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A study on the diversity of butterfly (Insecta: Lepidoptera) fauna in Buxa Tiger Reserve, West Bengal, India

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Abstract
A short-term systematic survey on butterfly diversity and abundance was carried out for a period of five days from 6th January to 10th January, 2024, to explore the butterfly fauna of Buxa Tiger Reserve, located at the foothills of Eastern Himalayas in the northern part of West Bengal. A total number of 65 different butterfly species belonging to 45 genera and six families were recorded from this protected area. Nymphalidae was the dominant family with the count of 19 number of genera and 30 number of species, followed by Lycaenidae (genera 12; species 13), Pieridae (genera 7; species 12), Papilionidae (genera 2; species 5) and Hesperiidae (genera 4; species 4). Family Riodinidae had only one species, i.e. *Zemeros flegyas flegyas.* Pieridae was the most abundant family (43.76%), followed by Nymphalidae (39.06), Lycaenidae (13.20%), Papilionidae (1.99%), Riodinidae (1.08%) and Hesperiidae (0.90%). Chocolate Albatross (*Appias lyncida*) of family Pieridae was recorded as the most abundant species with 63 individuals. The study area was rich in butterfly diversity which was confirmed by the score of the diversity indices where the calculated value of Shannon diversity index was 3.46, Simpson's index of diversity was 0.95, while Margalef's index was 10.13. In the study area, forest and grasslands provide a better combination of habitat to the butterfly community which might have a good impact on their abundance and diversity. As the present sampled location is facing an excessive tourist pressure, there is an urgent need of attention from the Government authorities to conserve this habitat. This study is likely to contribute towards the conservation of butterfly fauna along with biodiversity protection and ecosystem integrity.

Keywords: Biodiversity protection, butterfly diversity, buxa tiger reserve, diversity indices, Nymphalidae

Introduction

Faunal diversity of a forest is an indicator of the health of that forest ecosystem and it plays a key role in the maintenance and sustainability of the forest ecosystem. Nowadays, ecological indicator species are being used globally as a tool for assessing the biodiversity of an ecosystem. Reports on studying of indicator species of a forest will be useful for taking the forest management policies and also will portrait the after effect of forest management in terms of structure and function of that ecosystem (Pearce and Venier, 2006; Maleque *et al*., 2009) [29, 21].

Among the bioindicator species, butterflies are the most accepted one due to their attractive wing colouration patterns which make them easily identifiable, high diversity, short life history traits, host plant preferences and above all the sensitivity to environmental changes (Lee *et al*., 2016) [20]. Moreover, for the stability of food web, butterflies play a vital role as herbivores (Rusman *et al*., 2016; Chowdhury and Chowdhury, 2020) [35, 7] and prey of predators (Rusman *et al*., 2016; Chowdhury and Chowdhury, 2020) [35, 7]. They also serve as host of parasitoids (Chowdhury and Chowdhury, 2020; Van and Hanski, 2002) [7, 46], as surrogate species for faunal and floral diversity (Ehrlich and Raven, 1964) [11] and primarily as pollinators in maintaining and improving the community structure (Chowdhury and Chowdhury, 2020; Mukherjee *et al*., 2015) [7, 23].

Buxa Tiger Reserve is an average sized protected area, falls under the biogeographic province 7B lower Gangetic plain (Rodgers and Panwar, 1988) [33] and covers an area of about 760.87 sq. km, with a core area of 385 sq. km and a buffer zone of 375 sq. km (Sivakumar *et al*., 2006) [43]. This area includes a sanctuary of 269 sq. km and a National Park of 117.01 sq. km (Chakraborty *et al*., 2023) [5]. It is situated in the north-east corner of Jalpaiguri district of West Bengal between latitudes 26˚30" to 26˚55" North and longitudes 89˚20" to 89˚55" East of India. Bhutan and Assam border the northern and eastern boundaries respectively, while tea garden and agricultural fields border the western and southern boundaries respectively. The area comes in the transition zone between Biom-8 and Biome-12 (Chakraborty *et al*., 2023) [5]. This protected area is located in the foot hill of eastern Himalaya, Sinchula hill range lies on northern side of the reserve. The altitude of this reserve peaks up to about 1800m. Many rivers, namely Jayanti, Churnia, Sankosh, Raidak, Turturi, Phashkhawa, Dima and Nonani flow through the area. The forest of the reserve is under the moist tropical forest category and is classified according to Champion and Seth (1968) [6] into 8 sub-types. Among the 352 plant species of the reserve (NTCA, 2022) [25], the dominant species are Sal *(Shorea robusta*), Simul (*Bombax ceiba*), Gamar (*Gmelina arborea*), Chikrasi (*Chukrasia tabularis*) etc. while most notable major vertebrate population include tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*), wild boar (*Sus scrofa*), barking dear (*Muntiacus muntjak*) and sambar (*Rusa unicolor*). Beside the 68 mammalian species, this reserve is also home for various birds (more than 246 species), reptiles (41 species), fishes (103 species) and numerous insects (more than 500 species) (NTCA, 2022) [25]. When considering the invertebrate diversity, there is a lacuna of study reports conducting in Buxa Tiger Reserve.

Butterflies are among the best-known insects due to their size, shape and, attractive and diverse wing colouration and patterns. Reports on butterfly diversity are well on available from the different regions of India (Kumar *et al*., 2007; Verma, 2009; Sing, 2010; Kunte *et al*., 2012; Sengupta *et al*., 2014; Samanta *et al*., 2017) [15, 48, 42, 17, 40, 36]. Very few studies documented butterfly diversity of the Himalayan foot hill regions of West Bengal (Das *et al*., 2012; Roy *et al*., 2012; Pal *et al*., 2015; Chakraborty *et al*., 2023) [8, 34, 28, 5]. Sanctuary Asia in 2015 [37], reported that more than 500 species of butterflies were present in Buxa Tiger Reserve. The present study was undertaken with the main objective to explore the butterfly fauna and to carry out a systematic survey on diversity and abundance of butterfly community in Buxa Tiger Reserve.

Materials and Methods

Study area

The present study was carried out along the Buxa Road and forest trail from Rajabhatkhawa (26˚53'84" N, 89˚53'24" E) to the Buxa view point of Buxa Hill forest (26˚45'17" N, 89˚34'48" E) of about 12 km inside the Buxa Tiger Reserve, situated in Jalpaiguri district of West Bengal, India. The forest path up to the Santlabari was almost plain with shrubs and grassland, whereas from Santlabari to Buxa view point, the path was inside the dense forest of Sal, Simul, Gamar etc. with high elevation. The average annual rainfall of the study site is about 4100 mm and the temperature oscillates between 20˚C to 32˚C during summer and from 10˚C to 23˚C during winter.

Survey Techniques

Field surveys and data collection was based on a survey tour conducted from 6th January to 10th January, 2024 during the sunny days with good climatic conditions, neither heavy rain nor heavy wind. For sampling the butterflies, line transect method was used (Hossain and Adiya, 2016) [12]. The forest trail was used as fixed transects. To cover the 12 km survey path, a total number of six transects, each with 2000 m of length were executed per day. The entire surveys were carried out for consecutive five days and each survey followed the same transect path to reduce the number of variables as reported by Pyle (1992) [32]. The total count of 30 transects were studied. For the survey, the 12 km forest trail with 5 m on either side was trekked for five hours at a constant pace between 10:00 am to 3:00 pm using the standard Pollard walk methodology (Pollard, 1977; Pollard and Yates, 1993) [30, 31]. During the survey, all the butterfly species observed, were recorded with the number of each species.

Identification of most of the butterfly species were done through direct observation in the field or in critical cases through photographic evidences and identification following the keys of Kehimkar (2016) [14], Kunte *et al*., (2014) [18] and Dey *et al*., (2017) [10] or consulting the website of Butterflies of India (Butterflies of India, v. 3.03) [4]. During the survey, no capture or collection of butterflies were done. All common English names and scientific names followed in this study were in accordance with Varshney and Smetacek (2015) [47].

The relative abundance of each species was estimated on sighting records for the entire study period of sampling. To denote the most common to the rarest butterfly species (Pahari *et al*., 2018) [27], the recoded butterflies were broadly categorized into five groups: VR (very rare, <0.5), R (rare, 0.6-1), NR (not rare, 1.1-3.1), C (common, 3.2-10) VC (very common, 10.1-31.6) based on their relative abundances in the study site (Table 1).

Statistical Data analysis

For the understanding of the structure of butterfly community of the study site, α-diversity (diversity of species within a community) was measured using the following diversity indices. All the data were analyzed and calculated with the help of Microsoft Excel 2019 software. Species richness, species abundance and evenness were analyzed through Shannon index (Shannon and Weaver, 1963) [39], Simpson index (Simpson, 1964) [41], Margalef's index (Margalef, 1958) [22] and Pielou's index (Mulder *et al*., 2004) [24]. The log of butterfly species abundance data was used to construct a rank abundance curve or Whittaker plot (Whittaker, 1965) [49] of all the species to show their relative abundance in the study area.

Species richness

To measure species diversity, Shannon-Wiener index, also known as Shannon index of diversity was used. It is an information statistic index that integrate the number of species within a site with the relative abundance of each species (Odum, 1997) [26]. This index contributes some value for the rare species with very few individuals (Biswas *et al*., 2019) [3]. Shannon diversity index (H') depicted the two parameters, the species richness and their abundance in the community. It was calculated as follows:

Shannon diversity index (H') = $- \Sigma$ pi ln pi

Shannon $H_{max} = Log_{10}(S)$

Here, pi is the proportion of the i^{th} species in the community. S is number of species present in a community. The value of H' usually ranges between 1.5 to 3.5 and rarely exceeds 4.5.

Margalef's index (Margalef, 1958) [22] index is the measure of species richness, is calculated as follows:

$I_{Mg} = S-1/\ln N$

Here, N is the total number of individuals of all the species.

Species dominance

Dominance index (Berger and Parker, 1970) [1] was used to estimate the species dominance and was calculated as follows:

Dominance index (D_{BP})= ni/N,

Here, ni is the number of individuals of i^{th} species, and N is the total number of individuals of all the species with in a family or in the study area.

Species abundance

This index was used to measure the proportion of more common species in a community and it was calculated as follows:

Simpson's dominance index (Ds)= Σ^{S}_{i-1}[ni (ni-1)/N(N-1)]

$D = 1/ \Sigma^{S}_{i}$ pi^2

Here, pi is the dominance index (D_{BP}). The larger value of D represents the greater equitability. The value of Ds ranges between 0 to 1 and is inversely proportional to the wealth of species. As its value increases, the species diversity decreases. Hence, the more the Ds value is towards 0, the more abundance will be in the community.

Species evenness

Species evenness denotes the proportion or relative abundance of individuals among all the species. It indicates how their relative abundance is distributed in a community. Pielou's evenness index (J') was used to estimate the species evenness and calculated as follows:

Pielou's evenness index (J')= H'/ln S

Here, the value of J' ranges from 0 to 1. More the value inclined to 1, the more will be the evenness in the community, i.e. less variation of species in a community contributes higher value of J'.

Rank abundance curve

In ecology to display relative species abundance, rank abundance curve or Whittaker plot is used which is a graph, is prepared taking abundance rank on the X-axis against log of relative abundance on the Y-axis. Further, it depicts species richness as well as species evenness (Whittaker, 1965) [49].

Results

The geographical map and satellite overview of the present study site was shown in figure 1. The family-wise checklist of the recoded butterfly species from the study area, with their common and scientific names, relative abundance and WPA schedule (species enlisted in Indian Wildlife Protection Act, 1972) [45] is represented in Table 1. In the current study, 65 species of butterflies were recorded, belonging to 45 genera under six families from Buxa Tiger Reserve (Table 1). The families include Papilionidae with 2 genera and 5 species, Nymphalidae with 19 genera and 30 species, Pieridae with 7 genera 12 species, Lycaenidae with 12 genera and 13 species, Riodinidae with 1 genus and 1 species, and Hesperiidae with 4 genera and 4 species. The family Pieridae appeared to be the most abundant family, when considering the total number of individuals per family (43.76%), while family Nymphalidae found to be the most dominant family when total number of species (30 species) was considered. Hence, percentage composition of butterfly (figure 2) was higher in Pieridae, followed by Nymphalidae, Lycaenidae, Papilionidae and then in Riodinidae, and was found with the least percentage in family Hesperiidae. In the butterfly population of the study site, the percentage proportion of butterfly species and butterfly genera of the six families is represented in figure 3. It was noted that the percentage value of the total number of butterfly species per family, was more in family Nymphalidae (46.15%), followed by Lycaenidae (20%), Pieridae (18.46%), Papilionidae (7.69%) and then in Hesperiidae (6.15%), and least in Riodinidae (1.54%). The percentage of total number of butterfly genera of the six observed families, followed an almost similar trend as their species percentage composition; family Nymphalidae (42.22%) outnumbered the other families, followed by Lycaenidae (26.67%) Pieridae (15.56%), and then Hesperiidae (8.89%), while Riodinidae with the least percentage (3.77%). When data were compared between the family Papilionidae and Hesperiidae, it was observed that percentage of species was higher in Papilionidae and percentage of genera was in Hesperiidae.

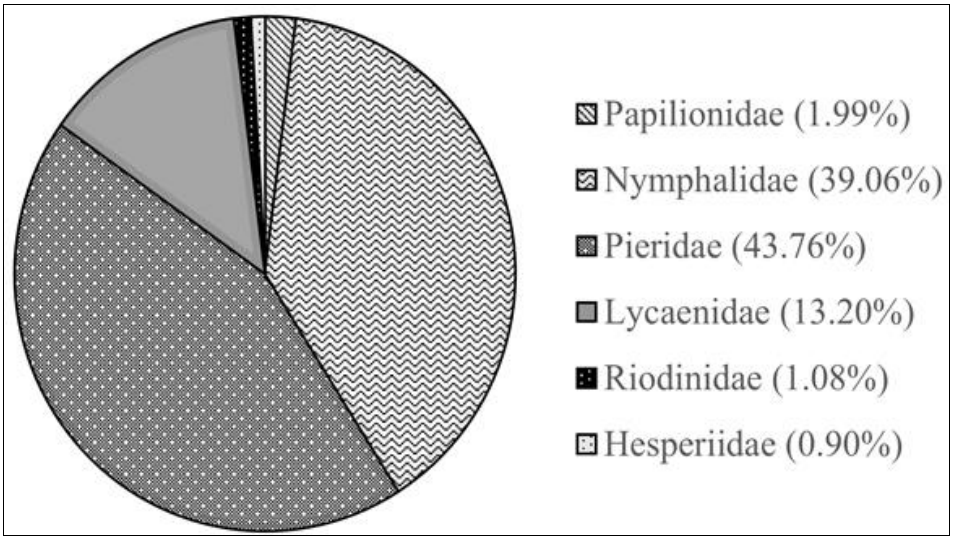
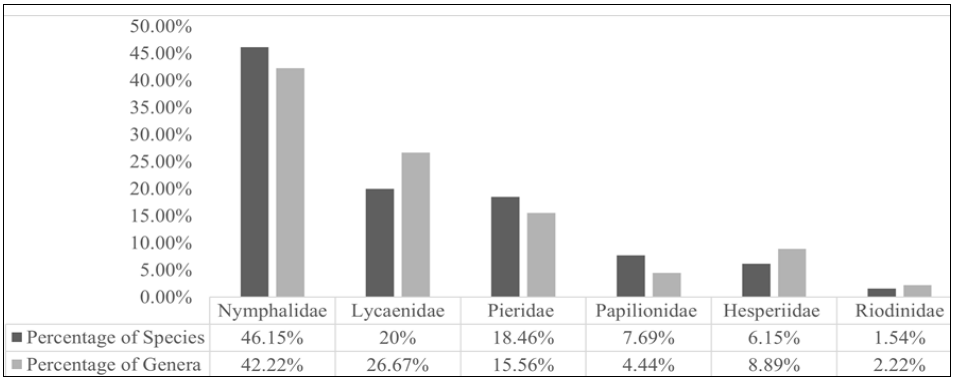


Fig 2: Percentage composition of six families of butterflies in the study area



	Nymphalidae	Lycaenidae	Pieridae	Papilionidae	Hesperiidae	Riodinidae
Percentage of Species	46.15%	20%	18.46%	7.69%	6.15%	1.54%
Percentage of Genera	42.22%	26.67%	15.56%	4.44%	8.89%	2.22%

Fig 3: Genus to species proportion of butterflies of six familie

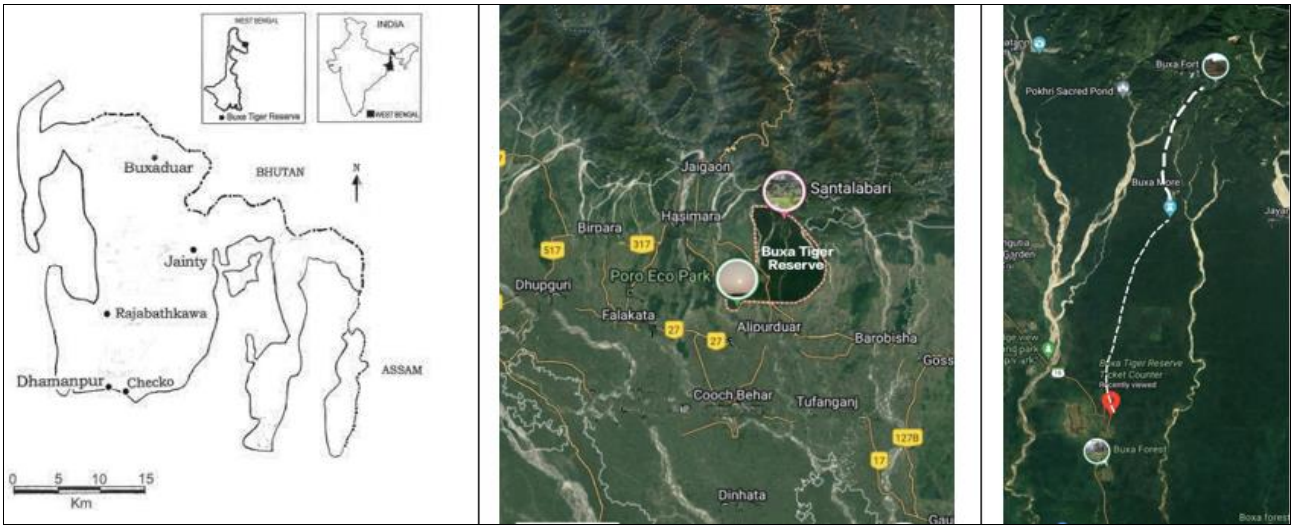


Fig 1: Map of Buxa Tiger Reserve, Jalpaiguri, West Bengal (left), satellite image of Buxa Tiger Reserve (middle), location of transects at study site (right) (https://images.app.goo.gl/itHhWMXWTbtVZdNKA and https://maps.app.goo.gl/G6HBWiNWbZzS6L8Y7)

Table 1: Checklist of butterfly species along with their family, relative abundance, status and WPA Schedule recoded in Buxa Tiger Reserve

Sl. No.	Family	Common Name	Scientific name	Relative Abundance (RA)	Status	WPA Schedule
1	Papilionidae	Common Bluebottle	*Graphium sarpedon*	0.18	VR	
2		Common Jay	*Graphium doson*	1.08	NR	
3		Common Mormon	*Papilio polytes*	0.18	VR	
4		Blue Mormon	*Papilio polymnestor*	0.18	VR	
5		Northern Lime Swallowtail	*Papilio demoleus demoleus*	0.36	VR	
6	Nymphalidae	Common Bush Brown	*Mycalesis perseus*	0.72	R	
7		Indian Long-branded Bush Brown	*Mycalesis mineus*	0.18	VR	
8		Dark Evening Brown	*Melanitis phedima*	0.72	R	
9		Dark-branded Bush Brown	*Melanitis phedima bela*	1.08	NR	
10		Oriental Common Evening Brown	*Melanitis leda leda*	1.08	NR	
11		Great Evening Brown	*Melanitis zitenius*	0.18	VR	
12		Great Eggfly	*Hypolimnas bolina*	0.18	VR	Schedule I
13		Oriental Chocolate Pansy	*Junonia iphita iphita*	3.25	C	
14		Grey Pansy	*Junonia atlites*	3.25	C	
15		Peacock Pansy	*Junonia almana*	1.08	NR	
16		Yellow Pansy	*Junonia hierta*	0.18	VR	
17		Lemon Pansy	*Junonia lemonias*	10.13	VC	
18		Grey Count	*Tanaecia lepidea*	0.18	VR	Schedule II
19		Common Earl	*Tanaecia Julii*	0.72	R	
20		Indian Nawab	*Charaxes bharata*	0.18	VR	
21		Himalayan Red Admiral	*Vanessa indica indica*	0.18	VR	
22		Common Five-ring	*Ypthima baldus*	3.25	C	
23		Common Four-ring	*Ypthima huebneri*	3.25	C	
24		Common Sailor	*Neptis hylas*	0.18	VR	
25		Orange Oakleaf	*Kallima inachus*	0.18	VR	
26		Commander	*Moduza procris*	1.27	NR	
27		Common Palmfly	*Elymnias hypermnestra*	0.18	VR	
28		Colour Sergeant	*Athyma nefte*	1.08	NR	
29		Staff Sergeant	*Athyma selenophora*	0.90	R	
30		Tawny Coster	*Acraea terpsicore*	0.18	VR	
31		Common Lascar	*Pantoporia hordonia*	1.08	NR	
32		Common Map	*Cyrestis thyodamas*	0.18	VR	
33		Plain Tiger	*Danaus chrysippus*	0.36	VR	
34		Blue Tiger	*Tirumala limniace*	0.36	VR	
35		Glassy Tiger	*Parantica aglea*	3.25	C	
36	Pieridae	Chinese Red-base Jezebel	*Delias pasithoe pasithoe*	1.08	NR	
37		Indian Jezebel	*Delias eucharis*	3.44	C	
38		Vietnamese Red-spot Jezebel	*Delias descombesi descombesi*	1.08	NR	
39		Yellow Orange-tip	*Ixias pyrene*	3.25	C	
40		Striped Albatross	*Appias libythea*	0.90	R	
41		Chocolate Albatross	*Appias lyncida*	11.39	VC	
42		Psyche	*Leptosia nina*	3.25	C	
43		Three-spot Grass Yellow	*Eurema blanda silhetana*	1.45	NR	

44		Common Grass Yellow	*Eurema hecabe*	10.13	VC	
45		Himalayan Cabbage White	*Pieris canidia indica*	1.08	NR	
46		Common Emigrant	*Catopsilia pomona*	5.61	C	
47		Mottled Emigrant	*Catopsilia pyranthe*	1.08	NR	
48	Lycaenidae	Oriental Common Pierrot	*Castalius rosimon rosimon*	3.25	C	Schedule I
49		Elbowed Pierrot	*Caleta elna*	0.18	VR	
50		Common Acacia Blue	*Surendra quercetorum*	0.36	VR	
51		Oriental Apefly	*Spalgis epius epius*	0.72	R	
52		Dark Grass Blue	*Zizeeria karsandra*	0.72	R	
53		Lackluster Oakblue	*Arhopala oenea*	0.18	VR	
54		Teesta Powdered Oakblue	*Arhopala bazalus teesta*	0.72	R	
55		Common Cerulean	*Jamides celeno*	0.18	VR	
56		Common Hedge Blue	*Acytolepis puspa*	3.44	C	
57		Angled Sunbeam	*Curetis acuta*	0.18	VR	
58		Pale Grass Blue	*Pseudozizeeria maha*	0.36	VR	
59		Indian Copper Flash	*Rapala pheretima petosiris*	1.63	NR	
60		Purple Sapphire	*Heliophorus epicles*	1.27	NR	
61	Riodinidae	Himalayan Punchinello	*Zemeros flegyas flegyas*	1.08	NR	
62	Hesperiidae	Common Awl	*Hasora badra*	0.36	VR	
63		Dark Palm-Dart	*Telicota bambusae*	0.18	VR	
64		Variable Plain Palm Dart	*Cephrenes acalle oceanica*	0.18	VR	
65		Oriental Common Dartlet	*Oriens gola*	0.18	VR	

VR= very rare (<0.5 RA), R= rare (0.6-1 RA), NR= not rare (1.1-3.1 RA), C= common (3.2-10 RA), VC= Very common (10.1-31.6 RA).
WPA- Species enlisted in Indian Wildlife Protection Act, 1972.

Of the recorded butterfly species from the present study site, most were 'common' and 'generalist' species (Sarma *et al*., 2012) [38], only three species were found as legally protected under different Schedules of the Wildlife Protection Act, 1972 [45], but no species was observed as globally threatened according to the IUCN Red List (Ver 3.1) [13], though, three species were found under the category least concern and were legally protected under different Schedules of the Wildlife Protection Act, 1972 [45]. Of these three legally protected species, Great Eggfly (*Hypolimnas bolina*) and Oriental Common Pierrot (*Castalius rosimon rosimon*) are protected under Schedule I, while Grey Count (*Tanaecia lepidea*) under Schedule II.

According to visibility and based on the values of relative abundance of the butterfly species (figure 4) of the study site, 31.65% of total number of butterflies, were considered under the category very common (VC), 38.52% were under common category (C), 17.54% were under not rare category (NR), 6.15% were under rare category (R) and lastly 6.15% butterfly species were under very rare category (VR). Among all the 65 butterfly species, recoded during the study period, 3 species were found under the VC category, 11 species under C category, 15 species under NR category, 8 species under R category and 28 species under VR category. Among all the recorded butterfly species from the study site, Chocolate Albatross (*A. lyncida*) under the family Pieridae, was found to be the most abundant butterfly species with maximum number of individuals (11.39%), it was followed by Common Grass Yellow (*Eurema hecabe*) of family

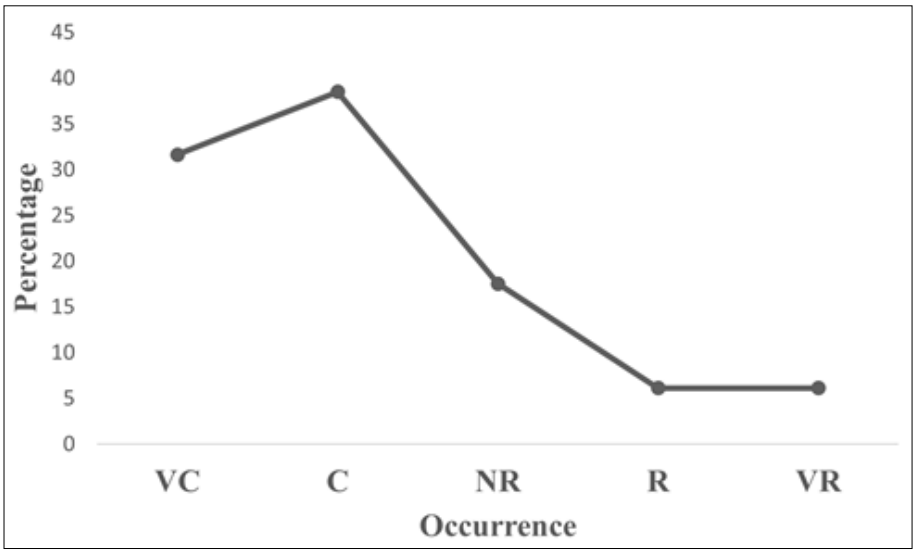


Fig 4: Occurrence of different butterfly species in the study area

Pieridae and Lemon Pansy (*Junonia lemonias*) of family Nymphalidae, both with 10.13% relative abundance and then Common Emigrant (*Catopsilia pomona*) of Pieridae family with 5.61% relative abundance, Common Hedge Blue (*Acytolepis puspa*) of family Lycaenidae with 3.44% relative abundance. In the butterfly community of the study area, Common Bluebottle, Common Mormon, Blue Mormon and Northern Lime Swallowtail under Papilionidae family, Indian Long-branded Bush Brown, Great Evening Brown, Great Eggfly, Yellow Pansy, Grey Count, Indian

Nawab, Himalayan Red Admiral, Common Sailor, Orange Oakleaf, Common Palmfly, Tawny Coster, Common Map, Plain Tiger and Blue Tiger under Nymphalidae family, Elbowed Pierrot, Common Acacia Blue, Lackluster Oakblue, Common Cerulean, Angled Sunbeam and Pale Grass Blue under Lycaenidae family, Common Awl, Dark Palm-Dart, Variable Plain Palm-Dart and Oriental Common Dartlet under Hesperiidae family were found to be very rare in number of individual (observed number: only one or two, relative abundance from 0.18% to 0.36%).

In the family Papilionidae, Common Jay (*Graphium doson*) was the most abundant species, followed by Northern Lime Swallowtail (*Papilio demoleus demoleus*), found with two in number and the remaining were observed with only one in number. In Nymphalidae family, Lemon Pansy counted more than the other species, followed by Oriental Chocolate Pansy (*Junonia iphita iphita*), Grey Pansy (*Junonia atlites*), Common Five-ring (*Ypthima baldus*), Common Four-ring (*Ypthima huebneri*) and Glassy Tiger (*Parantica aglea*), those were found to share equal number of butterflies. Whereas, in the family Nymphalidae, Indian Long-branded Bush Brown (*Mycalesis visala visasa*), Great Evening Brown (*Melanitis zitenius*), Great Eggfly (*H. bolina*), Yellow Pansy (*Junonia hierta*), Grey Count (*T. lepidea*), Indian Nawab (Charaxes bharata), Himalayan Red Admiral (*Vanessa indica indica*), Common Sailor (*Neptis hylas*), Orange Oakleaf (*Kallima inachus*), Common Palmfly (*Elymnias hypermnestra*), Tawny Coster (*Acraea terpsicore*) and Common Map (*Cyrestis thyodamas*) were found with only one in number. Under the family Pieridae, Chocolate albatross (*A. lyncida*) was more abundant, followed by Common Grass Yellow (*E. hecabe*), Common Emigrant (*C. pomona*), Indian Jezebel (*Delias eucharis*), Yellow Orange-tip (*Ixias pyrene*), Psyche (*Leptosia nina*) and then in Three-spot Grass Yellow (*Eurema blanda silhetana*), while Stiped Albatross (*Appias libythea*) was the sparse one. Similarly, in the family Lycaenidae, Common Hedge Blue (*Acytolepis puspa*) was the abundant in number of butterflies, followed by Oriental Common Pierrot (*C. rosimon rosimon*), whereas Elbowed Pierrot (*Caleta elna*), Lackluster Oakblue (*Arhopala oenea*), Common Cerulean (*Jamides celeno*) and Angled Sunbeam (*Curetis acuta*) were found with only one in number. Under the family Hesperiidae, Common Awl (*Hasora badra*) was well encounter compared to other species, those were noticed with only one in number. Himalayan Punchinello (*Z. flegyas flegyas*) was the only species recorded under the family Riodinidae.

Species richness of the recorded butterfly genera of the study area was shown in figure 5 which illustrated that the most prevalent genera were those, containing four and five number of species. The distribution of the butterfly species within different genera, was found highly skewed. In the present study, a large proportion of genera (32 out of 45) were represented by single species, while two species per genus was found in case of nine different genera. Similarly, three species per genus was noted in two different genera, while the four species per genus and five species per genus was found in single genus only.

The current study revealed that in the butterfly community, species to genus ratio (S/G= 1.44) was very low. The genus *Junonia*, under the family Nymphalidae, was the most diverse genus which include five different species, while genus *Melanitis*, also under the Nymphalidae family, was represented by four number of species and *Papilio* under the Papilionidae family and *Delias* under Pieridae family were represented by three species each. The genera *Graphium, Mycalesis, Tanaecia, Ypthima, Athyma, Appias, Eurema, Catopsilia* and *Arhopala,* were found to be represented by two species each, whereas the remaining 32 genera were noted to have single species in the study area.

The species diversity and species evenness of the studied butterfly community was expressed by values of Shannon diversity index (H'), Margalef's index (I_{Mg}), Pielou's evenness index (j') and Simpson's diversity index (Ds) as shown in Table 2. Shannon's index (H') denotes the species richness i.e. the total number of species as well as the rare species in a community. The calculative values of Shannon index (H') and Margalef's index (I_{Mg}) were 3.46 and 10.13 respectively, indicating that in Buxa Tiger Reserve, butterfly community was in the direction of an ideal natural community with high species richness. When considering the values of Pielou's evenness index (J'), it ranges between 0 and 1 and the calculated value was found 0.55, i.e. more evenness was not found in the sampled community. The Pielou's evenness index of the study area revealed that in the butterfly community of the study area, sustained a moderate evenness and the butterfly community was found toward the less even as the value was quite far from 1. Simpson's index (Ds) defines the abundance of a species in the community. The range of its value is from 0 to 1, and the more the index value close to 0 the more the species abundance in the community and when it is close to 1, species diversity is low. In the sampled butterfly community, the calculative value of Simpson's index (Ds) is 0.05. As the value of Ds was found just between 0 and 1, it indicates a moderate proportion of species abundance. The value of Simpson's index of diversity was 0.95, suggesting the studied butterfly community is a diverse one. The results of diversity indices of the sampled site, reflected that the butterfly community was highly diverse with moderate evenness and also with moderate abundance.

Table 2: Values of different biodiversity indices of butterfly population of the study area

Shannon diversity index (H')	Pielou's evenness index (j)	Simpson's index (Ds)	Simpson's index of diversity (Ds)	Margalef's index (I_{Mg})
3.46	0.55	0.05	0.95	10.13

The calculated values of Shannon diversity index (H'), Shannon H_{max}, Pielou's evenness index (j'), dominance index (D_{BP}) and Simpson's diversity index (Ds) were represented family wise in Table 3. The value of H' ranged from 0 to 2.69. The lowest value was observed in Riodinidae family having only one species, depicted that there was no species diversity in the family Riodinidae. The highest value was obtained from the Nymphalidae family which indicates that this family was most diverse family, followed by Pieridae (2.10) and Lycaenidae (2.09). This observation revealed that the butterfly community of the study site was ideal for nature. Furthermore, an ideal community of an area shows the value of evenness (J') is 1. In the present study, a higher value of evenness (J') was

found in the Hesperiidae family, followed by Papilionidae, Nymphalidae and then in Lycaenidae, while the J values of Riodinidae family was observed '0' as only one species recorded in this family. Obtained results of the present study revealed that in the study site, the dominant family was Nymphalidae (D= 9.19) and the dominant species of this family was Lemon Pansy. The family Pieridae was the subdominant family (D= 6.29) and Chocolate Albatross was the most dominant species of this family, followed by Common Grass Yellow. Common Hedge Blue, under the family Lycaenidae, Common Awl, under the family Hesperiidae and Common Jay, under the family Papilionidae were found to be the dominant species of their respective family.

Table 3: Values of different biodiversity indices of six butterfly families of the study area

Family	Shannon diversity index (H')	H_{max}	Pielou evenness index (j)	D_{BP} Higher	D_{BP} Lower	Simpson's diversity index (Ds)	D
Papilionidae	1.29	1.04	0.54	0.545	0.091	0.29	2.81
Nymphalidae	2.69	2.33	0.50	0.259	0.005	0.10	9.19
Pieridae	2.10	2.38	0.38	0.260	0.021	0.15	6.29
Lycaenidae	2.09	1.86	0.49	0.260	0.014	0.16	6.09
Riodinidae	0.00	0.78	0.00	1.000	1.000	1.00	1.00
Hesperiidae	1.33	0.70	0.83	0.400	0.200	0.10	3.57

The calculated values of the diversity indices indicated that, in the study area, among the six families, Nymphalidae was found the highly diverse family (Ds= 0.10, D= 9.19), followed by Pieridae (Ds= 0.15, D= 6.29) and Lycaenidae (Ds= 0.16, D= 6.09) and the family Riodinidae was found with no diversity (Ds= 1, D= 1) as only one species found in this family.

Figure 5, showing the rank abundance curve which portrayed the species diversity, whereas figure 6, showing the family wise rank abundance curve, expressed the family diversity. The rank abundance curve for the studied butterfly community showed strong evenness with a relatively low steep inclination except the rank 1st, 2nd and 3rd species (high steep) and moderate steep inclination from the 5th to 10th ranked species in the Whittaker plot. High evenness was found between various species as the high-ranking species have lower abundances compared to low-ranking species. Except the species, ranked from 1st to 4th, all the species specially 11th onwards, found in the plot with a low gradient that revealed high evenness among the species. On the other hand, the rank-abundance curve showed that species evenness was more in the family Hesperiidae and Papilionidae, whereas the family Nymphalidae and Pieridae had the less species evenness.

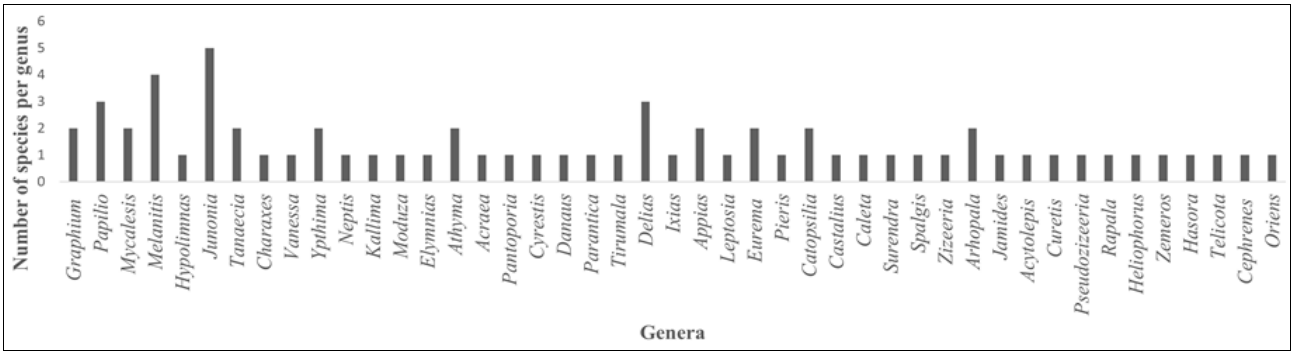


Fig 5: Species richness of the recorded butterfly genera of the study site

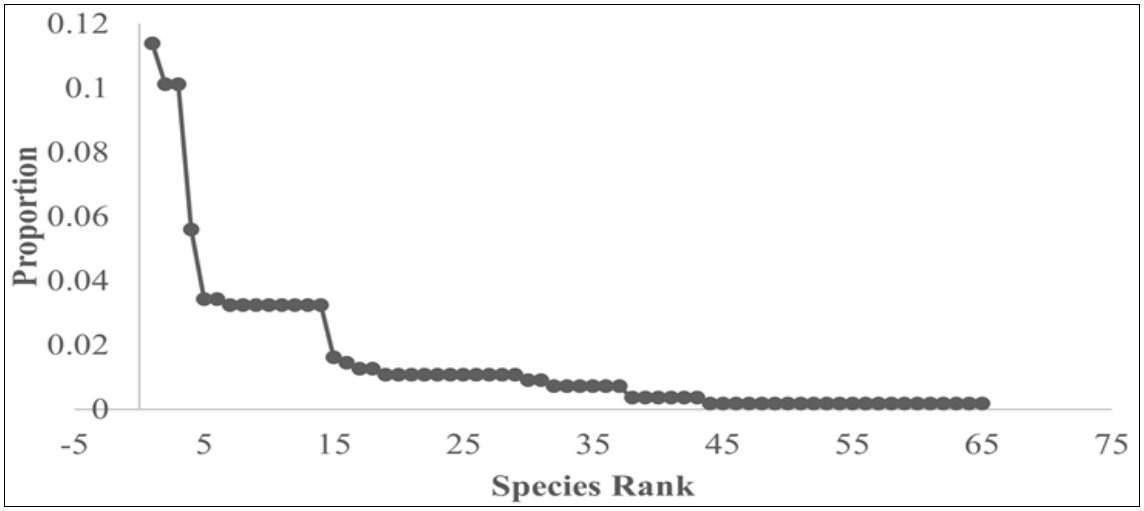


Fig 6: Rank abundance curve of 65 species of butterfly in the study are

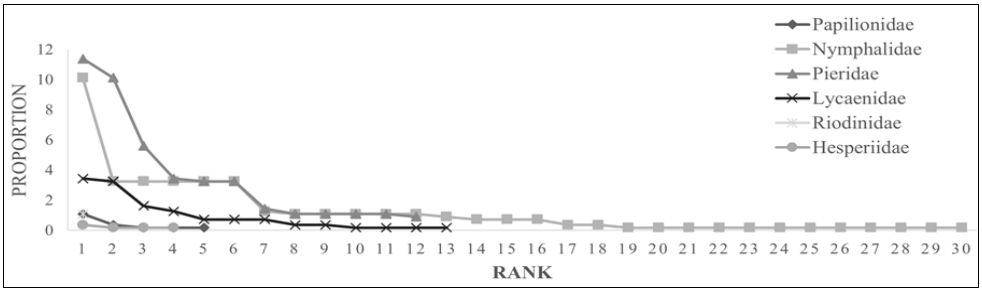


Fig 7: Rank abundance curve of six families of butterfly in the study area

i. *Heliophorus epicles*, ii. *Zemeros flegyas flegyas*, iii. *Leptosia nina*, iv. *Delias descombesi descombesi*, v. *Heliophorus epicles*, vi. *Appias lyncida*, vii. *Junonia almana*, viii. *Pieris canidia indica*, ix. *Vanessa indica indica*, x. *Parantica aglea*, xi. *Hypolimnas bolina*, xii. *Elymnias hypermnestra*, xiii. *Papilio demoleus demoleus*, xiv. *Zizeeria karsandra*, xv. *Delias eucharis*, xvi. *Rapala pheretima petosiris*, xvii. *Telicota bambusae*, xviii. *Hasora badra*, xix. *Junonia lemonias*, xx. *Tanaecia lepidea*.

Fig 8: Photographs of different butterfly species recorded in the study area

xxv. *Charaxes bharata*, xxvi. *Delias pasithoe pasithoe*, xxvii. *Athyma selenophora*, xxviii. *Junonia iphita iphita*, xxix. *Junonia atlites*, xxx. *Surendra quercetorum*, xxxi. *Castalius rosimon rosimon*, xxxii. *Athyma nefte*, xxxiii. *Spalgis epius epius*, xxxiv. *Catopsilia pomona*, xxxv. *Eurema hecabe*, xxxvi. *Appias libythea*, xxxvii. *Tirumala limniace*, xxxviii. *Graphium doson*, xxxix. *Acraea terpsicore*, xxxx. *Danaus chrysippus*

Fig 9: Photographs of different butterfly species recorded in the study area

xxxxi. *Melanitis mineus*, xxxxii. *Papilio polymnestor*, xxxxiii. *Arhopala oenea*, xxxxiv. *Pseudozizeeria maha*, xxxxv. *Melanitis phedima*, xxxxvi. *Melanitis zitenius*, xxxxvii. *Melanitis leda leda*, xxxxviii. *Mycalesis perseus*.

Fig 10: Photographs of different butterfly species recorded in the study area

Discussion

Among insects, butterflies have a significant importance in the ecosystem as their diversity, abundance or the occurrence acts as bioindicator of the health of terrestrial ecosystem. Buxa Tiger Reserve is a forest area with Sal, Simul, Gamar etc. trees and also with Shrubs and with open grasslands. These different types of vegetations may able to provide better availability and access of food (larval host plants and nectar) and shelter to the butterfly community of that region. Hence, it could be the major factor of the abundance of butterfly species in the sampled area. Das *et al*., (2012) [8] reported that forests and grasslands, altogether offer a better combination of habitat to the butterfly community as they obtained a good diversity of butterfly from this combination habitat of Gorumara National Park, West Bengal. The analysed results of Shannon diversity index score and Margalef's index score of the current study, also reveals that a handsome diversity exists in the study area as this location is with the combination habitat. Simpson's diversity index score showed that the butterfly community of the sampled area has great diversity with several species. Butterflies in the present study area, were found not more evenly distributed among different genera which was reflected in the Pielou's Evenness index score. This finding was also supported by the Simpson's Dominance index score which was just mid-point of its range value, indicating that few species might become the dominant species in near future.

Previous studies conducted in different parts of India, reported that Nymphalidae was the most dominant butterfly family (Kumar *et al*., 2007; Verma, 2009; Sing, 2010; Kunte *et al*., 2012; Sengupta *et al*., 2014; Samanta *et al*., 2017) [15, 48, 42, 17, 40, 36]. Earlier reports made by various researchers from the different habitat types of North Bengal districts, also collaborates well with the present finding of Nymphalids as most dominant one (Das *et al*., 2012; Roy *et al*., 2012; Pal *et al*., 2015; Datta and Ghosh, 2016; Bhutia and Sharma, 2020; Chakraborty *et al*., 2023) [8, 34, 28, 2, 5]. The least abundance of Riodinids found in the current study, is in the line with the reports made by Singh (2010) [42], Samanta *et al*., (2017) [36] and Chakraborty *et al*., (2023) [5].

In the present study, Common grass Yellow (*E. hecabe*) under the family Pieridae, was noted to have a high population and was found under VC category, might be due their polyphagous nature of feeding habit which is an evolutionary advantage that makes them one of the commonest butterflies worldwide (Larsen 1987) [19].

The wingspan ranges and body size of butterfly is a distinguishable feature of feeding habit of butterflies. Generally non-herb feeders have larger wingspan ranges and were mainly found in forested habitats, while herb feeders with smaller wingspan ranges were usually recorded from open habitats (Kunte, 1997) [16]. However, at Buxa Tiger Reserve both these groups of butterflies were observed as both the forested and open habitats were found to exist. In this study it was found that the population of tiny lycaenids was smaller than the large nymphalids and much adapted Pierids, might be due to competitive exclusion among the butterfly families those use same nectar sources. Though, the ill adapted small lycaenids were found to occur with moderate population, may be due to their poor dispersal abilities (Datta and Ghosh, 2016) [9].

As reported by Das *et al*., (2012) [8], the recorded butterfly species of the present study were seen basking, nectaring on flowering plants and gathering in large number for mud-puddling at the damp soil patches. Mud-puddling of male butterfly is associated with procurement of some important nutrients such as calcium, sodium, phosphorus etc. those are needed for the formation of their spermatophore (Smetacek, 2002) [44]. Moreover, Nymphalids and Lycaenids were also observed, sitting on over-ripe fruits which are alcohol-rich, fresh elephant dung, bird-dropping and faeces of carnivores etc. This finding was also confirmed by the observation of Das *et al*., (2012) [8].

The geographic position, unique climate, a good diversity of flowering and nectaring plants, adequate source of water and presence of combination habitats support and secure a rich diversity in the butterfly community of the Buxa Tiger Reserve.

The present study was conducted on a rapid inventory basis and there might be a chance of not recording of the less noticeable and cryptic species. Therefore, to speculate the

diversity status of the butterfly community of Buxa Tiger Reserve, further long-term surveys of the butterfly fauna at the other areas of this region are recommended which will be useful in planning of conservation initiatives by the government authorities.

Conclusion

The current study is only a preliminary observation on the butterfly species diversity and abundance of the Buxa Tiger Reserve, Jalpaiguri, West Bengal. The findings are encouraging and have significance as this study area is rich in butterfly fauna. This present report might be useful in monitoring the health, sustainability and functioning of ecosystem of the present study area. Hence, the current study will be a baseline platform for future research works. Although, more investigations on the butterfly diversity of this region covering more study areas will be required to predict the complete picture of the butterfly community of this region. For that, further researches on the seasonal variations in their diversity and abundance, identification of their different host plants and nectaring plants, understanding the nature of interaction between butterflies and flowering plants, exploring new species, estimating the effect of different environmental factors on their life cycle will be useful to conserve these butterfly communities for the continuity of ecosystem services and sustainable development. Anthropogenic disturbances like cutting of trees from forest, unplanned excessive tourist pressure etc., and poor habitat conservation efforts create threats for the ecosystem and wildlife of this region. Hence, survey at regular intervals will make aware the concerned government authorities about the anthropogenic impact. If found, then conservation strategies should be taken accordingly to save wildlife and their habitat, and more precisely to restore these important pollinators.

References

1. Berger WH, Parker FL. Diversity of planktonic foraminifera in deep sea sediments. Science,1970:168: 1345-1347.
2. Bhutia J, Sharma BK. Diversity of butterfly in south district of Sikkim. Life Sciences Leaflets,2020:4297:0976–1098.
3. Biswas SJ, Patra D, Roy S, Giri SK, Paul S, Hossain A. Butterfly diversity throughout Midnapore urban area in West Bengal, India. Journal of Threatened Taxa,2019:11(14):14816-14826.
4. Butterflies of India, v. 3.03. Kunte K, Sondhi S, Roy P. (Chief Editors). Indian Foundation for Butterflies and National Centre for Biological Sciences. Available from: https://www.ifoundbutterflies.org/
5. Chakraborty M, Baidya P, Singha R. Butterfly diversity along a short trekking route inside Buxa Tiger Reserve (National Park), West Bengal, India. Species Analysis Article,2023:24:e18s1018.
6. Champion HG, Seth SK. A Revised Survey of the Forest Types of India. Government of India, New Delhi, 1968.
7. Chowdhury S, Chowdhury SK. A study on butterfly diversity and related host plants in Joychandi Hill of Purulia district, West Bengal, India. IOSR Journal of Environmental Sciences, Toxicology and Food Technolology,2020:14(10):55-60.
8. Das RP, Saha GK, De JK, Sanyl AK. Diversity and habitat preferences of butterflies in Gorumara National Park, West Bengal, India. Journal of Research in Biology,2012:2(4):303-314.
9. Datta S, Ghosh S. Study on winter community of butterfly in a patch forest near Gorumara National Park, West Bengal. Heritage, 2016, 12-116.
10. Dey PK, Payra A, Mondal KA. Study on butterfly diversity in Singur, West Bengal, India. e-planet,2017:15(1):73-77.
11. Ehrlich PR, Raven PH. Butterflies and plants: a study in coevolution. Evolution, 1964, 586-608.
12. Hossain A, Aditya G. Avian Diversity in Agricultural Landscape: Records from Burdwan, West Bengal, India. Proceedings of the Zoological Society,2016:69(1):1-14.
13. IUCN. The IUCN Red List of Threatened Species. Version 2022-1. 2022. Available from: https://www.iucnredlist.org
14. Kehimkar I. Butterflies of India, Bombay Natural History Society. Mumbai: Oxford University Press, 2016.
15. Kumar MP, Hoset BB, Poomesha HC, Raghavendra GHT. Butterflies of the Tiger Lion Safari, Thyavarekoppa, Shimoga, Karnataka. Zoos' Print Journal,2007:22(8):2805.
16. Kunte K. Seasonal Pattern in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats. Journal of Biosciences,1997:22(5):593-603.
17. Kunte K, Sondhi S, Sangma BM, Lovalekar R, Tokekar K, Agavekar G. Butterflies of the Garo Hills of Meghalaya, north eastern India: Their diversity and conservation. Journal of Threatened Taxa, 2012. 10.11609/JoTT.o2945.2933–92.
18. Kunte K, Zhang W, Tenger Trolander A, Palmer DH, Martin A, Reed RD, *et al*. Double sex is a mimicry supergene Nature,2014:507:229-232.
19. Larsen TB. The butterflies of the Nilgiri Mountain of Southern India (Lepidoptera, Rhopalocar); Journal of the Bombay Natural History Society,1987:84:53.
20. Lee CM, Kim SS, Kwon TS. Butterfly fauna in Mount Gariwang-san, Korea. Journal of Asia-Pacific Biodiversity,2016:9(2):198-204.
21. Maleque MA, Maeto K, Ishii HT. Arthropods as bioindicators of sustainable forest management, with a focus on plantation forests. Applied Entomology and Zoology,2009:44(1):1-1.
22. Margalef R. Temporal succession and spatial heterogeneity in phytoplankton. In: Perspectives in marine biology, Buzzati Traverso (ed.), Univ. Calif. Press, Berkley, 1958, 323-347.
23. Mukherjee S, Banerjee S, Saha GK, Basu P, Aditya G. Butterfly diversity in Kolkata, India: An appraisal for conservation management. Journal of Asia-Pacific Biodiversity,2015:8(3):210-221.
24. Mulder CPH, Bazeley White E, Dimitrakopoulos PG, Hector A, Scherer-Lorenzen M, Schmid B. Species evenness and productivity in experimental plant communities. Oikos,2004:107:50–63.
25. NTCA. National Tiger Conservation Authority. Project Tiger. Govt of India, 2022. https://ntca.gov.in/assets/uploads/briefnote/buxa.pdf

26. Odum EP. Ecology: A Bridge between Science and Society. Sinauer Associated Inc. Sunderland, Massachusetts, USA, 1997.
27. Pahari PR, Mishra NP, Sahoo A, Bhattacharya T. A study on the butterfly diversity of Haldia industrial belt and adjacent rural area in Purba Medinipur District, West Bengal, India. World Scientific News,2018:97:207–224.
28. Pal S, Das D, Saha A, Chakraborty K. Holistic survey on butterfly diversity at two selected regions of the Northern parts of Bengal, India. International Research Journal of Natural and Applied Science,2015:2(4):42-57.
29. Pearce JL, Venier LA. The use of ground beetles (Coleoptera: Carabidae) and spiders (Araneae) as bioindicators of sustainable forest management: a review. Ecological Indicators,2006:6(4):780-93.
30. Pollard E. A method for assessing changes in the abundance of butterflies. Biological Conservation,1977:12(2):115–134.
31. Pollard E, Yates TJ. Monitoring butterflies for ecology and conservation. London: Chapman and Hall, 1993.
32. Pyle RM. Handbook for butterfly watchers., Boston: Houghton Mifflin Harcourt, 1992.
33. Rodgers WA, Panwar HS. Planning a Wildlife Protected Area Network in India – The Report. Volume 1 and 2. Wildlife Institute of India, Dehradun, 1988.
34. Roy US, Mukherjee M, Mukhopadhyay SK. Butterfly diversity and abundance with reference to habitat heterogeneity in and around Neora Valley National Park, West Bengal, India. Our Nature,2012:10:53–60.
35. Rusman R, Atmowidi T, Peggie D. Butterflies (Lepidoptera: Papilionoidea) of Mount Sago, West Sumatra: Diversity and Flower Preference. Hayati Journal of Biosciences,2016:23(3):132-137.
36. Samanta S, Das D, Mandal S. Butterfly fauna of Baghmundi, Purulia, West Bengal, India: A preliminary checklist. Journal of Threatened Taxa,2017:9(5):10198–10207.
37. Sanctuary Asia. https://www.sanctuaryasia.com/photograp hy/photofeature/10313–butterflies–of–buxa.html, 2015. Accessed on 16th September 2018.
38. Sarma K, Kumar A, Devi A, Mazumdar K, Krishna M, Mudoi P, *et al*. Diversity and habitat association of butterfly species in foothills of Itanagar, Arunachal Pradesh, India. Centre if Info Bio Technology journal of Zoology,2012:1(2):67–77.
39. Shannon CE, Weaver W. The Mathematical Theory of Communication. Urbana: The University of Illinois Press, 1963.
40. Sengupta P, Banerjee KK, Ghorai N. Seasonal diversity of butterflies and their larval food plants in the surroundings of upper Neora Valley Natonal Park, a sub–tropical broad leaved hill forest in the eastern Himalayan landscape, West Bengal, India. Journal of Threatened Taxa,2014:6(1):5327–5342.
41. Simpson GG. Species density in North American recent mammals. Systematic Zoology,1964:3:57–73.
42. Singh AP. Butterfly diversity in tropical moist deciduous sal forests of Ankua Reserve Forest, Koina Range, Saranda Division, West Singhbhum District, Jharkhand, India. Journal of Threatened Taxa, 2010. 10.11609/JoTT.o2274.1130–9.
43. Sivakumar S, Varghese J, Prakash J. Abundance of birds in different habitats in Buxa Tiger Reserve, West Bengal, India. Forktail,2006:22:128-133.
44. Smetacek P. The study of Butterflies: 5- Congregations, Courtship and Migration. Resonance,2002:7:6-14.
45. The Wildlife (Protection) Act, with the Wildlife (Protection) Amendment Act, 2002. The Gazette of India, 1972, 148. Available from: https://web.archive.org/web/2020113014 5631/http://legislative.gov.in/sites/defaul t/files/A1972-53_0.pdf
46. Van Nouhuys S, Hanski I. Colonization rates and distances of a host butterfly and two specific parasitoids in a fragmented landscape. Journal of Animal Ecology,2002:71:639-650.
47. Varshney RK, Smetacek P. A Synoptic Catalogue of the Butterflies of India. New Delhi: Indinov Publishing, 2015.
48. Verma SK. Species composition and seasonal variation of butterflies in Dalma Wildlife Sanctuary, Jharkhand, India. Journal of Threatened Taxa, 2009. 10.11609/JoTT.o2126.295–7
49. Whitaker RH. Dominance and diversity in land plant communities: numerical relations of species express the importance of competition in community function and evolution. Science,1965:147(3655):250–260.