest Importance Value Index (IVI) of 19.7674.

In Table 3, several ecological indices based on the diversity of butterfly species observed in the study area during the several seasons are shown. Of these, the post-monsoon period had the lowest value of the Margalef index (6.154), while the winter season had the highest species richness, as indicated by the highest Margalef index value (6.831). The monsoon season had the lowest dominance index (0.0435), indicating a more even distribution of species, whereas the winter had the highest dominance (0.0557). Similarly, the species dominance indicator, the Berger-Parker index, had a low value of 0.09492 in the post-monsoon and a maximum value of 0.12 in the winter. Diversity indices indicate a high butterfly density across the study area. The Simpson index ranged from 0.9565 in the monsoon to 0.9443 in winter.

The Shannon index, a widely used diversity measure, varied between 3.376 (monsoon) and 3.236 (winter), showing rich but slightly fluctuating diversity throughout the seasons. The evenness (E) shows how evenly individuals are distributed. It is higher in the pre-monsoon season (0.7821) and lowest in the winter season (0.6692). The Brillouin index (HB) shows the lowest value of 2.975 in the winter and the highest value of 3.189 in the monsoon, indicating substantial variation. Lastly, the Menhinick index (DMn) shows that species richness in relation to individual count was lowest during the monsoon (1.995) and highest during the pre-monsoon (2.65). Together, these results highlight the study area's dynamic and seasonally changing butterfly diversity [9]. These findings collectively underline the dynamic and seasonally shifting diversity of butterflies in the study area.

The values of Whittaker's Beta Diversity Index are represented in Table 4. While the lowest value (0.10811) was between the Post-monsoon and Winter, indicating relatively less change in species composition between these seasons, the highest value (0.09589) was recorded between the Pre-monsoon and Post-monsoon seasons, indicating an increase in species turnover.

Table 5 shows the result of one-way ANOVA based on the season-wise variation of Brillouin index. It shows that the F value (9.78) is greater than the F crit value (6.59). It means the null hypothesis is rejected, indicating a statistically significant difference among the group means. At least one group of the Brillouin index is significantly different from the others.

In Table 6, the Tukey test result shows that there is a significant difference at three points: Monsoon and Pre-monsoon, Monsoon and Winter, and lastly Post-monsoon and Winter. This result indicates seasonal variation significantly affects the Brillouin diversity index between specific seasons. Other ecological indices like Simpson, Shannon, Dominance, etc., are accepting null hypothesis that clearly suggests seasonal variation is not significantly affecting those indices like the Brillouin index does.

The study site has trees, dense shrubs, and grasses that offer butterflies ideal shelter. There are various nectaring and host plants in the area (Table 7), resulting in it being a good habitat that is suitable for laying eggs and for a source of sufficient nectar [5,10]. The most commonly found host plants among them are *Lantana*, *Imperata*, and *Calotropis*, which attracted a wide variety of butterfly species to this area.

An Individual-based Rarefaction (IR) curve, which compares species richness across sample sizes, is shown in Figure 3. The Y-axis (Taxa ± 95% confidence) represents the number of taxa (species) expected for a given number of individuals, with 95% confidence intervals, and the X-axis (Individuals) represents the number of individuals sampled. Multiple coloured curves represent different seasons (Pre-monsoon, Monsoon, Post-monsoon, Winter). Each curve shows how species richness accumulates with the increasing number of individuals sampled in that season. Monsoon season (blue curve) has the highest species richness, reaching the highest point on the y-axis. Post-monsoon (green curve) has the lowest species richness among all the seasons.

Fig.4 is cluster analysis; the dendrogram is used to show the connections between various seasons. The vertical axis indicates the degree of similarity between the seasons. Higher values representing higher similarity. Seasons that are more similar to each other are joined together earlier in the dendrogram, making clusters.

For instance, Post-monsoon and Monsoon are clustered together (~0.92), indicating a high degree of similarity between them. Post-monsoon and Monsoon joined at a higher point compared to the merge point of Pre-monsoon with this (Post-monsoon and Monsoon) cluster, showing that Post-monsoon and Monsoon are more similar to each other than Pre-monsoon. Winter is the most distinct season, as it joins at ~0.82 the rest of the cluster at the lowest similarity level [13].

Discussion

This study on butterfly diversity in Mukutmanipur highlights its ecological wealth and butterfly seasonal dynamics. The fact that 42 species are documented under 31 genera and five families indicates the biological significance of the area. This study area has seasonal variation in butterfly diversity, thus giving an idea of habitat heterogeneity due to the presence of host and nectar plants all over the study area [12]. The most species-rich and abundant family was Nymphalidae, confirming findings of other tropical and subtropical ecosystems. Nymphalidae is a family that generally have high flexibility and wide ecological niches. Likewise, the Lycaenidae and Pieridae families were also well represented, most probably due to the availability of host plants and the right microhabitat for the taxon. However, the low abundance of the Hesperiidae and Papilionidae families could possibly be due to their tolerance of disturbance in the habitat, that are more specialised habitats, or that the host plant requirements demand too much from these families. Overall, this seasonal survey has revealed the highest diversity and abundance of butterflies at this time of year, with 382 individuals and 39 species being found, probably because the monsoon season has the most vegetation cover, the most floral abundance and the most favoured conditions for larval host plants and nectar resources.

When compared to other seasons, winter has the highest Margalef index, which indicates high species richness, but at the same time the lowest evenness and the highest dominance values indicate that there was some species in the survey very much abundant at this time. Diversity indices further support the dynamic nature of butterfly communities. The Simpson and Shannon indices show overall high diversity, though they exhibited seasonal fluctuation. In winter, a relatively lower Simpson index (0.9443) and higher in monsoon (0.9565) indicate more equitable species distribution during the winter season. The highest level of Evenness (E) appears during the pre-monsoon season, representing a more uniform distribution of individuals within species during this period of transition. With the highest values for density, abundance, and relative density metrics, *Eurema hecabe* was clearly the most ecologically significant species based on the Importance Value Index (IVI). This suggests that populations may be able to withstand a range of environmental conditions. In Whittaker's index-based beta diversity study, there was a great deal of seasonal variation in species composition, but the greatest change occurred between pre- and post-monsoon seasons, this could reflect changes in vegetation cover and the availability of resources. At the same time, winter and post-monsoon seasons showed little change, thus suggesting that community composition was rather stable between those two periods. The results of the ANOVA analysis show that ecological indices have less change between seasons despite the Brillouin index being significantly different with respect to the distribution of butterflies. These findings suggest that monitoring should be long-term, seasonal and stratified for biodiversity.

Table 1: Family-wise distribution of different species of Butterflies recorded in four different seasons in Mukutmanipur with local area status.

Common name	Scientific Name	Number of Individuals						Status in study area	IUCN status
		Pre monsoon	Monsoon	Post monsoon	Winter	Total	Species density		
Lycaenidae									
Common Pierrot	*Castalius rosimon*	5	6	9	5	25	0.00313	C	Not Evaluted
Lime Blue	*Chilades lajus*	15	10	20	27	72	0.00900	VC	Not Evaluted
Tiny grass Blue/ lesser	*Zizula hylax*	0	3	0	1	4	0.00050	VR	Least Concern
Dark grass Blue	*Zizeeria karsandra*	14	16	12	19	61	0.00763	VC	Least Concern
Common Silverline	*Cigaritis vulcanus*	0	5	1	0	6	0.00075	R	Not Evaluted
Forget Me Not	*Catochrysops strabo*	7	17	15	8	47	0.00588	C	Not Evaluted
Grass Jewel	*Freyeria trochylus*	0	0	0	5	5	0.00063	VR	Not Evaluted
Plain Cupid	*Chilades pandava*	2	8	14	5	29	0.00363	C	Not Evaluted
Gram Blue	*Euchrysops cnejus*	0	21	9	17	47	0.00588	C	Not Evaluted
Pale Grass Blue	*Pseudozizeeria maha*	3	18	7	4	32	0.00400	C	Not Evaluted
Papilionidae									
The Lime	*Papilio demoleus*	4	8	5	0	17	0.00213	C	Not Evaluted
Common Mormon	*Papilio polytes*	4	14	7	3	28	0.00350	C	Least Concern
Common Rose	*Pachliopta aristolochiae*	3	6	3	4	16	0.00200	C	Least Concern
Pieridae									
Common Gull	*Cepora nerissa*	3	3	2	3	11	0.00138	R	Least Concern
Mottled Emigrant	*Catopsilia pyranthe*	5	38	28	9	80	0.01000	VC	Not Evaluted
Common Grass Yellow	*Eurema hecabe*	21	31	27	27	106	0.01325	VC	Not Evaluted
Common Wanderer	*Pareronia valeria*	4	5	6	3	18	0.00225	C	Not Evaluted
Psyche	*Leptosia nina*	5	6	9	8	28	0.00350	C	Not Evaluted
Common Emigrant	*Catopsilia pomona*	6	13	9	9	37	0.00463	C	Not Evaluted
Pioneer or Cape White	*Belenois aurota*	3	7	3	1	14	0.00175	R	Not Evaluted

Nymphalidae									
Great Eggfly	*Hypolimnas bolina*	2	5	5	4	16	0.00200	C	Not Evaluted
Lemon Pansy	*Junonia lemonias*	5	5	6	3	19	0.00238	C	Not Evaluted
Plain Tiger	*Danaus chrysippus*	4	0	0	3	7	0.00088	R	Not Evaluted
Common Crow	*Euploea core core*	15	17	23	7	62	0.00775	VC	Not Evaluted
Common Tiger	*Danaus genutia*	8	28	19	6	61	0.00763	VC	Not Evaluted
Common Evening Brown	*Melanitis leda*	4	6	5	4	19	0.00238	C	Not Evaluted
Common Bushbrown	*Mycalesis perseus*	4	8	5	7	24	0.00300	C	Not Evaluted
Common Sailor	*Neptis hylas*	4	0	0	2	6	0.00075	R	Not Evaluted
Common Baron	*Euthalia aconthea*	2	4	3	4	13	0.00163	R	Not Evaluted
Peacock Pansy	*Junonia almanac*	6	7	7	4	24	0.00300	C	Not Evaluted
Chocolate Pansy	*Junonia iphita*	5	5	3	4	17	0.00213	C	Not Evaluted
Angel Castor	*Ariadne Ariadne*	3	6	2	2	13	0.00163	R	Not Evaluted
Common Castor	*Ariadne merione*	5	9	5	3	22	0.00275	C	Not Evaluted
Tawny Coster	*Mycalesis mineus*	6	13	7	3	29	0.00363	C	Not Evaluted
Commander	*Moduza procris*	1	1	0	0	2	0.00025	R	Not Evaluted
Yellow Pansy	*Junonia hierta*	1	5	2	1	9	0.00113	R	Not Evaluted
Grey Pansy	*Junonia atlites*	5	11	6	3	25	0.00313	C	Not Evaluted
Blue Pansy	*Junonia orithiya*	3	6	0	1	10	0.00125	R	Not Evaluted
Hesperidae									
Grizzled Skipper	*Pyrgus malvae*	4	3	3	4	14	0.00175	R	Not Evaluted
Chestnut Bob	*Iambrix salsala*	0	3	3	1	7	0.00088	R	Not Evaluted
Common Redeye	*Matapa aria*	2	4	3	1	10	0.00125	R	Not Evaluted
Rice Swift	*Borbo cinnara*	2	1	2	0	5	0.00063	VR	Not Evaluted
VC-Very common (> 50 individuals); C-Common (15–50 individuals); R-Rare (5–15 individuals); VR-Very Rare (< 5 individuals)									

Table 2: List of Butterflies with Density per Day (DD), Relative Density (RD), Frequency (F), Relative Frequency (RF), Abundance (A), Relative Abundance (RA) and Importance Value Index (IVI)

Scientific Name	DD	RD	F%	RF	A	RA	IVI
Castalius rosimon	1.0417	2.2789	100.0000	4.4860	1.0417	1.3252	8.0901
Chilades lajus	3.0000	6.5631	100.0000	4.4860	3.0000	3.8167	14.8658
Zizula hylax	0.1667	0.3646	16.6667	0.7477	1.0000	1.2722	2.3845
Zizeeria karsandra	2.5417	5.5604	100.0000	4.4860	2.5417	3.2336	13.2800
Cigaritis vulcanus	0.2500	0.5469	25.0000	1.1215	1.0000	1.2722	2.9407
Catochrysops strabo	1.9583	4.2843	100.0000	4.4860	1.9583	2.4915	11.2617
Freyeria trochylus	0.2083	0.4558	16.6667	0.7477	1.2500	1.5903	2.7937
Chilades pandava	1.2083	2.6435	95.8333	4.2991	1.2609	1.6041	8.5467
Euchrysops cnejus	1.9583	4.2843	87.5000	3.9252	2.2381	2.8474	11.0569
Pseudozizeeria maha	1.3333	2.9169	91.6667	4.1121	1.4545	1.8505	8.8796
Papilio demoleus	0.7083	1.5496	37.5000	1.6822	1.8889	2.4031	5.6350
Papilio polytes	1.1667	2.5523	41.6667	1.8692	2.8000	3.5622	7.9837
Pachliopta aristolochiae	0.6667	1.4585	29.1667	1.3084	2.2857	2.9080	5.6748
Cepora nerissa	0.4583	1.0027	33.3333	1.4953	1.3750	1.7493	4.2473
Catopsilia pyranthe	3.3333	7.2924	100.0000	4.4860	3.3333	4.2408	16.0191
Eurema hecabe	4.4167	9.6624	100.0000	4.4860	4.4167	5.6190	19.7674
Pareronia valeria	0.7500	1.6408	62.5000	2.8037	1.2000	1.5267	5.9712
Leptosia nina	1.1667	2.5523	58.3333	2.6168	2.0000	2.5445	7.7136
Catopsilia pomona	1.5417	3.3727	79.1667	3.5514	1.9474	2.4775	9.4016
Belenois aurota	1.2727	1.2762	45.8333	2.0561	1.2727	1.6192	4.9514
Hypolimnas bolina	0.6667	1.4585	37.5000	1.6822	1.7778	2.2617	5.4025
Junonia lemonias	0.7917	1.7319	54.1667	2.4299	1.4615	1.8594	6.0213
Danaus chrysippus	0.2917	0.6381	20.8333	0.9346	1.4000	1.7811	3.3538
Euploea core core	2.5833	5.6516	100.0000	4.4860	2.5833	3.2866	13.4241
Danaus genutia	2.5417	5.5604	91.6667	4.1121	2.7727	3.5275	13.2001
Melanitis leda	0.7917	1.7319	58.3333	2.6168	1.3571	1.7266	6.0754
Mycalesis perseus	1.0000	2.1877	58.3333	2.6168	1.7143	2.1810	6.9855
Neptis hylas	0.2500	0.5469	16.6667	0.7477	1.5000	1.9083	3.2029
Euthalia aconthea	0.5417	1.1850	37.5000	1.6822	1.4444	1.8377	4.7049
Junonia almanac	1.0000	2.1877	37.5000	1.6822	2.6667	3.3926	7.2626
Junonia iphita	0.7083	1.5496	50.0000	2.2430	1.4167	1.8023	5.5949
Ariadne Ariadne	0.5417	1.1850	37.5000	1.6822	1.4444	1.8377	4.7049
Ariadne merione	0.9167	2.0054	41.6667	1.8692	2.2000	2.7989	6.6735
Mycalesis mineus	1.2083	2.6435	66.6667	2.9906	1.8125	2.3059	7.9400
Moduza procris	1.0000	0.1823	8.3333	0.3738	1.0000	1.2722	1.8284
Junonia hierta	1.2857	0.8204	29.1667	1.3084	1.2857	1.6357	3.7645
Junonia atlites	1.6667	2.2789	62.5000	2.8037	1.6667	2.1204	7.2030
Junonia orithiya	2.5000	0.9115	16.6667	0.7477	2.5000	3.1806	4.8398
Pyrgus malvae	0.5833	1.2762	25.0000	1.1215	2.3333	2.9685	5.3662
Iambrix salsala	0.2917	0.6381	12.5000	0.5607	2.3333	2.9685	4.1674
Matapa aria	0.4167	0.9115	25.0000	1.1215	1.6667	2.1204	4.1534
Borbo cinnara	0.2083	0.4558	20.8333	0.9346	1.0000	1.2722	2.6626

Table 3: Diversity indices of butterflies recorded in Mukutmanipur in four different seasons

Metric	Pre-monsoon	Monsoon	Post-monsoon	Winter
Taxa (S)	37	39	36	38
Individuals	195	382	295	225
Dominance (D)	0.04437	0.04352	0.04827	0.05572
Simpson (1-D)	0.9556	0.9565	0.9517	0.9443
Shannon (H)	3.365	3.376	3.272	3.236
Evenness (e^H/S)	0.7821	0.7498	0.7325	0.6692
Brillouin	3.069	3.189	3.062	2.975
Menhinick	2.65	1.995	2.096	2.533
Margalef	6.827	6.391	6.154	6.831
Equitability (J)	0.9319	0.9214	0.9131	0.8896
Fisher alpha	13.53	10.87	10.75	13.1

Table 4: Whittaker's Beta Diversity of butterflies in four different seasons at Mukutmanipur

	Pre monsoon	Monsoon	Post monsoon	Winter
Pre monsoon	0	0.07895	0.09589	0.09333
Monsoon	0.078947	0	0.04	0.09091
Post monsoon	0.09589	0.04	0	0.10811
Winter	0.093333	0.09091	0.10811	0

Table 5: Result of ANOVA based on season-wise variation of the Brillouin index

ANOVA: Brillouin Index						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.101223	3	0.033741	9.782126549	0.02587464	6.591382116
Within Groups	0.013797	4	0.00344925			
Total	0.11502	7				

ANOVA-Analysis of variance; SS-Sum of squares; df-Degrees of freedom; MS-mean squares; F stat- F statistic; P-value- probable value; F crit- critical value of F distribution; F stat values are significant at $p < 0.05$

Table 6: Tukey HSD post hoc test among groups of Brillouin index

Multiple Comparison of Means - **Tukey HSD post-hoc test** , FWER=0.05						
group1	**group2**	**Mean diff.**	**p-adj**	**lower**	**upper**	**reject**
Monsoon	**Post Monsoon**	0.067	0.6484	0.2623	0.1283	**FALSE**
Monsoon	**Pre monsoon**	0.1947	0.0499	0.3899	0.0005	**TRUE**
Monsoon	**Winter**	0.3017	0.4969	0.4969	0.1064	**TRUE**
Post Monsoon	**Pre monsoon**	0.1277	0.2054	0.2054	0.0676	**FALSE**
Post Monsoon	**Winter**	0.2347	0.0197	0.4299	0.0394	**TRUE**
Pre monsoon	**Winter**	0.107	0.3232	0.3022	0.0883	**FALSE**

Table 7: List of host plants and nectaring plants in the study area

Name of the Nectar Host Plant	Family	Flowering Season	Flower Colour	Type of Plant
Lantana camara	Verbenaceae	Throughout year	Yellow, Orange, Red & Pink	Shrub
Nerium oleander	Apocynaceae	Throughout year	Pink	Shrub
Caesalpinia pulcherrima	Fabaceae	Throughout year	Red	Shrub
Tamarindus indica	Caesalpiniaceae	May to Aug	Pale Yellow	Tree
Chromolaena odorata	Asteraceae	Sept-Dec	White	Shrub
Tridax procumbens	Asteraceae	Throughout Year	Yellowish White	Herb
Tephrosia purpurea	Fabaceae	Sept-Oct	Purple	Shrub
Cassia occidentalis	Fabaceae	July-Dec	Yellow	Shrub
Sida acuta	Malvaceae	Aug-Dec	Yellow	Herb
Catharanthus roseus	Apocynaceae	Throughout year	Pink	Shrub
Calotropis procera	Apocynaceae	Aug-Dec	White with purple crown	Shrub
Ixora coccinea	Rubiaceae	Throughout year	Pink	Shrub
Sida cordifolia	Malvaceae	Aug-Dec	Yellow	Herb
Imperata cylindrica	Poaceae	Aug-Sept	Silvery White	Herb

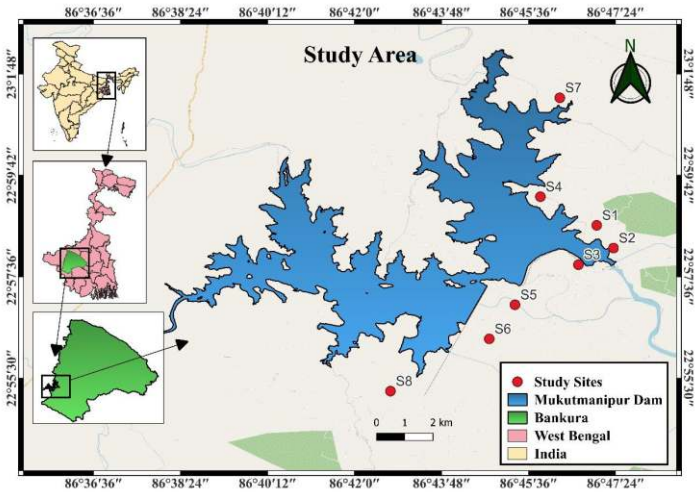

Figure 1: Map of the study area

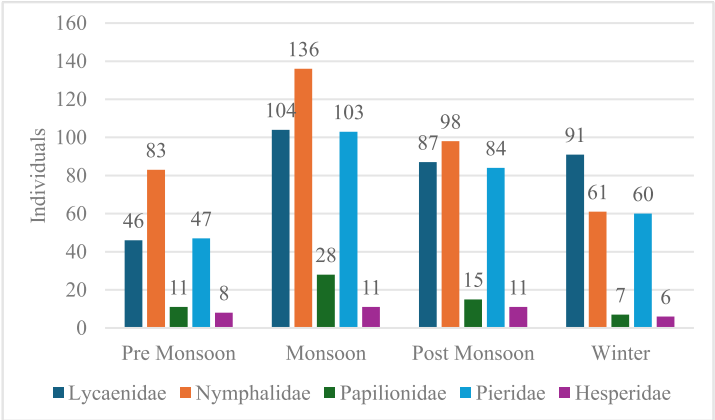

Figure 2: Seasonal distribution of butterflies in Mukutmanipur

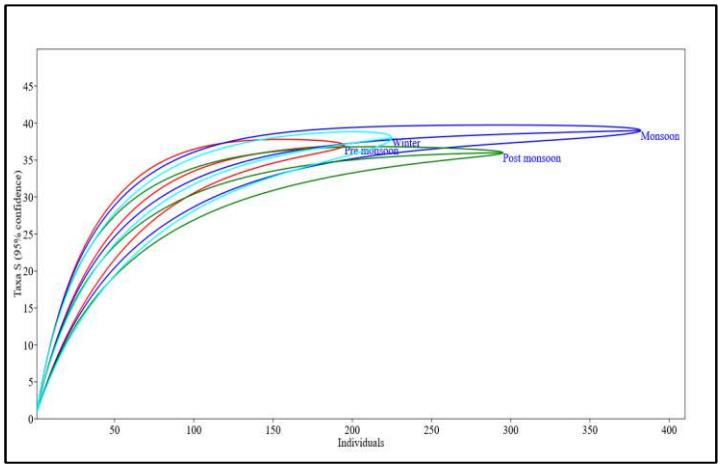

Figure 3: Individual-based Rarefaction (IR) analysis curve in four different sampling seasons

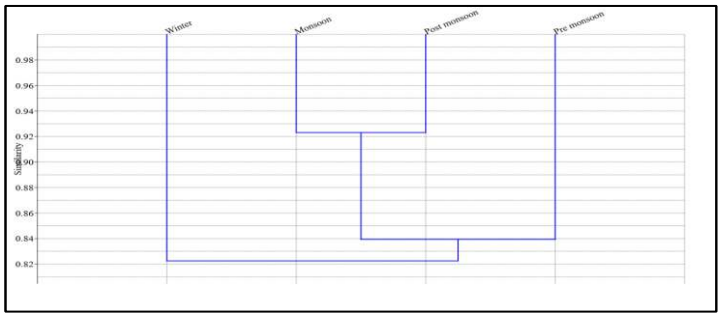

Figure 4: Hierarchical cluster analysis based on the Jaccard similarity index between four sampling seasons

Figure 5: [a] Nymphalidae (1-14): (1) Blue Tiger (2) Peacock Pansy (3) Plain Tiger (4) Common Crow (5) Common Sailor (6) Common Castor (7) Common Tiger (8) Great Eggfly (9) Yellow Pansy (10) Lemon Pansy (11) Blue Pansy (12) Commander (13) Common Bush brown (14) Blue Moon; [b] Lycaenidae (15-19): (15) Plain Cupid (16) Common Pierrot (17) Tiny grass blue (18) Grass Jewel (19) Dark grass blue; [c] Papilionidae (20-23): (20) The Lime (21) Pioneer or Cape White (22) Common Mime (23) Common Rose; [d] Pieridae (24-26): (24) Common Emigrant (25) Common Wanderer (26)Psyche; [e] Hesperidae (27-28): (27) Chestnut Bob (28) Grizzled Skipper

Conclusion

Mukutmanipur is a very vibrant ecosystem with numerous seasonal and taxonomic variations, and this study brings forth the butterfly diversity at Mukutmanipur. The area has great riches. It also gets impacted due to seasonal changes in climate and availability of habitat, and hence has a lot of dynamic nature [4]. The monsoon season turned out to be the most productive one in terms of the number of individuals and species richness, with unique community characteristics during winter. Families like Nymphalidae, Lycaenidae and Pieridae being more abundant indicates their adaptability. However, the low utility of families like Papilionidae and Hesperiidae means the need for careful application of habitat management facilities. Ecological indices, rarefaction curves and cluster analysis together give a system in constant change with species turnover, evenness and dominance fluctuating with the seasons of this area [13], this provides a picture of a finely balanced ecosystem of this area. The statistically significant seasonal differences show that the monitoring needs to be continued with a seasonally inclusive approach to attain the full information about species diversity in Mukutmanipur. Butterflies are one of the important species of diversity in Mukutmanipur. They provide fantastic information on how the diversity of species changes with seasons [1]. Their results confirm the need for proper conservation management and more ecological research work especially during different seasons. These vulnerable but important pollinators are able to survive and continue to perform their natural role by protecting their habitat.

Abbreviations

D-Density per Day H-Shannon index
RD-Relative Density D-Simpson's Index of Diversity
F%-Frequency (F%) HB-Brillouin Index
RF-Relative frequency DBP-Berger-Parker index
A -Abundance DMg-Margalef index
RA-Relative Abundance DMn-Menhinick's Index
IVI-Importance Value Index E-Evenness
ANOVA -Analysis of variance VC-Very Common
C-Common R-Rare
VR-Very Rare

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