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An insight into the abundance and diversity of butterfly (Insecta: Lepidoptera) fauna in surrounding vegetation of Subhas Sarobar, Kolkata, India

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Key words: Diversity indices, Nymphalidae, Species richness, Subhas Sarobar, Urbanization

Abstract

Butterflies are the indicator species as their diversity and abundance represent the health of a habitat and act as a tool for monitoring the impact of urbanization in an area. The aim of the present research paper is to estimate the diversity and abundance of butterfly fauna in the surrounding vegetation of Subhas Sarobar, Kolkata, India. The present study recorded 74 butterfly species of 5 families and 56 genera, which were sampled over a period of nine months from June 2023 to February 2024. Out of 74 species, 16 species belong to family Nymphalidae, 17 species to Lycaenidae, 3 species to Papilionidae, 10 species to Pieridae and 10 species to Hesperiidae correspondingly. Lycaenidae was the most prevailing family owing to their species richness. Nymphalidae family dominated the recorded species (45.14%) over Pieridae (25.72%), Lycaenidae (14.41%), Papilionidae (10.25%), and Hesperiidae (4.48%). Based on the sightings of the butterfly species, 78.66% were very common category, 15.90% under common category, 4.16% under fairly common category and 1.28% under uncommon category. Ten species of the recorded butterflies are legally protected under different Schedules as per the Indian Wildlife Protection Act, 1972. Values of different diversity indices such as Shannon's index (H'=3.79), 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. This study is expected to contribute necessary information toward the conservation of the habitat as well as the butterfly fauna in the surrounding vegetation of Subhas Sarobar, Kolkata and similar geographic areas.

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Introduction

Among the many different insects, butterflies are not only the most enchanting Lepidoptera, but also a taxonomically and ecologically well-studied group throughout the world (Ghazoul, 2002; Thomas, 2005). On a global scale, more than 19,000 butterfly species have been documented to date (Larsen *et al.*, 2011), of which around 1500 species are recorded from India (Kunte, 1997), depicting that butterfly is one of the species rich and diversified fauna in the world. Wide distribution and dispersal ability of butterflies is associated with their evolutionary advantages that making them morphologically and physiologically fit to adapt in different natural conditions (Mallick, 2023). For terrestrial ecosystems, butterflies are considered as indicator taxa as provide the information about the health of the ecosystem (Thomas, 2005; Bonebrake *et al.*, 2010), habitat quality and anthropogenic disturbances (Kocher and Williams, 2000; Koh 2007). As butterflies and their caterpillars are host plants specific, their diversity portraits the complete picture of the overall plant diversity, especially the shrubs and herbs diversity in a given area (Padhye *et al.*, 2006). Hence, butterfly diversity of an area is positively related with the plant diversity of that area (Leps and Spitzer, 1990). Butterflies, being exothermic, are highly sensitive to change in microclimate, environment, and season (Koh, 2007). For all these reasons, butterflies are the crucial component of ecosystems (Scott and Lemieux, 2005), particularly of the terrestrial community structure (Pahari *et al.*, 2018) and their loss in diversity or extinction make adverse effects on ecosystem functioning (Altermatt and Pearse, 2011) as they are coupled with various ecosystem services which are critical for sustenance of the environmental quality and integrity (Kumar, 2013). They play an important role for the stability in food web as herbivores (Rusman *et al.*, 2016), pollinators (Atmowidi *et al.*, 2007; Mukherjee *et al.*, 2015), host of parasitoids (van Nouhuys and Hanski, 2002) and prey of predators (Rusman *et al.*, 2016).

Over the last few decades, various anthropogenic interferences like farmland intensification, intensive logging, urbanization and industrialization cause alteration, fragmentation or degradation of habitat, and sudden climatic changes have led to modification of the habitat structure and function, and thereby change in vegetation type and structure which in turn showed negative impact on the butterfly diversity as butterflies sense quickly to these changes (Clark *et al.*, 2007; Mora *et al.*, 2011). Monitoring the diversity of butterfly is now becoming an essential tool to estimate the effects of the expansion of residential, industrial and commercial area and also a useful tool for making decisions and adopting strategies related to biodiversity conservation as well as the conservation of butterflies (Saikia *et al.*, 2009; Mukherjee *et al.*, 2015).

Several previous study reports stated that there sustains an inversely proportional relationship between the species richness, diversity and abundance of butterfly, and anthropogenic development like urbanization and industrialization through construction of roads, buildings and lawns (Clark *et al.*, 2007; Pocewicz *et al.*, 2009). So, the natural diversity and abundance of butterfly steadily decline as a consequence of the continued deterioration of the quantity and quality of natural habitat by human mismanagement and pollution (Malagrino *et al.*, 2008). Concrete constructions consistently substitute the natural and semi-natural habitats, which have a negative impact on natural biodiversity as well as on the diversity of butterfly population. Additionally, pollutions provide a negative impact on the quality of vestigial habitats and aggravated the biodiversity loss (Mitra *et al.*, 2023). Moreover, extensive usage of mosquito-repellent fumigants, might have considerable role in the decrease of the abundance of butterflies.

Several studies by various investigators have been conducted to unfold the impact of urbanization on butterfly fauna in different parts of India (Tiple, 2011; Kunte *et al.*, 2012; Majunder *et al.*, 2012; Tiple, 2012; Harsh, 2014; Dey *et al.*, 2017; Janwe *et al.*, 2022). Butterfly diversity and abundance have been documented from different urban areas of West Bengal, particularly from Kolkata and its adjacent

areas (Basu, 2011; Chowdhury and Soren, 2011; Biswas *et al.,* 2014; Nair *et al.*, 2014; Mukherjee *et al.*, 2015; Mukherjee *et al.*, 2016; Maity *et al.*, 2016; Bhattacharya *et al.*, 2018; Mitra *et al.*, 2023).

The present study was conducted in the surrounding vegetation of Subhas Sarobar, locally called Beliaghata Lake. It is one of the significant recreational areas of Kolkata. The total area including the lake and surrounding vegetation is 39.60 ha of which the water body is about 16.29 ha. It is considered as the lung of East Calcutta. The park area is covered by open grassland with various species of flora especially herbs, shrubs and trees and different variety of flowering plants. The lake is home of different species of fishes and water birds. The park also houses various species of birds and during winter migratory birds are spotted. This area is witnessing fast-urbanization due to rapid anthropogenic development of eastern Kolkata.

For the need of systematic study on the diversity of butterfly fauna, the present investigation was undertaken to explore the status of butterfly fauna in the surrounding vegetation of Subhas Sarobar, Kolkata, West Bengal, India and to determine if industrialization and urbanization have any adverse impact on the abundance and diversity of butterfly in Kolkata.

Materials and methods

Study area

The current study was carried out in the surrounding vegetation of Subhas Sarobar (Fig. 1) is located in eastern Kolkata, West Bengal, India, just beside the Eastern Metropolitan Bypass, one of the busiest roads of Kolkata. It is situated at 22˚34'N latitude and 88˚24'E longitudes. It covers an area of 39.60 ha with 23.31 ha of surround land area which has open made-made grasslands, different species of trees, shrubs, herbs and flowering plants.

Three seasons, summer, monsoon and winter were found in the study area. During summer season, the area experiences maximum 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.

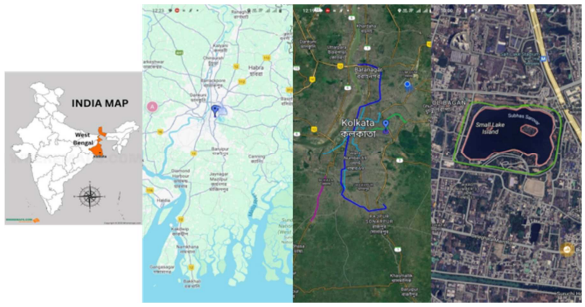

Fig. 1. Map of India (left one: https://images.app.goo.gl/w7Yv8XNjUsQ1M1ZcA), satellite image of Subhas Sarobar (right three: https://maps.app.goo.gl/bia7G92JKnnf5CjA6).

Survey techniques

The present study observations were made from June 2023 to February 2024. A regular survey was carried out through random visit between 8:00 hrs and 11:00 hrs during period 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 done by visual counter method through simple observation, observation through binocular and captured photography.

Most of them were identified through direct observation during surveys or in difficult cases photographs were taken and identified according to field guide books and standard published literatures (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, Fig. 2), they were ranked as UC (uncommon=1 individual recorded; minimum abundance), FC (fairly common=2-3), C (common=4-9) and VC (very common=10-96) to indicate the rarest to the most common butterfly species (Sing, 2017).

Statistical data analysis

Richness, diversity, dominance and abundance of the recorded butterfly species were determined through 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/ $\Sigma^{S}{}_{i}$ pi^2

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

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

Here, pi is the proportion of the i^{th} species in the community. N is the number of species present 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

The checklist of the recorded butterflies observed during the entire survey period was presented in Table 1 along with their common and scientific names, relative abundance and WPA schedule (species enlisted in Indian Wildlife Protection Act, 1972). The present study recorded the presence of 74 species of butterflies belonging to five families and 56 genera from the study site during the sampling surveys. The most common species sampled during the study was the Common Evening Brown (*Melanitis leda*) which constituted 7.36% followed by Common Palmfly (*Elymnias hypermenstra*) with 6.51%, Psyche (*Leptosia nina*) with 6.19%, Plain Tiger (*Danaus chrysippus*) with 4.91%, Common Grass Yellow (*Eurema hecabe*) with 4.48%, Indian Cabbage White (*Pieris canidia*)with 4.16%, Common Emigrant (*Catopsilia pomona*) with 3.63%, Grey Pansy (*Junonia atlites*) with 3.52% and Great Eggfly (*Hypolimnas bolina*) with 3.09% of the total butterfly abundance in the study area. The butterflies, observed between 2% to 3% of the total recorded butterflies, were Dark Grass Blue (*Zizeeria karsandra*), Dark Evening Brown (*Melanitis phedima*), Common Baron (*Euthalia aconthea*), Pea Blue (*Lampides boeticus*), Common Mormon (*Papilio polytes*) and Tailed Jay (*Graphium agamemnon*) accordingly in which last three butterfly species share an equal percentage of occurrence. The remaining 59 species, individually had less than 2% abundance of the total abundance of the sampled site.

In the butterfly community of the study area, Angled Castor (*Ariadne ariadne*) and Common Leopard (*Phalanta phalantha*) under Nymphalidae family, Common Cerulean (*Jamides celeno*), Common Lineblue (*P. nora*), Forget-me-not (*Catochrysops strabo*), Indian Sunbeam (*Curetis thetis*) and Apefly (*Spalgis epius*) under family Lycaenidae, Crimson Rose (*Pachliopta hector*) under family Papilionidae, Yellow Orange-tip (*Lxias pyrene*) under Pieridae family and Brown Awl (*Badamia exclamationis*), Indian Palm Bob (*Suastus gremius*) and Chestnut Bob (*Lambrix salsala*) under Hesperiidae family, were the rarest butterfly species as their recorded number of individual was only one in the study area (relative abundance: 0.11%).

When family-wise most counted species was taken under consideration, it was found that under the family Nymphalidae Common Evening Brown (*M. leda*) was the dominant species followed by Common Palmfly (*E. hypermenstra*), under the family Lycaenidae Dark Grass Blue (*Z. karsandra*) was the most abundant species, followed by Pea Blue (*L. boeticus*), under the family Pieridae Psyche (*L. nina*) was well encounter compared to other species, followed by Common Grass Yellow (*E. hecabe*), Indian Cabbage White (*P. canidia*) and Common Emigrant (*C. pomona*) and under the family Hesperiidae, Indian Skipper (*Spialia galba*) was counted more than the other species of this family.

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

SL.	Family	Common name	Scientific name	Relative Abundance (RA)	Status	WPA schedule
1	Nymphalidae	Plain Tiger	*Danaus chrysippus*	4.91	VC	
2		Sriped Tiger	*Danaus genutia*	0.21	FC	
3		Glassy Tiger	*Parantica aglea*	1.71	VC	
4		Blue Tiger	*Tirumala limniace*	0.96	C	
5		Common Palmfly	*Elymnias hypermenstra*	6.51	VC	Schedule I
6		Common Castor	*Ariadne merione*	0.96	C	
7		Angled Castor	*Ariadne ariadne*	0.11	UC	
8		Great Eggfly	*Hypolimnas bolina*	3.09	VC	
9		Commander	*Moduza procris*	0.96	C	
10		Peacock Pansy	*Junonia almana*	0.85	C	
11		Lemon Pansy	*Junonia lemonias*	1.39	VC	
12		Chocolate Pansy	*Junonia iphita*	1.81	VC	
13		Grey Pansy	*Junonia atlites*	3.52	VC	
14		Tawny Coster	*Acraea terpsicore*	0.32	FC	
15		Common Evening Brown	*Melanitis leda*	7.36	VC	
16		Dark Evening Brown	*Melanitis phedima*	2.45	VC	
17		Common Crow	*Euploea core*	0.96	C	
18		Common Three Ring	*Ypthima asterope*	0.21	FC	
19		Common Four Ring	*Ypthima huebneri*	0.32	FC	Schedule IV
20		Common Five Ring	*Ypthima baldus*	1.28	VC	
21		Common Baron	*Euthalia aconthea*	2.24	VC	Schedule II
22		Common Sailer	*Neptis hylas*	0.32	FC	
23		Dark Brand Bushbrown	*Mycanitis mineus*	0.75	C	
24		Common Bushbrown	*Mycanitis perseus*	1.81	VC	
25		Common Leopard	*Phalanta phalantha*	0.11	UC	
26	Lycaenidae	Lime Blue	*Chilades laius*	1.71	VC	
27		Zebra Blue	*Leptotes plinius*	0.53	C	
28		Tiny Grass Blue	*Zizula hylax*	0.75	C	
29		Pea Blue	*Lampides boeticus*	2.03	VC	Schedule II
30		Plains Cupid	*Chilades pandava*	0.32	FC	
31		Common Ciliate Blue	*Anthene definita*	0.96	C	
32		Dark Grass Blue	*Zizeeria karsandra*	2.88	VC	
33		Pale Grass Blue	*Pseudozizeeria maha*	1.71	VC	
34		Common Cerulean	*Jamides celeno*	0.11	UC	
35		Common Lineblue	*Prosotas nora*	0.11	UC	Schedule II
36		Gram Blue	*Euchrysops cnejus*	0.96	C	
37		Quaker	*Neopithecops zalmora*	0.32	FC	
38		Slate Flash	*Rapala manea*	0.32	FC	
39		Forget-me-not	*Catochrysops strabo*	0.11	UC	
40		Indian Sunbeam	*Curetis thetis*	0.11	UC	
41		Apefly	*Spalgis epius*	0.11	UC	
42		Common Pierrot	*Castalius rosimon*	1.39	VC	Schedule I
43	Papilionidae	Common Mormon	*Papilio polytes*	2.03	VC	
44		Blue Mormon	*Papilio polymnestor*	0.32	FC	
45		Common Mime	*Papilio clytia*	1.60	VC	Schedule 1
46		Lime Butterfly	*Papilio demoleus*	1.92	VC	
47		Tailed Jay	*Graphium agamemnon*	2.03	VC	
48		Common Jay	*Graphium doson*	1.49	VC	
49		Common Rose	*Pachliopta aristolochiae*	0.75	C	
50		Crimson Rose	*Pachliopta hector*	0.11	UC	Schedule I
51	Pieridae	Indian Cabbage White	*Pieris canidia*	4.16	VC	
52		Psyche	*Leptosia nina*	6.19	VC	
53		Striped Albatross	*Appias libythea*	0.96	C	Schedule II
54		Pioneer White	*Belenois aurota*	0.32	FC	
55		Common Gull	*Cepora nerissa*	1.60	VC	Schedule II
56		Three Spot Grass Yellow	*Eurema Blanda*	0.64	C	
57		Common Grass Yellow	*Eurema hecabe*	4.48	VC	
58		Small Grass Yellow	*Eurema brigitta*	0.32	FC	
59		Common Emigrant	*Catopsilia pomona*	3.63	VC	
60		Mottled Emigrant	*Catopsilia pyranthe*	0.96	C	
61		Common Jezebel	*Delias eucharis*	1.71	VC	
62		Common Wanderer	*Pareronia valeria*	0.64	C	

63		Yellow Orange-tip	*Ixias pyrene*	0.11	UC
64	Hesperiidae	Small-branded Swift	*Pelopidas mathias*	0.53	C
65		Large Banded Swift	*Pelopidas subochracea*	0.32	FC
66		Grass Demon	*Udaspes folus*	0.32	FC
67		Brown Awl	*Badamia exclamationis*	0.11	UC
68		Commom Banded Awl	*Hasora chromus*	0.64	C
69		Indian Skipper	*Spialia galba*	0.96	C
70		Straight Swift	*Parnara guttata*	0.64	C
71		Rice Swift	*Borbo cinnara*	0.53	C
72		Indian Palm bob	*Suastus gremius*	0.11	UC
73		Chestnut Bob	*Lambrix salsala*	0.11	UC
74		Bush Hopper	*Ampittia dioscorides*	0.21	FC

UC= Uncommon (1 individual recorded), FC= Fairly Common (number of individual: 2-3), C= Common (number of individual: 4-9), VC= Very Common (number of individual: 10-96). WPA- Species enlisted in Indian Wildlife Protection Act, 1972.

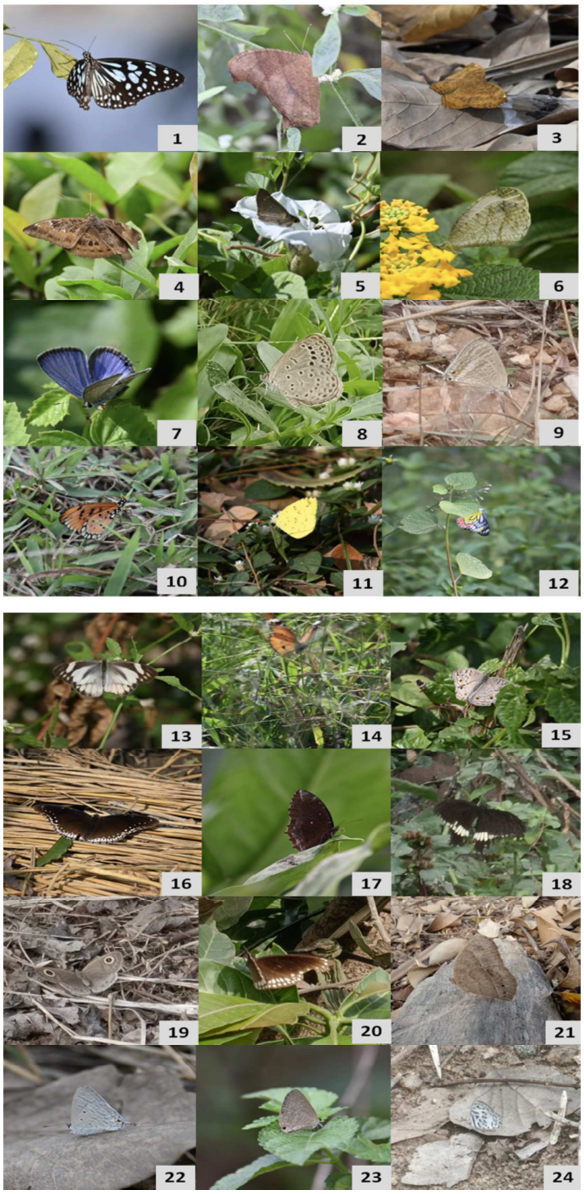

Fig. 2. Photographs of different butterfly species recorded in the study area

1) *Tirumala limniace*, 2) *Melanitis phedima*, 3) *Ariadne merione*, 4) *Euthalia aconthea*, 5) *Pelopidas mathias*, 6) *Leptosia nina*, 7) *Chilades pandava*, 8) *Pseudozizeeria maha*, 9) *Lampides boeticus* 10) *Acraea terpsicore*, 11) *Eurema hecabe*, 12) *Delias eucharis*, 13) *Appias libythea,* 14) *Danaus chrysippus,* 15) *Junonia atlites* 16) *Hypolimnas bolina* 17) *Elymnias hypermenstra* 18) *Papilio polytes* 19) *Ypthima huebneri* 20) *Euploea core* 21) *Mycanitis perseus* 22) *Catochrysops Strabo* 23) *Jamides celeno* 24) *Castalius rosimon*

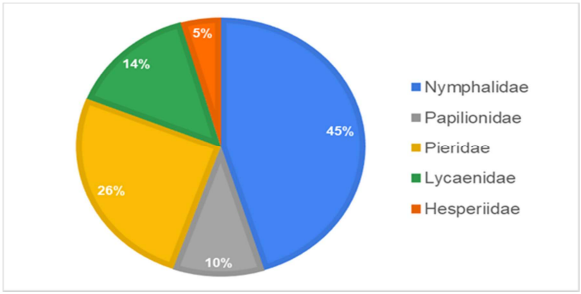

Fig. 3. Percentage composition of five families of butterflies in the study area

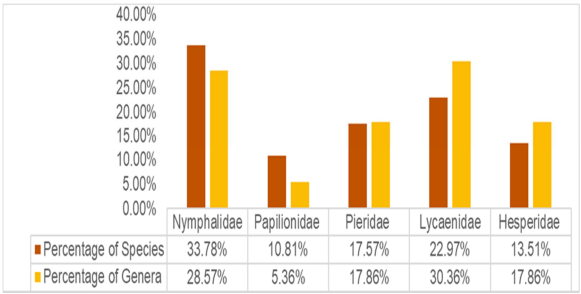

Fig. 4. Genus to species proportion of butterflies of five families

Family Nymphalidae was the dominant family as the maximum number of butterflies were recorded under this family with 45.14% of the total population, followed

by Pieridae (25.72%), Lycaenidae (14.41%), Papilionidae (10.25%) and Hesperiidae (4.48%) (Fig. 3).

When the generic diversity was considered, it was noted that the family Lycaenidae had the highest number of genus (30.36%), followed by Nymphalidae (28.57%). Both the family Pieridae and Hesperiidae were found to have the same number of genera which was 17.86% of the total recoded genera and the lowest percentage of genera was observed under the family Papilionidae (5.36%). Considering the species-wise distribution of butterflies, the family Nymphalidae had the highest number of species (33.78%), followed by Lycaenidae (22.97%), Pieridae (17.57%), Hesperiidae (13.51%) and Papilionidae (10.81%) (Fig. 4).

Genus-wise species distribution showed genus *Junonia* of family Nymphalidae and genus *Papilio* of family Papilionidae were the most dominant genus, each with four species namely *Junonia almanac*, *Junonia lemonias*, *Junonia iphita* and *Junonia atlites* under Nymphalidae and *Papilio polytes*, *Papilio polymnestor*, *Papilio clytia* and *Papilio demoleus* under Papilionidae. While three species were found from the genus *Ypthima* of family Nymphalidae (*Ypthima Asterope*, *Ypthima huebneri* and *Ypthima baldus*) and genus *Eurema* of family Pieridae (*Eurema Blanda*, *Eurema hecabe* and *Eurema brigitta*). Two species per genus were observed from 8 genera namely *Danaus*, *Ariadne*, *Melanitis* and *Mycanitis* from the family Nymphalidae, *Graphium* and *Pachliopta* from the family Papilionidae, *Catopsilia* from the family Pieridae and *Pelopidas* from the family Hesperiidae. On the other hand, majority of the genus were noted to have single species (44 genera). Species to genus ratio (S/G= 1.32) was found very low in the butterfly population of the study area.

The majority of the recorded butterfly species from the sampled site were 'common' and 'generalist' species (Sarma *et al.*, 2012) and no species was observed as globally threatened according to the IUCN Red List (Ver 3.1), though only ten species were found as legally protected under different Schedules of the Wildlife Protection Act, 1972. Of these legally protected species, Common Palmfly (*E. hypermenstra*), Common Pierrot (*C. rosimon*), Common Mime (*P. clytia*) and Common Rose (*Pachliopta hector*) are protected under Schedule I, while Common Baron (*Euthalia aconthea*), Pea Blue (*L. boeticus*), Common Lineblue (*P. nora*), Stiped Albatross (*Appias olferna*), Common Gull (*Cepora nerissa*) under Schedule II and Common Four Ring (*Y. huebneri*) under Schedule IV.

Fig. 5. Occurrence of different butterfly species in the study area

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)
3.79	0.89	0.03	0.97

Based on the values of the occurrence of the butterfly species (Fig. 5) in the sampled area, 78.66% butterflies of the population were seen under the category very common (VC), 15.90% were under common (C) category, 4.16% were under fairly common (FC) category and 1.28% were under uncommon (UC) category. Of the total recorded 74 species of butterfly, 28 species were found under the VC category, 20 species under C category, 14 species under FC category and 12 species under UC category.

The species diversity and evenness of the study site 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 value of Shannon's index (H'=3.79) revealed that species richness and diversity of the butterfly community of Subhas Sarobar study area was very high and in the direction of an ideal natural

community. The abundance of the butterfly species in the community is estimated by the value of Simpson's index (Ds=0.03) which was more inclined toward 0 that indicated a high species abundance in the studied butterfly community. While the value of Simpson's diversity index (D) was 0.97, indicating the studied butterfly community was a diverse one. The value of Pielou's evenness index (J') was 0.89 in the present study which depicts that the more evenness exist in the studied butterfly community as the value was inclined toward the '0'. The values of the studied diversity indices expressed that the butterfly community of the study area was highly diverse with high evenness and high abundance.

Table 3 illustrated 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 recoded five families ranged from 1.87 to 2.75. The lowest value obtained from Papilionidae family as in the studied community only eight species recoded under this family, whereas the highest from the Nymphalidae family as the maximum number of species were recorded under this family, followed by Lycaenidae (2.40), Hesperidae (2.18) and then in Pieridae (2.13). The values of the Shannon diversity index (H') of the five families indicated that the family Nymphalidae and Lycaenidae were diverse. The values of evenness (J') determine either the community of an area is ideal or not. In the present study, the value of J' was higher in the family Hesperiidae (0.91), followed by Papilionidae (0.90) and then in both the families Nymphalidae and Lycaenidae and the lower value was found in the family Pieridae (0.83). The values of Simpson's reciprocal index (Dr) of the five recorded families depicted that the higher diversity of butterfly was in the family Nymphalidae (Dr=11.83) followed by Lycaenidae (Dr=8.94) and then in Hesperiidae (Dr=7.74), while Papilionidae was less diverse family (Dr= 6.04).

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	2.75	2.63	0.85	0.08	0.92	11.83
Lycaenidae	2.4	2.13	0.85	0.11	0.89	8.94
Papilionidae	1.87	1.98	0.9	0.16	0.84	6.04
Pieridae	2.13	2.38	0.83	0.14	0.86	6.8
Hesperiidae	2.18	1.62	0.91	0.11	0.89	7.74

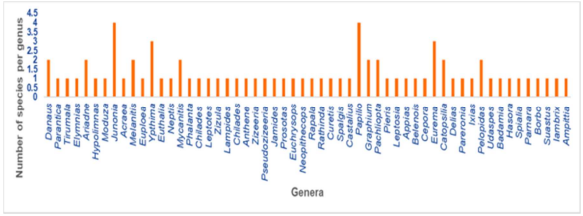

Fig. 6. Species richness of the recorded butterfly genera of the study site

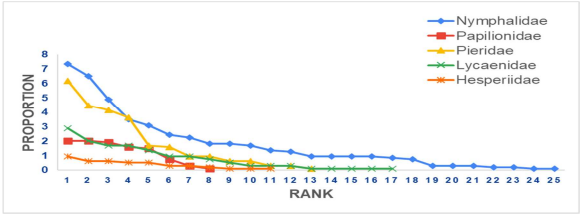

Fig. 8. Rank abundance curve of five families of butterfly in the study area

Fig. 7. Rank abundance curve of 74 species of butterfly in the study area

Obtained result of Berger-Parker index indicated that the dominant family was Nymphalidae (D_{BP}= 0.45) and the dominant species was Common Evening Brown, *M. leda* (D_{BP}= 0.07) in the study area. Common Evening Brown (D_{BP}= 0.16) of the family Nymphalidae, Dark Grass Blue (D_{BP}= 0.20) of the family Lycaenidae, Common Mormon and Tailed Jay

(D_{BP}= 0.20) under the family Papilionidae, Indian Cabbage White (D_{BP}= 0.24) under the family Pieridae and Indian Skipper (D_{BP}= 0.21) under the family Hesperiidae were found to be the dominant species within their respective family.

Fig. 6, 7 and 8 displayed the Whittaker plot i.e. species-wise rank abundance curve which explains the species diversity and family-wise rank abundance curve which elucidates the family diversity respectively. Whittaker plot describes the abundance of the high-ranking and low-ranking species are very much different and also displayed a strong evenness with a relatively low steep inclination except the 1st twelve ranked species with high steep inclination. The high-ranking species have lower abundances compared to low-ranking species. High abundance with high evenness between various species was noted from 49th to 74th ranked species, followed by 28th to 48th ranked species also with high evenness between them and then from 13th to 27th ranked species with high evenness. When considering family-wise rank abundance curve, more evenness was observed in case of the family Hesperiidae, then in Papilionidae, moderate evenness in Nymphalidae and Lycaenidae, while the family Pieridae showed relatively less evenness.

Discussion

The present study was the first time that butterfly diversity and abundance was evaluated in the Subhas Sarobar region, the lung of eastern Kolkata, is situated just beside the very busy road, Eastern Metropolitan Bypass and amidst the urban settlement. Butterfly species richness recorded in the present study is comparable to the earlier records on butterfly diversity of other urban areas of India (Sarma *et al.*, 2012; Arya *et al.*, 2014; Kumar 2014). Several studies were conducted on diversity of butterfly fauna in and around Kolkata. In this regard, Chowdhury and Chowdhury (2007) reported 33 butterfly species from the Mudialy Ecological Park, and Chowdhury and Soren (2011) revealed 74 species from the East Kolkata Wetland. A total number of 96 species of butterfly were recorded from urban Kolkata by Mukherjee *et al.*, (2015) and 54 species from Kolkata metropolis also by Mukherjee *et al.*, (2016). Bhattacharya *et al.*, (2018) documented 57 species from the campus of Ramakrishna mission Vivekananda centenary College, Rahatra. Chowdhury (2022) and Mitra *et al.* (2023) recoded 33 butterfly species in and around the Lake Town area and 21 species from the Rammohan College Campus, Kolkata respectively. Butterfly species recorded in the present study is consistent with few previous studies (Chowdhury and Soren, 2011), although variations in species richness with other investigation reports were found, possibly because of difference in study period, size of sampling area or the nature of habitat within the sampling area. In the present study, the sample size and the sampling area was larger, and the study was conducted for a prolonged period. Moreover, this study highlighted that the vegetation around the Subhas Sarobar is a preferred habitat for the butterflies as plenty of greenery is found there with lots of trees, herbs, shrubs and also with patches of grasslands which provide them nectar (food). This is the primary cause of the high diversity and abundance of butterfly species in the study area.

The number of butterfly families recorded in the present study was remained similar to the records on the butterfly families in different areas of Kolkata bearing similar habitat (Mukherjee *et al.*, 2015; Mukherjee *et al.*, 2016; Bhattacharya *et al.*, 2018; Chowdhury, 2022). By contrast, the recorded number of families of the butterfly fauna from East Calcutta wetland and Rammohan College campus, differed from the present findings (Chowdhury and Soren, 2011; Mitra *et al.*, 2023). The observed variation in family composition of butterfly community of East Calcutta wetland was primarily due to the difference of habitat. Availability of larval host plants and nectar plants render stability to the butterfly community and their assemblage in this habitat. Whereas only 21 butterfly species belonging to 4 families were documented from Rammohan College campus, by location it is the heart of the city Kolkata. The occurrence and diversity of butterflies were relatively

less as anthropogenic disturbances mainly the pollution, usage of insecticide and disturbed vegetation, and shortage of potential habitat with insufficiency of flowering and host plants provide negative impact on their population.

The dominant butterfly family of the present study area was Nymphalidae when considering the butterfly abundance and Lycaenidae when considering the species diversity. Hence, the maximum number of butterflies were recorded from Nymphalidae family followed by Lycaenidae, which well corroborates with studies elsewhere in Kolkata (Chowdhury and Soren, 2011; Mukherjee *et al.*, 2016; Bhattacharya *et al.*, 2018). In contrary, Mukherjee *et al.* (2016) observed an inverse trend of that findings from Kolkata city that was most observed butterfly family was Lycaenidae, followed by Nymphalidae. While Chowdhury (2022) and Mitra *et al.* (2023) recoded Nymphalidae was the dominant family followed by Pieridae in Lake Town area and Rammohan College campus of Kolkata respectively.

In current study, under the family Nymphalidae, 16 genera and 25 species of butterfly were found from the study site. While under the family Nymphalidae, 16 genera and 27 species from Kolkata city (Mukherjee *et al.*, 2015), 13 genera and 18 species were recorded from Kolkata metropolis (Mukherjee *et al.*, 2016), 15 genera and 24 families from East Kolkata Wetlands (Chowdhury and Soren, 2011), 16 genera and 19 species from Vivekananda centenary college campus (Bhattacharya *et al.*, 2018), 8 genera and 10 species from Lale Town area (Chowdhury, 2022) and 11 genera and 12 species from Rammohan College campus (Mitra *et al.*, 2023) were documented earlier.

Under the family Lycaenidae, the recorded number of both the genus and species was 17 from the present sampled area. Similarly, from East Kolkata Wetlands the number was 18 for both the genus and species (Chowdhury and Soren, 2011). Whereas, from Kolkata city, number of genus and species were 25 and 30 respectively (Mukherjee *et al.*, 2015), from Kolkata metropolis, 12 and 13 respectively (Mukherjee *et al.*, 2016). On the other hand, from Lake Town area only 3 genera with single species were recorded (Chowdhury, 2022) and from Rammohan College campus, no Lycaenids were found (Mitra *et al.*, 2023).

Under family Pieridae, from the present study area, 10 genera and 13 species were observed. From East Kolkata Wetlands the recorded number of genus and species under Pieridae, were 8 and 11 respectively (Chowdhury and Soren, 2011). While 9 genera and 12 species from Kolkata city (Mukherjee *et al.*, 2015), 7 genera and 9 species from Kolkata metropolis (Mukherjee *et al.*, 2016), 5 genera and 6 species from Vivekananda centenary college campus (Bhattacharya *et al.*, 2018), 6 genera and 7 species from Lake Town area (Chowdhury, 2022) and 5 genera and 5 species from Rammohan College campus (Mitra *et al.*, 2023) were recorded previously.

Under family Hesperiidae, in the current study, 10 genera and 11 species were found. Under this family, the number of genus and species from East Kolkata Wetlands were 11 and 12 respectively (Chowdhury and Soren, 2011). From Kolkata city, under Hesperiidae, 17 genera and 18 species (Mukherjee *et al.*, 2015), from Kolkata metropolis 7 genera and 8 species (Mukherjee *et al.*, 2016) and from Vivekananda centenary college campus 9 genera with single species (Bhattacharya *et al.*, 2018) were reported. From Lake Town and Rammohan College campus only one genus with single species (Chowdhury, 2022; Mitra *et al.*, 2023) were documented under the family Hesperiidae.

Under family Papilionidae, from the study area 3 genera and 8 species were recorded. From East Kolkata Wetlands, under Papilionidae 3 genera and 8 species (Chowdhury and Soren, 2011), from Kolkata city 4 genera and 9 families (Mukherjee *et al.*, 2015), from Kolkata metropolis 4 genera and 6 families (Mukherjee *et al.*, 2016), from Vivekananda centenary college campus 4 genera and 7 species

(Bhattacharya *et al.*, 2018), from Lake Town 3 genera and 7 species (Chowdhury, 2022), from Rammohan College campus 3 genera with single species (Mitra *et al.*, 2023) were recorded.

Diversity observed in species and genus under the recorded families of butterfly from different areas of Kolkata was shaped by the vegetation of that area (Ockinger and Smith, 2006; Ockinger *et al.*, 2006; 2009). The areas like Lake Town, Rammohan College campus and Vivekananda centenary college campus were reported as less diverse in butterfly species richness that perhaps due to occurrence of less abundance of plant species those are either host plants or nectar plants of butterfly population. By contrast, the East Kolkata Wetlands (Chowdhury and Soren, 2011) and few selected areas of Kolkata (Mukherjee *et al.*, 2015; 2016) hosted a large number of butterfly species possibly as a consequence of larger areas with diverse vegetation pattern. Consistent with this fact the present study observation recorded a higher diversity in the butterfly fauna in Subhash Sarobar. The present sampled area is more diverse in terms of the vegetation with adequate available space for plant growth, with open grasslands and gardens with flowering plants and it is a patch of greenery exists in the most crowded and urbanized city, Kolkata. The present observation on diversity and abundance of butterfly fauna reflects the study area is a healthy ecosystem patch in the busiest location of the city.

Conclusion

Butterflies are known as bewitching species perform multiple roles in ecosystems services through helping in pollination, serving as important food chain components and acting as potentially useful ecological indicator species by providing information on environmental condition and health of an ecosystem. Therefore, exploration of butterfly fauna thus becomes an important tool for environmental monitoring and habitat assessment. High abundance of butterfly characteristically indicates the habitat is an improved ecological unit (Roy, 2022). Urbanization is associated with habitat degradation, habitat modification and alteration in local climatic circumstances, which adversely effect on plant species diversity and on ground water and soil quality (Sing *et al.*, 2009; Garg *et al.*, 2009). Hence urban development negatively affects nature biodiversity (Malagrino *et al.*, 2008). Butterflies are useful indicators of urbanization as their diversity and abundance of an area could be readily surveyed and the survey reports are becoming important in identifying the biodiverse habitats under threat as well as have potential of indicating the need of preserving of these habitats, and are also important in taking management strategies for the conservation of the habitat and the butterfly fauna. The present study will serve as a baseline and further research on butterfly diversity and abundance from other urban areas are essential in future. In Kolkata, gardens and parks are limited, but these are diverse in butterfly fauna. Hence, maintenance of these green spaces is recommended for long-term conservation of butterfly fauna while sustaining the ecosystem services.

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