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A report on diversity and abundance of butterfly (Lepidoptera: Rhopalocera) fauna at the surrounding vegetation of Rabindra Sarobar, Kolkata, West Bengal, India

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Key words: Anthropogenic activities, Diversity indices, Nymphalidae, Rabindra sarobar, Species richness

Abstract

Butterflies are considered indicator species for conservation planning and environmental monitoring as their diversity and abundance are visibly affected by anthropogenic activities. In this study, the diversity and abundance of butterfly fauna in the surrounding vegetation of Rabindra Sarobar, Kolkata, India was assessed to provide baseline information on the size of species richness and prospective utilization in urban planning and conservation. A total of 64 butterfly species under 5 families and 44 genera were recorded over a period of ten months from June 2023 to March 2024. Family Nymphalidae (36.85% of population) was found dominant with 17 genera and 26 species, followed by Lycaenidae (30.72%, 11genera, 12 species), Pieridae (22.77%, 9 genera, 12 species), Papilionidae (7.01%, 3 genera, 9 species) and Hesperiidae (2.65%, 4 genera, 5 species). Eleven species were found legally protected under different Schedules of the Wildlife Protection Act, 1972. Values of different diversity indices such as Shannon's index (H'=3.69), Pielou's evenness index (J'=0.89) and Simpson's index (Ds=0.03) showed a high diversity, evenly distribution and high abundance persisted in the butterfly community. Information from this preliminary study is expected to be useful toward the conservation of the habitat as well as the butterfly fauna in the study area and similar geographic areas.

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Introduction

Monitoring biological diversity is becoming an essential tool to estimate the alteration of the environmental quality at the local as well as regional scale. Studies on species diversity and abundance are the prior required element to quantify the environmental impact on biota and any prior species diversity investigations are a prerequisite to adopting habitat management strategies (Nichols and Williams, 2006). Appraisal of taxa-specific species richness capacitates a more realistic and accurate assessment of the ecosystem functions and services derived from the specified taxon (Diaz *et al.*, 2006). Diversity analysis of a single taxon or restricted number of taxa is worthwhile as their presence or absence and abundance records are useful for the population size estimation (Williams *et al.*, 2002; Koleff *et al.*, 2003; MacKenzie, 2005) whereas resource limitation impedes the selection of several taxa or the whole community (Mihindukulasooriya *et al.*, 2014). The diversity of a target taxon varies with the features of the landscapes, more precisely with the nature and quality of the habitat and climatic conditions (Boggs, 1986). Butterflies are one of the best-known insects for their variety, presence in all types of environments, the beauty of their wing colouration and patterns and also for their role as effective ecological indicators of terrestrial ecosystems (Venkataramana, 2010). Hence, butterflies are the potential taxa, chosen for the estimation of biodiversity essential for biological conservation and also for monitoring the environmental conditions (Simonson *et al.*, 2001). Any certain change in environmental quality is readily assessed by the change in their diversity, abundance or sometimes local extinction (Hogsden and Hutchinson, 2004). Moreover, butterflies provide several ecological services which are essential for the sustenance of environmental quality and integrity (Kumar, 2013).

Worldwide, over 19,000 butterfly species have been recorded (Kunte, 2000), of which from India, around 1500 species are documented, including 107 swallowtail butterflies (Papilionidae), 521 brush-footed butterflies (Nymphalidae), 109 white and yellow butterflies (Pieridae), 443 small blue butterflies (Lycaenidae) and 321 skippers (Hesperiidae) (Gaonkar, 1996; Kunte, 1997). Diversity and abundance of butterfly species decline day by day with the increase of urban elements like roads, buildings and other concrete constructions and with the expansion of residential, industrial and commercial areas, associated with the depletion of the quantity and quality of natural habitat, habitat degradation or disruption and fragmentation which adversely affects the natural biodiversity of that area (Clark *et al.*, 2007; Malagrino *et al.*, 2008). Urbanization, pollution, excessive usage of fumigant pesticides etc. provide a negative impact on butterfly populations (Pollard and Yates, 1993). Several earlier studies reported the impact of urban development on butterfly fauna, and their richness and abundance in Kolkata and its adjoining areas (Moore, 1882; Niceville, 1885; Ghosh and Siddique, 2005; Ghosh, 2009; Ghosh, 2010; Chowdhury and Chowdhury, 2007; Chowdhury and Das, 2007; Chowdhury and Soren, 2011; Basu Roy, 2011; Biswas *et al.*, 2012; Nair *et al.*, 2014; Biswas *et al.*, 2014; Mukherjee *et al.*, 2016; Maity *et al.*, 2016; Bhattacharya *et al.*, 2018; Mitra *et al.*, 2023). For continuous monitoring of the environmental condition of Kolkata, systematic surveys on butterfly fauna from different regions of Kolkata are essential.

Keeping this view in mind, the present study was undertaken to document the diversity and abundance of butterfly fauna in the surrounding vegetation of Rabindra Sarobar, Kolkata, West Bengal, India, to provide necessary information on the conservation management of habitat and butterflies for sustaining ecosystem services.

Materials and methods

Study area

The current study was carried out in the surrounding vegetation of Rabindra Sarobar (Fig. 1), an artificial lake of national importance as 2nd largest lake in Kolkata, is located in southern Kolkata, West Bengal, India, surrounded by Southern Avenue at the north, Russa Road at the west, Dhakuria at the east, and the Kolkata Sub-urban Railway track at the south.

Fig. 1. Map of West Bengal, India (left one: https://images.app.goo.gl/w7Yv8XNjUsQ1M1ZcA), satellite image of Kolkata and Rabindra Sarobar (right three)

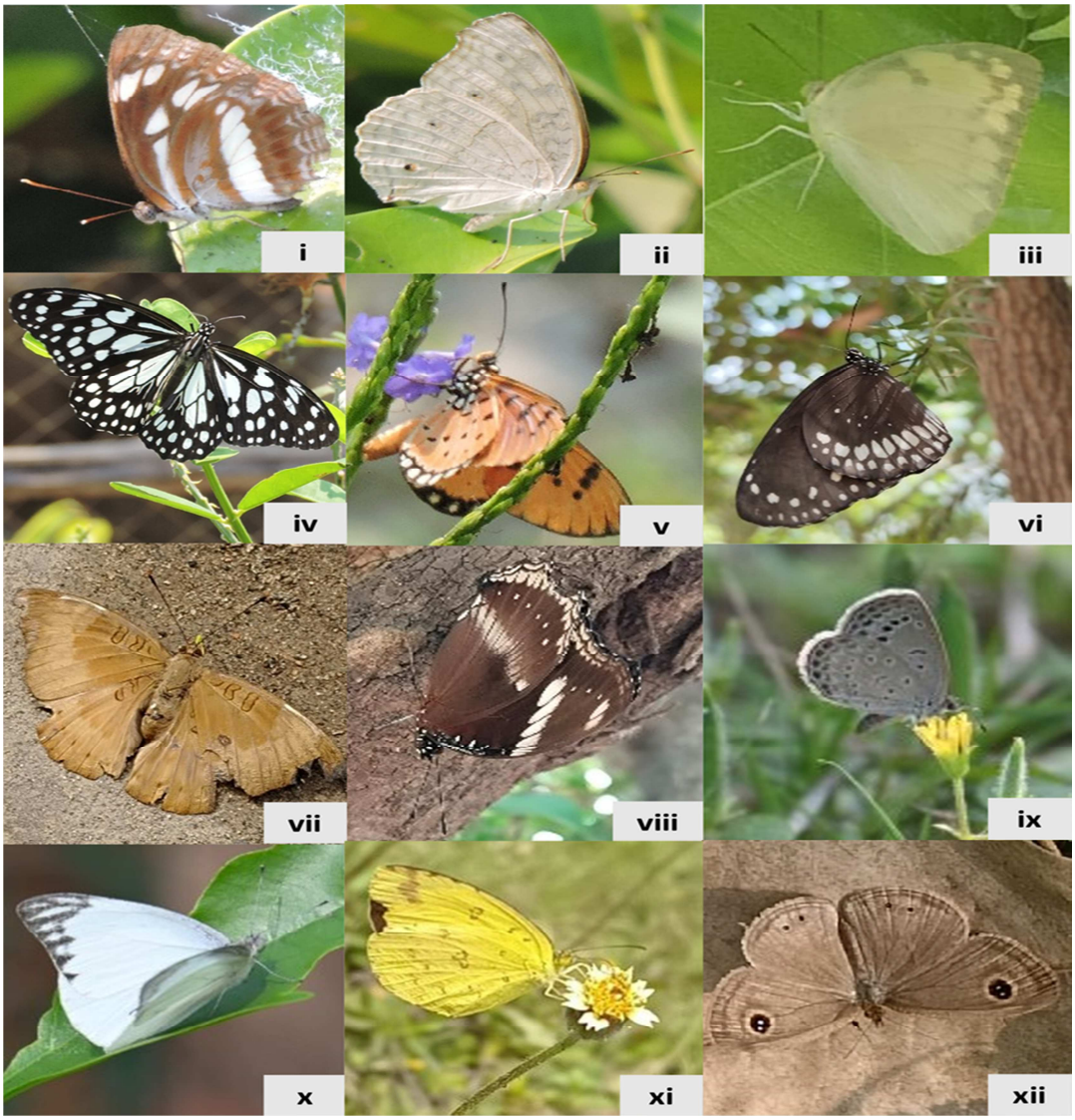

Fig. 2. Photographs of different butterfly species recorded in the study area
i. *Neptis jumbah*, ii. *Junonia atlites*, iii. *Catopsilia pomona*, iv. *Tirumala limniace*, v. *Acraea terpsicore*, vi. *Euploea core*, vii. *Euthalia aconthea*, viii. *Hypolimnas bolina*, ix. *Pseudozizeeria maha*, x. *Appias olferna*, xi. *Eurema hecabe*, xii. *Ypthima huebneri.*

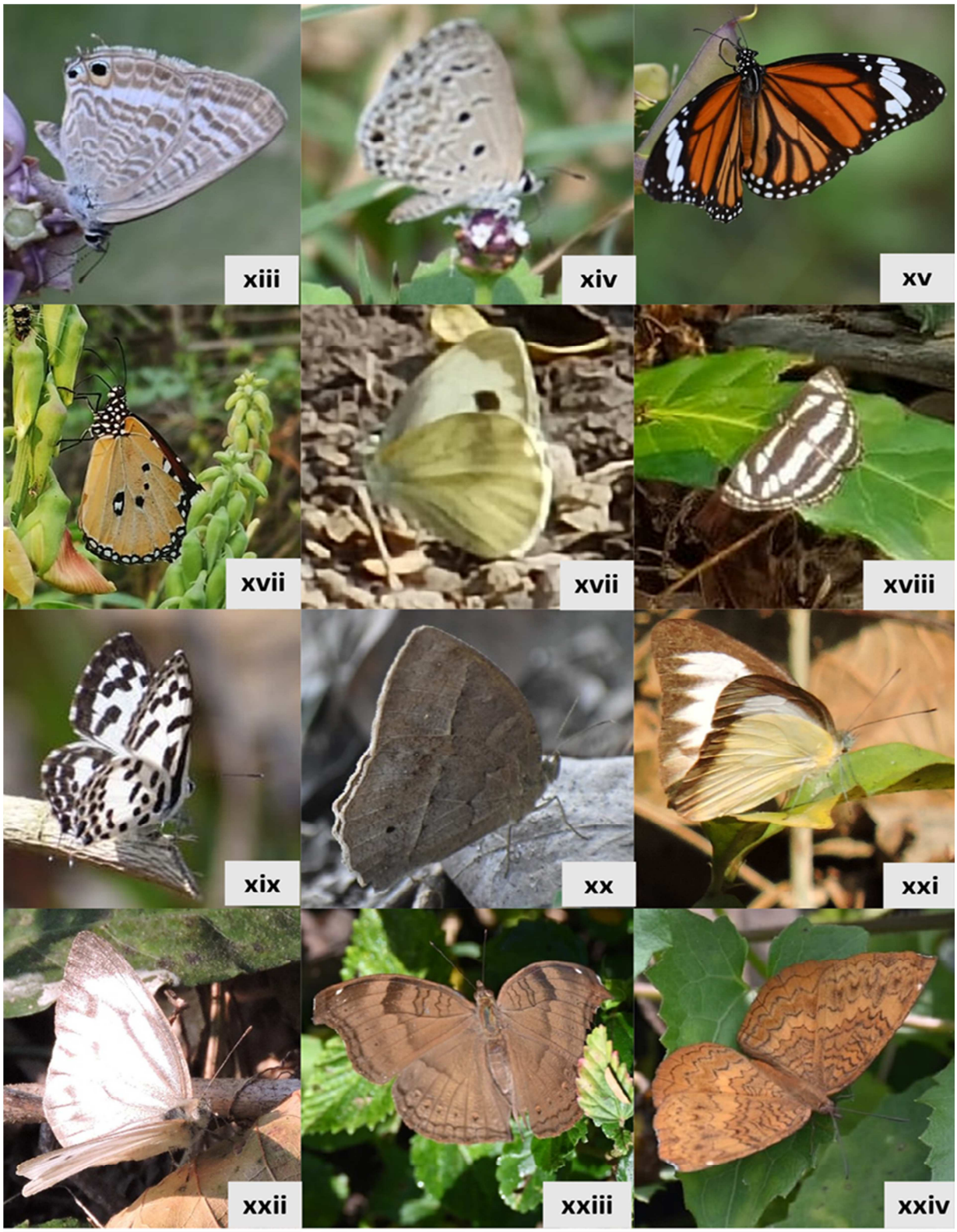

Fig. 3. Photographs of different butterfly species recorded in the study area
xiii. *Lampides boeticus*, xiv. *Chilades lajus*, xv. *Danaus genutia*, xvi. *Danaus chrysippus*, xvii. *Pieris rapae*, xviii. *Neptis hylas*, xix *Castalius rosimon*., xx. *Melanitis leda*, xxi. *Appias lyncida*, xxii. *Appias olferna*, xxiii. *Junonia iphita*, xiv. *Ariadne merione*.

Table 1. Checklist of butterfly species along with their family, relative abundance, status and WPA Schedule recoded in the study area.

SL.		Common name	Scientific name	Relative abundance(RA)	Status	WPA schedule
1	Papilionidae	Common Mormon	*Papilio polytes*	1.81	C	
2		Crimson Rose	*Pachliopta hector*	0.38	R	Schedule- I
3		Common Rose	*Pachliopta aristolochiae*	0.98	NR	
4		Common Bluebottle	*Graphium sarpedon*	0.56	NR	
5		Common Jay	*Graphium doson*	0.31	R	
6		Tailed Jay	*Graphium agamemnon*	1.78	C	
7		Common Mime	*Papilio clytia*	0.35	R	Schedule- I
8		Red Helen	*Papilio helenus*	0.17	R	
9		Lime Butterfly	*Papilio demoleus*	0.66	NR	
10	Nymphalidae	Common Palmfly	*Elymnias hypermnestra*	4.74	VC	
11		Common Crow	*Euploea core*	1.81	C	Schedule- IV
12		Common Castor	*Ariadne merione*	2.41	C	
13		Plain Tiger	*Danaus chrysippus*	3.91	VC	
14		Blue Tiger	*Tirumala limniace*	3.56	VC	
15		Common Sailor	*Neptis hylas*	4.18	VC	
16		Yellow Coster	*Acraea issoria*	0.17	R	
17		Tawny Coster	*Acraea terpsicore*	1.78	C	
18		Glassy Tiger	*Parantica aglea*	0.24	R	
19		Common Sergeant	*Athyma perius*	0.45	R	
20		Great Eggfly	*Hypolimnas bolina*	0.31	R	
21		Common Baron	*Euthalia aconthea*	0.59	NR	Schedule- II
22		Chestnut-Streaked Sailor	*Neptis jumbah*	0.28	R	
23		Commander	*Moduza procris*	0.66	NR	
24		Dark Blue Tiger	*Tirumala septentrionis*	0.03	VR	
25		Grey Pansy	*Junonia atlites*	0.07	VR	
26		Chocolate Pansy	*Junonia iphita*	0.35	R	
27		Chestnut Tiger	*Parantica sita*	0.17	R	
28		Angled Castor	*Ariadne ariadne*	1.08	NR	
29		Common Evening Brown	*Melanitis leda*	0.66	NR	
30		Common Five-ring	*Ypthima baldus*	4.01	VC	
31		Short Banded Sailor	*Neptis columella*	0.49	R	
32		Common Four-ring	*Ypthima huebneri*	1.32	NR	
33		Striped Tiger	*Danaus genutia*	1.88	C	Schedule- 1
34		Common Bushbrown	*Mycalesis perseus*	0.91	NR	
35		Common Gull	*Cepora nerissa*	0.77	NR	Schedule- II
36	Pieridae	Common Grass Yellow	*Eurema hecabe*	3.73	VC	
37		Chocolate Albatross	*Appias lyncida*	0.49	R	Schedule- II
38		Tree Yellow	*Gandaca harina*	2.27	C	
39		Psyche	*Leptosia nina*	4.95	VC	
40		Cabbage White	*Pieris rapae*	0.59	NR	
41		Lemon Emigrant	*Catopsilia pomona*	3.17	C	
42		Common Wanderer	*Pareronia valeria*	0.24	R	
43		Mottled Emigrant	*Catopsilia pyranthe*	3.94	VC	
44		Common Albatross	*Appias albina*	0.84	NR	Schedule- II
45		Striped Albatross	*Appias olferna*	1.78	C	Schedule- IV
46		Common Jazebel	*Delias eucharis*	0.70	NR	
47		Clouded Yellow	*Colias croceus*	0.07	VR	
48	Lycaenidae	Common Pierrot	*Castalius rosimon*	0.63	NR	Schedule- I
49		Forget-me-not	*Catochrysops strabo*	5.40	VC	
50		Pale Grass Blue	*Pseudozizeeria maha*	4.99	VC	
51		Plains Cupid	*Catochrysops vapanda*	3.56	VC	
52		Ceraunus Blue	*Hemiargus ceraunus*	3.97	VC	
53		Pea Blue	*Lampides boeticus*	2.34	C	Schedule- II
54		Slate Flash	*Rapala manea*	0.38	R	
55		Lime Blue	*Chilades lajus*	0.87	NR	
56		Tiny Grass Blue	*Zizula hylax*	5.06	VC	
57		Zebra Blue	*Leptotes plinius*	0.38	R	

58		Dark Grass Blue	*Zizeeria karsandra*	3.10	C
59		Striped Pierrot	*Tarucus nara*	0.03	VR
60	Hesperiidae	Indian Palm Bob	*Suastus gremius*	0.42	R
61		Common Banded Awl	*Hasora chromus*	0.73	NR
62		Small Banded Swift	*Pelopidas mathias*	0.91	NR
63		Indian Skipper	*Spialia galba*	0.35	R
64		Large Banded Swift	*Pelopidas subochracea*	0.24	R

VC (very common= more than 100 sightings), C (common=51-100), NR (not rare=16-50), R (rare=3-15), VR (very rare= 1-2) to indicate the rarest to the most common butterfly species (Tiple *et al.*, 2006) WPA- Species enlisted in Indian Wildlife Protection Act, 1972

It is situated between 22˚30'30" N to 22˚30'42" N latitude and 88˚21'E to 88˚22'E longitudes. It spread over an area of 78.07 ha with 48.53 ha of surrounding land area which has sports ground, parks, motorable roads, paved footpaths, open spaces with man-made grasslands, different species of trees, shrubs, herbs and flowering plants, it is a heaven for floral diversity.

The area has a humid tropical climate having three seasons, summer, monsoon and winter. During summer season, the area experiences a maximum temperature of 42˚C with an average of 36˚C and during summer season, the lowest temperature is around 10˚C with an average of 13˚C. Annual rainfall is about 1836.5 mm.

Survey techniques

The present study observations were performed from June 2023 to March 2024. A regular survey was conducted through random visits between 8:00 hrs and 11:30 hrs, and between 15:00 hrs to 17:30 hrs during periods of good weather (no heavy rain or strong winds). During each sampling occasion, butterflies were recorded with their number from the randomized quadrates of 10m×10m on either side of the laid transect (Kumari *et al.*, 2023). Data collection was accomplished by the visual counter method through simple observation, observation through binoculars and captured photography (Fig. 2 and 3).

Most of them were identified through direct observation during surveys or in difficult cases photographs were taken and identified according to field guidebooks and standard published literature (Kunte *et al.*, 2014; Kehimkar, 2016; Dey *et al.*, 2017).

No butterflies were collected or captured during the sampling.

Based on the sightings of the recorded butterflies in the study area (Table 1), they were ranked as VC (very common= more than 100 sightings), C (common=51 to 100), NR (not rare=16 to 50), R (rare=3 to15), VR (very rare= 1 to 2) to indicate the most common to the rarest butterfly species (Tiple *et al.*, 2006).

Statistical data analysis

The richness, diversity, dominance and abundance of the recorded butterfly species were determined through the Shanon index (Shannon and Weaver, 1963), Dominance index (Berger and Parker, 1970), Simpson's diversity index and Simpson's index (Simpson, 1964). Species evenness was determined by Pielou's evenness index (Mulder *et al.*, 2004). A rank abundance curve was prepared to explain species richness as well as species evenness (Whittaker, 1965).

Shannon diversity index (H') = - Σ pi ln pi

Shannon H_{max}= Log_1 (N)

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

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

Simpson's diversity index (D)= 1-$\Sigma^{S}_{i=1}$[ni (ni-1)/N(N-1)]

Simpson's reciprocal index (Dr)= 1/ Σ^{S}_{i} pi^2

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

Berger-Parker dominance index (D_{BP})= ni max/N

Margalef's index (Dmg)= (S-1)/ln(N)

Here, pi is the proportion of the i^{th} species in the community. N is the number of species present in a community. S is the number of genera in a community. ni is the number of individuals of i^{th} species.

All the diversity indices were analyzed and calculated with the help of Microsoft Excel 2019 software.

Results

Geographical location and satellite view of the present study site are shown in Fig. 1. The checklist of the observed butterfly species is given in Table 1 along with their common and scientific names, relative abundance and WPA schedule (species enlisted in the Indian Wildlife Protection Act, 1972). The present study has recorded a total of 64 species of butterflies belonging to five families and 44 genera from the study site during the course of sampling surveys. The results showed that Nymphalidae was the most abundant family as the maximum number of butterflies were recorded under this family with 36.85% of the total population, followed by Lycaenidae (30.72%), Peridae (22.77%), Papilionidae (7.01%) and the least abundant family Hesperiidae (2.65%) (Fig. 4).

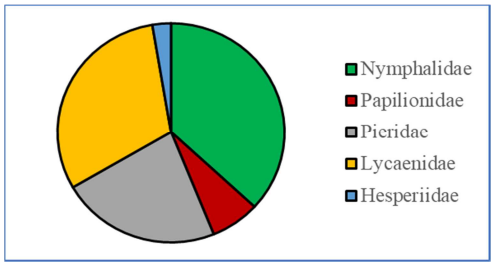

Fig. 4. Percentage composition of five families of butterflies in the study area

When the genus-wise diversity was taken under consideration, it was observed that the family Nymphalidae had the highest number of genera (38.64%), followed by Lycaenidae (25%), Pieridae (20.45%), Hesperiidae (9.09%) and then Papilionidae (6.82%) (Fig. 5). When species-wise distribution of butterflies was considered, the family Nymphalidae had the highest number of species (40.63%). Both the family Lycaenidae and Pieridae were found to have 12 species (18.75% of the total recorded species) and the least number of species was observed under the family Hesperiidae (7.81%) (Fig. 5).

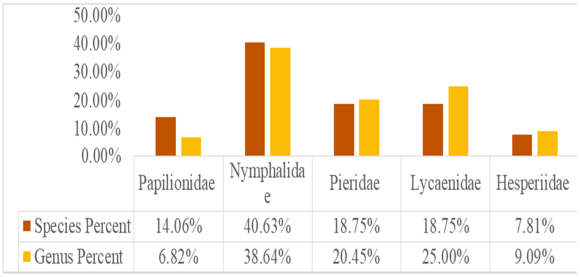

Fig. 5. Percentage composition of five families of butterflies in the study area

The most abundant species sampled in the study site was the Forget-me-not (*Catochrysops strabo*) with 155 sightings, followed by Tiny Grass Blue (*Zizula hylax*) with 145 sightings, Pale Grass Blue (*Pseudozizeeria maha*) with 143 sightings, Psyche (*Leptosia nina*) with 142 sights, Common Palmfly (*Elymnias hypermnestra*) with 136 sights, Common Sailor (*Neptis hylas*) with 120 sights, Ceraunus Blue (*Hemiargus ceraunus*) with 114 sights, Mottled Emigrant (*Catopsilia pyranthe*) with 113 sights and Plain Tiger (*Danaus chrysippus*) with 112 sights.

Under the family Nymphalidae, Common Palmfly (*E. hypermnestra*) was the most counted species followed by Common Sailor (*N. hylas*), Plain Tiger (*D. chrysippus*), Blue Tiger (*Tirumala limniace*), and the least counted species was Dark Blue Tiger (*Tirumala septentrionis*). Under the Lycaenidae family, the most abundant species was Forget-me-not (*C. strabo*), followed by Tiny Grass Blue (*Z. hylax*), Pale Grass Blue (*P. maha*), Ceraunus Blue (*H. ceraunus*), Plains Cupid (*Catochrysops vapanda*), and Striped Pierrot (*Tarucus nara*) was the rarest butterfly species. When considering the family Papilionidae, it was found that Common Mormon (*Papilio polytes*) and Tailed Jay (*Graphium agamemnon*) were well encountered compared to other species, followed by Common Rose (*Pachliopta aristolochiae*) and Red Helen (*Papilio helenus*) was the least counted species. Under Pieridae family Psyche (*Leptosia nina*) was the more abundant, followed by Mottled Emigrant (*C. pyranthe*), Common Grass Yellow (*Eurema hecabe* and Lemon Emigrant (*Catopsilia pomona*), and Clouded Yellow

(*Colias croceus*) was the lowest numbered species, while under the family Hesperiidae, Small Banded Swift (*Pelopidas mathias*) and Large Banded Swift (*Pelopidas subochracea*) was counted in maximum and minimum number respectively.

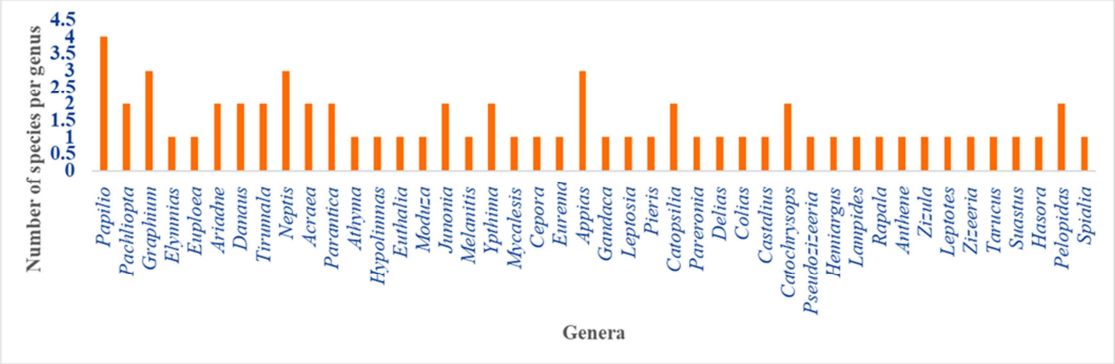

Fig. 6. Species richness of the recorded butterfly genera of the study site

In the butterfly community of the study site, the genus *Papilio* of the family Papilionidae, was noted to comprise a maximum number of species (Fig. 6) i.e. with four species namely *Papilio polytes*, *Papilio clytia*, *Papilio helenus* and *Papilio demoleus*. While three species were found from the genus *Graphium* of Papilionidae (*Graphium sarpedon*, *Graphium doson* and *Graphium agamemnon*), genus *Neptis* of Nymphalidae (*Neptis hylas*, *Neptis jumbah* and *Neptis columella*), genus *Appias* of Pieridae (*Appias lyncida*, *Appias albina*, *Appias olferna*). Two species per genus were observed from 11 genera namely genus *Pachliopta* from the family Papilionidae, genus *Ariadne*, *Danaus*, *Tirumala*, *Acraea*, *Parantica*, *Junonia* and *Ypthima* from the family Nymphalidae, genus *Catopsilia* from the family Pieridae, genus *Catochrysops* from the family Lycaenidae and genus *Pelopidas* from the family Hesperiidae. Whereas, 29 genera were recorded to have single species in each genus. Species to genus ratio (S/G= 1.45) was found very low in the butterfly population of the study area. Most of the recorded butterfly species from the study area were 'common' and 'generalist' species (Sarma et al., 2012) and no species was found as globally threatened according to the IUCN Red List (Ver 3.1), though only eleven species were found as legally protected under different Schedules of the Wildlife Protection Act, 1972. Among them, Crimson Rose (*Pachliopta hector*), Common Mime (*Papilio clytia*), Striped Tiger (*D. genutia*) and Common Pierrot (*Castalius rosimon*) are protected under Schedule I, while Common Baron (*Euthalia aconthea*), Common Gull (*Cepora nerissa*), Chocolate Albatross (*Appias lyncida*), Common Albatross (*Appias albina*) and Pea Blue (*Lampides boeticus*) under Schedule II, and Common Crow (*Euploea core*) and Striped Albatross (*Appias olferna*) under Schedule IV. Depending on the occurrence of the recorded butterfly species (Fig. 7) in the sampled area during the study period, butterflies were grouped into five broad classes namely very common (VC), common (C), not rare (NR), rare (R) and very rare (VR). The study found 55% of butterflies of the population were seen under the VC category, 24.13% were under the C category, 13.46% were under the NR category, 6.21% under the R category and 0.21% were under the VR category. Of the total recorded 64 species of butterfly, 13 species were found under the VC category, 11 species under the C category, 17 species under the NR category, 19 species under the R category and 4 species under the VR category.

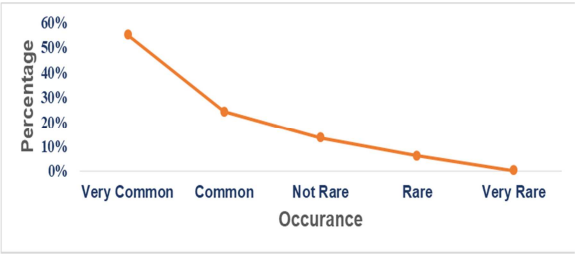

Fig. 7. Occurrence of different butterfly species in the study area

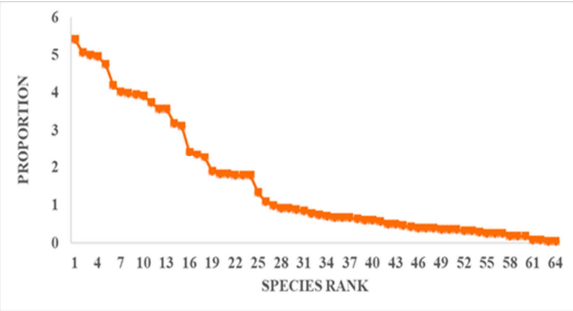

Fig. 8. Rank abundance curve of 64 species of butterfly in the study area

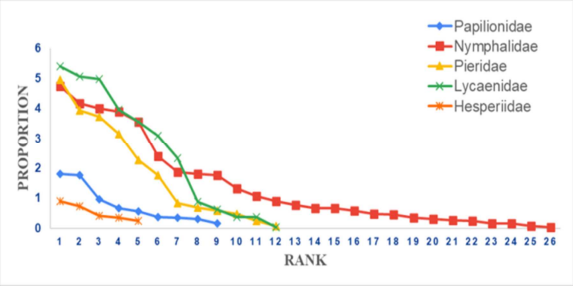

Fig. 9. Rank abundance curve of five families of butterfly in the study area

The species diversity and evenness of butterfly fauna in the study area were expressed by the values of Shannon diversity index (H'), Simpson's index (Ds), Simpson's diversity index (D) and Pielou's evenness index (j') (Table 2). The Shannon's diversity index value of 3.69 indicated high species richness and diversity existed in the butterfly community of the study area which revealed that the butterfly population was in the direction of an ideal natural community. The value of Simpson's index (Ds=0.03) was more inclined toward 0 which depicted a high species abundance in the studied butterfly community. Whereas the Simpson's diversity index (D) value of 0.97 indicated the studied butterfly community was a diverse one. The Margalef Richness index (Dmg) value of 7.92 indicates high species richness. The Pielou's evenness index (J') value was 0.89 in the present study and it revealed high evenness found in the occurrence of recorded butterflies in their population as the value was inclined toward the 'o'. The results of the studied diversity indices expressed that the butterfly community of the sample site was highly diverse with high abundance and high evenness.

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 diversity index (D)
3.69	0.89	0.03	0.97

Table 3 shows family-wise results of studied diversity indices, such as Shannon diversity index (H'), Shannon H_{max}, Pielou's evenness index (j'), dominance index (D_{BP}), Simpson's index (Ds), Simpson's diversity index (D) and Simpson's reciprocal index (Dr). The value of H' of the recorded five families ranged from 1.64 to 2.78. The lowest value was obtained from the family Hesperiidae as in the studied butterfly community, only five species were recorded under this family, whereas the highest was from the Nymphalidae family as the maximum number of species were recorded under this family, followed by Lycaenidae (2.14), Pieridae (2.11) and then Papilionidae (1.94). The values of the Shannon diversity index (H') depicted that the family Nymphalidae was the most diverse family among all the five families. In the present study, Pielou's evenness index (J') was higher in the family Hesperiidae (0.99), followed by Papilionidae (0.88), Lycaenidae (0.86) and then in both the families Nymphalidae and Pieridae (0.85).

Obtained results of Simpson's reciprocal index (Dr) of the five recorded families depicted that the higher diversity was found in the family Nymphalidae (Dr=12.79) followed by Lycaenidae (Dr=7.57), Pieridae (Dr= 6.99) and then in Papilionidae (Dr=5.74), while the family Hesperiidae was the less diverse family (Dr= 2.47). The result of the Berger-Parker index indicated that the dominant family was Nymphalidae (D_{BP}= 0.37) and the dominant species was the Common Palmfly, *E. hypermnestra* (D_{BP}= 0.05) in the study area. When family-wise dominance was considered, Common Palmfly (D_{BP}= 0.13) within the family Nymphalidae, Forget-me-not (D_{BP}= 0.18) of the family Lycaenidae, Common Mormon (D_{BP}= 0.26) under the family Papilionidae, Psyche (D_{BP}= 0.22) under the family Pieridae and Small Banded Swift (D_{BP}= 0.44) under the family Hesperiidae were found to be the dominant species.

Table 3. Values of different biodiversity indices of five butterfly families of the study area

Family	Shannon diversity index (H')	Shannon H_{max}	Pielou's evenness index (j)	Simpson's index (Ds)	Simpson's diversity index (D)	Simpson's reciprocal index (Dr)
Nymphalidae	2.78	3.02	0.85	0.08	0.92	12.79
Lycaenidae	2.14	2.94	0.86	0.13	0.87	7.57
Papilionidae	1.94	2.30	0.88	0.17	0.83	5.74
Pieridae	2.11	2.81	0.85	0.14	0.86	6.99
Hesperiidae	1.64	1.77	0.99	0.38	0.61	2.47

Fig. 8 and 9 showed the Whittaker plot i.e. species-wise rank abundance curve which describes the species diversity and the family-wise rank abundance curve which illustrates the family diversity respectively. The rank abundance curve of the recorded butterflies showed a steep inclination at first in the Whittaker plot which indicates that some species in the studied community occurred in high abundance compared to other remaining species which occurred in low abundance. When considering the family-wise rank abundance curve, more evenness was observed in the case of the family Nymphalidae, moderate evenness in Hesperiidae and Papilionidae, while the family Pieridae and Lycaenidae showed relatively less evenness.

Discussion

Butterflies, the charismatic species provide multiple ecosystem services for human well-being (Kurtz *et al.*, 2001; Nelson, 2007, Guiney and Oberhauser, 2008). For the maintenance of ecosystem structure and function, butterflies perform an eminent role as pollinators, herbivores and prey of several predators (Bonebrake *et al.*, 2010). Globally, butterflies are well-studied taxa (Ghazoul, 2002) and their utility as an indicator of environmental conditions, habitat quality and anthropogenic disturbance is the basis of studying butterfly diversity at a spatio-temporal scale (Kocher and Williams, 2000; Stefanescu *et al.*, 2004). These hexapods are extremely sensitive to changes in microclimate (Fordyce and Nice, 2003). Larval stages of most butterfly species are very host-specific and inhabited in a narrow niche and thus depending on the network of preferred habitats their metapopulations are formed (Thomas *et al.*, 2001; Anthes *et al.*, 2003). A small change in habitat, might be insignificant, though cause the migration or local extinction of native butterfly populations (Kunte, 1997; Blair, 1999; Mennechez *et al.*, 2003). Hence, local extinction or any changes in the butterfly community commence the 'butterfly effect' which ultimately affects the entire ecosystem (Altermatt and Pearse, 2011). Thereby, alterations in the land use pattern shape landscape profile in the course of ecological succession are portrayed conspicuously by the changes in the diversity, abundance and distribution of butterfly fauna (Mukherjee *et al.*, 2015).

Anthropogenic disturbances such as urbanization, industrialization, and use of excessive pesticides and pollution, all these are associated with habitat loss or fragmentation, habitat degradation and deterioration of habitat quality leading to a reduction of resource quality that causes adverse influence on the butterfly fauna or sometimes local extinction (McKinney, 2002; Fahrig, 2003; Clark *et al.*, 2007; Henry *et al.*, 2012). Therefore, recent ecological studies give importance to the systematic survey reports of the indicator taxa (Blair, 1999; Hogsden and Hutchinson, 2004). Ecologists considered the butterfly as an Umbrella species for conservation planning and management (Betrus *et al.*, 2005). Butterfly diversity reports are one of the most acceptable tools for biodiversity studies and pollution, habitat and conservation management (Hortal *et al.*, 2015). Hence, systematic surveys on butterfly diversity and abundance in a region typically of an urban area supposed to be useful for continuous monitoring of the environmental quality of the concerned area. In this regard, the butterfly might be a role model group from the conservation perspective (Watt and Boggs, 2003; Ehrlich and Hanski, 2004).

The current study carried out in the surrounding vegetation of Rabindra Sarobar, Kolkata, India, has attempted to analyze the anthropogenic impact on the butterfly community of that area.

Earlier studies on the butterfly fauna from the urban areas of India recorded the butterfly diversity which is comparable to the present study (Sarma *et al.*, 2012; Arya *et al.*, 2014; Kumar, 2014). A total number of 64 species belonging to five families were recorded from the study site. Previous studies carried out in Kolkata, reported 33 butterfly species from the Mudialy Ecological Park (Chowdhury and Chowdhury, 2007), 74 species from the East Kolkata Wetland (Chowdhury and Soren, 2011), 96 species from urban Kolkata (Mukherjee *et al.*, 2015), 54 species from Kolkata metropolis also (Mukherjee *et al.*, 2016). 57 species from the campus of Ramakrishna Mission Vivekananda Centenary College, Rahatra (Bhattacharya *et al.*, 2018), 33 butterfly species from the Lake Town area (Chowdhury, 2022) and 21 species from Rammohan College Campus (Mitra *et al.*, 2023). The variation in species diversity might be due to the nature of the habitat within the sampling area or its size (Nair *et al.*, 2014) and also due to the type of vegetation found. If the sampled area was dominated by the nectar plants and host plants of butterflies, high diversity and abundance are observed.

In the study area, all the recorded butterflies belonged to five families which is found consistent with the earlier studies conducted in a few other areas of Kolkata bearing similar habitats (Mukherjee *et al.*, 2015; Mukherjee *et al.*, 2016; Bhattacharya *et al.*, 2018; Chowdhury, 2022). Although, variation in the recorded total number of families of butterflies was noted, from East Calcutta wetland and Rammohan College campus (Chowdhury and Soren, 2011; Mitra *et al.*, 2023). This variation is primarily due to habitat conditions and the availability of the food plants in the study area (Kunte, 2000).

Occurrence and butterfly richness were reported relatively less in the Rammohan College campus (21 butterfly species belonging to 4 families) and the mentioned possible causes were anthropogenic disturbances mainly the pollution, usage of insecticide, disturbed vegetation, and shortage of potential habitat with insufficiency of flowering and host plants, those provide a negative impact on their population (Mitra *et al.*, 2023).

Nymphalidae dominated among the five recorded butterfly families with 17 species and 36.85% of the total population. This finding is at par with the observations of earlier studies elsewhere in Kolkata (Chowdhury and Soren, 2011; Mukherjee *et al.*, 2016; Bhattacharya *et al.*, 2018). On the contrary, Mukherjee *et al.* (2016), Chowdhury (2022) and Mitra *et al.* (2023) stated that in Kolkata city Lycaenidae was the predominant family, followed by Nymphalidae and Pieridae respectively. Butterflies under the Nymphalidae family, are polyphagous in nature and are active fliers, thereby they are found in several types of habitats (Majunder *et al.*, 2013). Compared to other butterfly families, Nymphalidae is the best-adapted and predominant family and dominates throughout the country. Butterflies under the Papilionidae and Hesperiidae family were the less frequent, due to their low ecological tolerance, selection for relatively less disturbed habitat and most of them are host plant-specific (Majunder *et al.*, 2013).

Accountable elements such as variation in habitats, vegetation types (Ockinger and Smith, 2006; Ockinger *et al.*, 2006; 2009), occurrence of species-specific host plants, availability and abundance of larval host plants and nectar plants (Gutierrez and Mendez, 1995; Ockinger *et al.*, 2009; Nimbalkar *et al.*, 2011), climatic conditions (Bhusal and Khanal, 2008), sampling areas (Chowdhury and Soren, 2011), sample sizes (Nair *et al.*, 2014) and impact of human interferences, provide solo or combined effect on butterfly fauna of an area and is the reason for the observed differences in species and genus of butterflies encountered, and also in the abundance of butterfly species recorded in Kolkata, India. Consistent with this view, in this study, diverse vegetation with adequate available space for plant

growth, open grasslands and gardens with flowering plants support butterfly diversity and abundance of the sample site which is a patch of greenery within the heavily populated and utmost urbanized city, Kolkata. The present findings on butterfly diversity and abundance reflect the study area is a healthy ecosystem patch within the busiest location of the city.

Conclusion

Though the present survey-based study on butterfly fauna at Rabindra Sarobar, is only a preliminary observation of the butterfly species diversity and abundance of the south Kolkata region, Kolkata, West Bengal, it has significance as data recorded in this study might be helpful to establish precious information as a reference. On ecological aspects, there is a need for long-term observation through systematic surveys on the species richness and abundance of butterfly fauna in the study area because the recorded butterfly family and species list of the present study is not final and exhaustive. Future studies on butterfly diversity and community structure should be undertaken to set up to date the butterfly checklist of the study area. These reports are required to estimate the anthropogenic impact on the study area as butterflies are sensitive to minor changes in environmental conditions. These periodically conducted survey reports could be used as a tool for assessing the ecosystem health, stability and functioning of this concerned locality and will facilitate conservation measures. Moreover, further studies on butterfly fauna covering more study areas may promote awareness among local people and government authorities to adopt and implement conservation policies for wildlife and their habitat.

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