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A report on butterfly diversity and abundance of Alipore Zoological Garden, Kolkata, West Bengal, India

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Abstract
Butterflies, the indicator species are used as a tool for monitoring the health of a habitat as their diversity and abundance reflect the impact of urbanization in an area. The current study was undertaken to estimate the diversity and abundance of butterfly fauna in Alipore Zoological Garden, Kolkata India. A total number of 72 butterfly species of 6 families and 52 genera were recorded over a period of one year from August, 2023 to July, 2024. Among 72 butterfly species, 29 species belonged to family Nymphalidae, 14 species to Lycaenidae, 7 species to Papilionidae, 13 species to Pieridae, 8 species to Hesperiidae and 1 species to Riodinidae. Nymphalidae was the most predominant family owing to their species richness, whereas the family Pieridae (37.41%) was found to dominate over Nymphalidae (36.70%), Lycaenidae (16.10%), Papilionidae (7.80%), Hesperiidae (1.92%) and Riodinidae (0.08%). Based on the sightings of the butterfly species in the study site, 66.13% butterflies of the population were under the category very common (VC), 22.28% under common (C) category, 10.58% under not rare (NR) category, 0.96% under rare (R) category and 0.05% under very rare (VR) category. A total number of 14 species of the documented butterflies are legally protected under Wildlife Protection Act, 1972. The results of different diversity indices, Shannon's index (H'=3.96), Pielou's evenness index (J=0.92) and Simpson's index of diversity (D=0.02) showed that the butterfly fauna in the study area was highly diverse with even distribution and high abundance. Findings from this study is expected to provide useful documentation regarding the butterfly fauna in the vegetation of Alipore Zoological Garden, Kolkata and similar geographic areas which in turn are helpful towards the conservation of habitats.

Keywords: Alipore Zoological Garden, diversity indices, Nymphalidae, species richness, urbanization

Introduction

Biodiversity is a vital tool for recognizing the changes in habitat along with the environment. Alteration in the biodiversity of a habitat is caused mainly due to human interference and environmental degradation. Insects are one of the most diverse organisms in the world, thus playing an important role in determining the terrestrial ecosystem's biodiversity. Among all the described faunal biodiversity, the insects occupy the largest proportion and contribute to about 75% of all the identified animal species (Das *et al*., 2024) [13]. Butterflies are the most recognizable group belonging to order Lepidoptera among the insects and are also an ecologically well-studied order around the globe (Ghazoul, 2002; Thomas, 2005) [15, 44]. In biodiversity studies butterflies are considered as the "flagship of taxa". Due to their visual values butterflies are appraised as one of the most charming insects on the earth and are also accounted as natural heritage due to their behavioural display (Kasambe, 2016) [16]. Butterflies are sustaining the terrestrial ecosystem by acting as local pollinators and increasing the biomass of various plants (Atmowidi *et al*., 2007) [2]. Caterpillars feed on specific host plant foliage while adult butterflies feed on pollens and nectars (Nimbalkar *et al*., 2011) [34] thus showing a symbiotic relationship between flowers and butterflies (Koneri *et al*., 2020) [18]. Thus, plant diversity of an region is favorably corelated with the butterfly community of that region (Leps and Spitzer, 1990) [25]. Moreover, butterflies are essential component in food-web by being herbivores (Rusman *et al*., 2016) [39], pollinators (Atmowidi *et al*., 2007) [2], parasitoid hosts (Van Nouhuys and Hanski, 2002) [46] and predator's prey (Rusman *et al*., 2016) [39]. These enchanting elements of nature are good indicators of the terrestrial ecosystem as they are able to provide knowledge about the ecological changes and environmental health (Bonebrake *et al*., 2010) [7]. These creatures are very much sensitive to their surrounding environment and their diversity and abundance are altered due to solar radiation, availability of host plants, farmland intensification, intensive logging, urbanization, industrialization, sudden weather and climatic changes etc. (Mora *et al*., 2011) [29]. It has been reported through several studies that there exists an inverse affinity between species richness, diversity, abundance of butterfly and anthropogenic interferences like urbanization and industrialization (Clark *et al*., 2007; Pocewicz *et al*., 2009) [11, 38]. So, human mismanagement and pollution ultimately results in deterioration of habitat quality and quantity which is the cause of a steady decline in the diversity of these charismatic species (Malagrino *et al*., 2008; Mitra *et al*., 2023) [26, 28]. Natural and semi-natural habitats are continuously replaced by concrete constructions which exerts a negative effect on natural biodiversity as well as butterfly diversity. Moreover, there might be a decrease in the abundance of butterflies due to the extensive usage of mosquito repellant fumigants.

Being such sensitized species, butterflies are used as sample organisms of a specific habitat for identifying the habitat patterns (Gaonkar, 1996) [14]. Monitoring the butterfly diversity has now been considered as an essential tool for the geological studies and also for adopting management strategies regarding biodiversity conservation (Watt and Boggs, 2003; Mukherjee *et al*., 2015) [49, 31]. Still now

28,000 butterfly species have been identified throughout the world while in India nearly about 1500 species belonging to six families (Papilionidae, Nymphalidae, Pieridae, Lycaenidae, Riodinidae and Hesperiidae) have been recorded (Gaonkar, 1996; Larsen *et al*., 2011) [14, 24]. Among them, some species are endemic and some are endangered according to IUCN Red List (Cotton *et al*., 2015) [12]. From different urban areas of West Bengal, particularly from Kolkata and its adjacent areas several studies have been conducted to document the butterfly diversity and abundance (Mukherjee *et al*., 2016; Nair *et al*., 2014; Bhattacharya *et al*., 2018; Mitra *et al*., 2023) [30, 33, 4, 28]. The Alipore Zoological Garden, is India's oldest zoological park and a big tourist attraction spot which is situated in Kolkata, India. It is not only recognized for its diverse collection of animals and plants but also contains a high-spirited butterfly ecosystem. The unique habitat within the zoo, consists of a mix of lush green vegetation of flowering plants, and carefully curated landscapes which establishes an ideal environment for butterflies to sustain. As no previous studies have been conducted on butterfly diversity of any zoological garden in West Bengal. Hence, the present study was undertaken to explore the captivating world of butterflies by evaluating their diversity and abundance in Alipore Zoological Garden, Kolkata, West Bengal, Kolkata.

Materials and methods

Study area

The Alipore Zoological Garden is one of India's oldest zoos and covers an area of about 18.811 ha. It is situated in Alipore, Kolkata, West Bengal (Latitude: 22°32'9.29"N and Longitude: 88°19'55.39" E). Satellite image of the study area was shown in figure 1. Alipore Zoological Garden is the most popular tourist attraction spot of Kolkata with the highest footfall of visitors during the winter season. The zoo houses a wide range of animals, totaling around 1300 individuals. Not only that, the zoo acts as an ecological heaven for various migratory birds. The area contains loamy alluvial soil possessing a mix of lush green vegetation. The zoo experiences a moderate temperature with the onset of summer in March and ending with the beginning of the rainy season. The highest temperature of summer is about 45℃ averaging with about 37℃. The winter season spans from the end of the rainy season until February, with an average temperature of about 13℃. Monsoon extends from July to September with an annual rainfall of approximately 1641.4 mm in Kolkata.

Fig 1: Map of West Bengal, India
(left one: https://images.app.goo.gl/w7Yv8XNjUsQ1M1ZcA), satellite image of Alipore Zoological Garden (right two: https://maps.app.goo.gl/MmSsahptG13Knd1n7).

Survey techniques

Observational surveys of the present study were conducted from August, 2023 to July, 2024 during the sunny days with pleasant climatic conditions, neither heavy rainfall nor heavy winds. A periodic study was done through random visits between 10:00 hours to 13:00 hours and 16:00 hours to 17:00 hours. Butterflies were counted and carefully noted from the randomized quadrates of 10m × 10m on the both sides of the laid transect, during each sampling occasion (Kumari *et al*., 2023) [20]. Most of the butterfly species were identified through visual encounter method by naked eye or binoculars and in critical cases photographs and videos were taken and then identification was done following the keys of Kehimkar (2016) [17], Kunte *et al*., (2014) [21]. No butterflies were collected, captured or harmed during this process. In the present study all common English names and scientific names were in accordance with Varshney and Smetacek (2015) [47]. Based on their sightings in the study site, the recorded butterflies were grouped into 5 categories and represented as VR (very rare; 1-2), R (rare; 3-15), NR (not rare; 16-50), C (common; 51-100), VC (very common; more than 100) to determine the most common and rarest species of butterfly (Tiple *et al*., 2006) [45].

Statistical data analysis

All the diversity indices were assessed by calculating with the help of Microsoft Excel 2019 software which helped in turn to understand the community structure of the butterfly species in the sampled site. Species richness, abundance and evenness were determined through Shannon index (Shannon and Weaver, 1963) [41], Simpson index (Simpson, 1964) [43] and Pielou's index (Mulder *et al*., 2004) [32] respectively. To explain species richness and evenness a rank abundance curve was prepared (Whittaker, 1965) [50].

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

Shannon H_{max}= Log_1 (N)

Dominance index (D_{BP}) = ni/N (Berger and Parker, 1970) [3]

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

Simpson's index of diversity (D) = 1-Σ^{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

Here, pi is the proportion of the i^{th} species in the butterfly community. N is the number of species present in a butterfly fauna. Ni is the number of individuals of i^{th} species.

Results

Satellite overview of Alipore Zoological Garden, the present study site was shown in figure 1, whereas, table 1 which consisted of butterfly family, common and scientific names of the observed butterflies and their relative abundance, status, and WPA schedule (Wildlife Protection Act, 1972), represented the preliminary checklist of the butterflies recorded during the entire survey period. During the present survey a total number of 72 species of butterflies belonging to six families and 52 genera were recorded from the study site, among which the most common species found during the study was the Mottled Emigrant (*Catopsilia pyranthe*) constituting 5.06% followed by Common Grass Yellow (*Eurema hecabe*) with 4.94%, Striped Albatross (*Appias libythea*) with 4.09%, Common Emigrant (*Catopsilia Pomona*) with 3.93% and Plain Tiger (*Danaus chrysippus*) with 3.08%. Small Grass Yellow (*Eurema brigitta*), Common Albatross (*Appias albina*), Dark Grass Blue (*Zizeeria karsandra*), Tiny Grass Blue (*Zizula hylax*),

Common Crow (*Euploea core*), Clouded Yellow (*Colias croceus*), Common Gull (*Cepora nerissa*), Chocolate Albatross (*Appias lyncida*), Common Palmfly (*Elymnias hypermenstra*), Psyche (*Leptosia nina*), Great Eggfly (*Hypolimnas bolina*), Grey Pansy (*Junonia atlites*), Peacock Pansy (*Junonia almana*) and Blue Tiger (*Tirumala limniace*) were those butterflies recorded between 2% to 3% of the total species.

The total number of 19 butterflies species observed between 1% to 2% of the total documented butterflies, those were Psyche (*Leptosia nina*), Clouded Yellow (*Colias croceus*), Common Gull (*Cepora nerissa*), Common Albatross (*Appias albina*), Small Grass Yellow (*Eurema brigitta*), Tiny Grass Blue (*Zizula hylax*), Glassy Tiger (*Parantica aglea*), Common Castor (*Ariadne merione*), Angled Castor (*Ariadne ariadne*), Tawny Coster (*Acraea terpsicore*), Pea Blue (*Lampides boeticus*), Common Bluebottle (*Graphium sarpedon*), Tree Yellow (*Gandaca harina*) and many more. Less than 1% abundance of the total abundance of the study site was noted for the rest of the species individually.

Upon considering the community of butterflies of the sampled site, Gaudy Baron (*Euthalia lubentina*) under Nymphalidae family and Common Rose (*Pachliopta aristolochiae*) under Papilionidae family were identified as the rarest species in the entire site, their recorded number of individuals was only one and two respectively (relative abundance: 0.02% and 0.03% respectively). Zebra Blue (*Leptotes plinius*) under Lycaenidae family, Lime (*Papilio demoleus*) under Papilionidae family, Punchinello (*Zemeros flegyas*) under Riodinidae family Dark Small Branded Swift (*Pelopidas mathias*), Small Branded Swift (*Pelopidas mathias*), Grass Demon (*Udaspes folus*) and Brown Awl (*Badamia exclamationis*) under Hesperiidae family, were the rare one as their recoded relative abundance were either 0.2% or less than that in the study area.

When family-wise most frequent species were considered, it was noted that under the family Nymphalidae Plain Tiger (*Danaus chrysippus*) was the dominant species followed by Common Crow (*Euploea core*), Common Palmfly (*Elymnias hypermenstra*), Great Eggfly (*Hypolimnas bolina*), Grey Pansy (*Junonia atlites*), Peacock Pansy (*Junonia almana*), Blue Tiger (*Tirumala limniace*), Glassy Tiger (*Parantica aglea*), Common Castor (*Ariadne merione*). Among family Lycaenidae, Dark Grass Blue (*Zizeeria karsandra*) was the dominant one, while Tiny Grass Blue (*Zizula hylax*) and Pea Blue (*Lampides boeticus*) were well encountered compared to other species. Under family Pieridae Mottled Emigrant (*Catopsilia pyranthe*) was the most abundant followed by Common Grass Yellow (*Eurema hecabe*) and Striped Albatross (*Appias libythea*), Common Emigrant (*Catopsilia pomona*), Small Grass Yellow (*Eurema brigitta*), Common Albatross (*Appias albina*), Clouded Yellow (*Colias croceus*), Common Gull (*Cepora nerissa*), Striped Albatross (*Appias libythea*), Chocolate Albatross (*Appias lyncida*), Psyche *(Leptosia nina*) and Tree Yellow (*Gandaca harina*), and under family Hesperiidae, Indian Skipper (*Spialia galba*) was counted more than other species of this family.

Family Pieridae was the most abundant one as the highest number of the butterflies were documented under this family constituting 37.41% of the total population, followed by Nymphalidae (36.70%), Lycaenidae (16.10%), Papilionidae (7.80%), Hesperiidae (1.92%) and lastly Riodinidae (0.08%) (Figure 2).

When the generic variability was taken under consideration, it was noticed that family Nymphalidae had the largest number of genus (36.54%), followed by Lycaenidae (25%) and Pieridae (17.31%). The family Papilionidae and Hesperiidae were found to have 5.77% and 13.46% of the total recorded genera respectively and the minimum percentage of genera was listed under the family Riodinidae (1.92%) (Figure 2).

Most of the butterfly species of the study area were 'common' and 'generalist species' and none of them were universally threatened according to the IUCN Red List (Ver 3.1), though only 14 species were provided legal protection under different schedules of the Wildlife Protection Act, 1972. Among them, Common Palmfly (*Elymnias hypermenstra*), Common Pierrot (*Castalius rosimon*), Common Mime (*Papilio clytia*) and Crimson Rose (*Pachliopta hector*) are protected under Schedule I while Common Baron (*Euthalia aconthea*), Grey Count (*Tanaecia lepidea*), Common Five Ring (*Ypthima baldus*), Gram Blue (*Euchrysops cnejus*), Pea Blue (*Lampides boeticus*), Common Gull (*Cepora nerissa*) and Chocolate Albatross (*Appias lyncida*) under Schedule II and Gaudy Baron (*Euthalia lubentina*), Common Four Ring (*Ypthima huebneri*) and Striped Albatross (*Appias libythea*) under Schedule IV.

When the occurrence of the butterfly species was considered in the sampled area, it was revealed that 66.13% butterflies of the population were under the category very common (VC), 22.28% were under common (C) category, 10.58% were under not rare (NR) category, 0.96% under rare (R) category and 0.05% under very rare (VR) category. Of the total recorded 72 butterfly species, 25 species were registered under the VC category, 18 species under C category, 19 species under NR category, 8 species under R category and species under 2 VR category.

Distribution of species according to genus (Figure 2) indicated genus *Junonia* of family Nymphalidae was the most dominant genus with four species namely *Junonia iphita, Junonia lemonias, Junonia almanac* and *Junonia atlites* followed by *Papilio* of family Papilionidae and *Appias* of family Pieridae with three species each namely *Papilio clytia, Papilio polytes* and *Papilio demoleus* under family Papilionidae, and *Appias albina, Appias libythea* and *Appias lyncida* under family Pieridae. Two species per genus were observed from 13 genera namely *Ariadne, Euthalia, Danaus, Parantica, Neptis, Acraea* and *Ypthima* from family Nymphalidae, *Catochrysops* from family Lycaenidae, *Pachliopta* and *Graphium* from family Papilionidae, *Catopsilia* and *Eurema* from family Pieridae and *Pelopidas* from family Hesperiidae. On the contrary, most of the genera were recorded with single species (36 genera). Species to genus ratio (S/G= 1.38) was found to be very low in the butterfly community of the study site.

Species diversity, abundance and evenness of butterfly population of the study area, were elicited by the values of Shannon diversity index (H'), Simpson's diversity index (Ds), Simpson's index of diversity (D) and Pielou's evenness index (J') (table 2). Value of Shannon's index (H') of the present study was 3.96 which explained the notably higher taxa richness and diversity of the butterfly community of Alipore Zoological Garden. The high value of H' indicated that the studied butterfly community was in the

direction of an ideal natural community. While the abundance of the butterfly species in a sampled community is depicted by the value of Simpson's index of diversity (D) which was 0.02 obtained from the present study area. Calculated value of D was found more inclined towards '0' expressing the fact that there subsisted a high species abundance in the butterfly community. Again, the value of Simpson's diversity index (Ds) was 0.98, which was more inclined towards 1 that indicated the currently studied butterfly community was a diverse one. The value of Pielou's evenness index (J') was 0.92 in the studied butterfly community which was close to 1 asserted the existence of more evenness in the sampled butterfly community.

The results of family-wise diversity indices, such as Shannon diversity index (H'), Shannon $H_{max,}$ Pielou's evenness index (J'), Simpson's diversity index (Ds), Simpson's index of diversity (D) and Simpson's reciprocal index (Dr) are illustrated in table 3. The lowest value of H' was 0 which was obtained from the family Riodinidae because in the studied community only one species was recorded in this family, whereas the highest value was 3.17 which was procured from the family Nymphalidae as the maximum number of species were counted in this family, followed by Pieridae (2.47), Lycaenidae (2.44) and Hesperiidae (1.94) and then in Papilionidae (1.72). Values of Shannon diversity index (H') of the six studied families revealed that the family Nymphalidae was the most diverse family followed by Pieridae and Lycaenidae. The value of evenness (J') of an ideal community is inclined towards '1'. Here the values for J' were ranged from 0.00 to 0.96, obtaining the higher value from the family Pieridae (0.96), followed by Nymphalidae (0.94) and then from both the families Lycaenidae (0.93) and Hesperiidae (0.93). In case of the family Papilionidae, it was 0.88 and the lowest value of J' was found in family Riodinidae (0.00). The values of Simpson's reciprocal index (Dr) of the six recorded families from the study site spanned from 1 to 21.11. The picked value of Dr stated the family was highly diverse in species composition, and it was recorded from the family Nymphalidae, followed by Pieridae (10.94), Lycaenidae (9.87), Hesperiidae (6.04), Papilionidae (4.95), Riodinidae (1.00). The result revealed that the family Hesperiidae and Papilionidae were less diverse, and the family Riodinidae had only one species.

Figure 3 showed the species-wise rank abundance curve, namely Whittaker plot which illustrates the species diversity and family-wise rank abundance curve that describes the family diversity. The Whittaker plot elucidates the abundance of the species by the inclination of the curve, high-ranking species are more abundant than the low-ranking species which are less abundant. This plot also reflects the evenness among the different species recorded from the study site by its slope that is a steep gradient in the plot line states low evenness exists among the different observed species in the community as there are two distinct points, one is high-ranking with much higher species abundance and one is low-ranking with less species abundance, while a sallow gradient depicts high evenness among the recorded species as the abundances of different species in the shallow line are similar with each other. The plot (Figure 3i) revealed that the first seven species are higher in abundance with less evenness as there found a steep gradient in the curve. Species rank seventh onwards the abundances of the observed butterfly species were decreased accordingly with increased evenness among the recorded species in the community. When observing the family-wise rank abundance curve (Figure 3ii) of the six families, it was noted that more evenness was in Pieridae, followed by moderate evenness in family Hesperiidae, followed by Nymphalidae, Lycaenidae, Pieridae, Papilionidae.

Table 1: Checklist of butterfly species along with their family, relative abundance, status and WPA Schedule recoded in Alipore Zoological Garden, Kolkata

Sl. No.	Family	Common Name	Scientific name	Relative Abundance (RA)	Status	WPA schedule
1	Nymphalidae	Common Castor	*Ariadne merione*	1.80	VC	
2		Angled Castor	*Ariadne ariadne*	1.35	C	
3		Common Baron	*Euthalia aconthea*	0.79	NR	Schedule II
4		Gaudy Baron	*Euthalia lubentina*	0.02	VR	Schedule IV
5		Plain Tiger	*Danaus chrysippus*	3.08	VC	
6		Striped Tiger	*Danaus genutia*	0.98	C	
7		Common Crow	*Euploea core*	2.62	VC	
8		Common Palmfly	*Elymnias hypermenstra*	2.32	VC	Schedule I
9		Chestnut Tiger	*Parantica sita*	0.59	NR	
10		Common Sailer	*Neptis hylas*	1.06	C	
11		Chestnut-Streaked Sailer	*Neptis jumbah*	1.06	C	
12		Common Sergeant	*Athyma perius*	0.69	NR	
13		Blue Tiger	*Tirumala limniace*	2.02	VC	
14		Five-Bar-Swordtail	*Graphium antiphates*	0.25	NR	
15		Common Evening Brown	*Melanitis leda*	1.29	C	
16		Grey Count	*Tanaecia lepidea*	0.42	NR	Schedule II
17		Glassy Tiger	*Parantica aglea*	1.87	VC	
18		Bamboo Treebrown	*Lethe europa*	0.25	NR	
19		Common Leopard	*Phalanta phalantha*	0.77	NR	
20		Tawny Coster	*Acraea terpsicore*	1.65	C	
21		Yellow Coster	*Acraea issoria*	0.52	NR	
22		Commander	*Moduza procris*	1.29	C	
23		Great Eggfly	*Hypolimnas bolina*	2.25	VC	

24		Chocolate Pansy	*Junonia iphita*	0.67	NR	
25		Lemon Pansy	*Junonia lemonias*	0.52	NR	
26		Peacock Pansy	*Junonia almana*	2.05	VC	
27		Grey Pansy	*Junonia atlites*	2.19	VC	
28		Common Four Ring	*Ypthima huebneri*	0.96	C	Schedule IV
29		Common Five Ring	*Ypthima baldus*	1.36	C	Schedule II
30	Lycaenidae	Lime Blue	*Chilades laius*	0.92	C	
31		Zebra Blue	*Leptotes plinius*	0.20	R	
32		Tiny Grass Blue	*Zizula hylax*	2.66	VC	
33		Gram Blue	*Euchrysops cnejus*	0.64	NR	Schedule II
34		Pea Blue	*Lampides boeticus*	1.82	VC	Schedule II
35		Plains Cupid	*Luthrodes pandava*	1.14	C	
36		Common Ciliate Blue	*Anthene emolus*	0.72	NR	
37		Dark Grass Blue	*Zizeeria karsandra*	2.69	VC	
38		Pale Grass Blue	*Pseudozizeeria maha*	1.35	C	
39		Common Cerulean	*Jamides celeno*	0.32	NR	
40		Plain Cupid	*Catochrysops vapanda*	1.31	C	
41		Forget-Me-Not	*Catochrysops strabo*	0.81	NR	
42		Indian Sunbeam	*Curetis thetis*	0.57	NR	
43		Common Pierrot	*Castalius rosimon*	0.94	C	Schedule I
44	Papilionidae	Common Mime	*Papilio clytia*	1.73	VC	Schedule I
45		Common Mormon	*Papilio polytes*	1.61	C	
46		Lime	*Papilio demoleus*	0.12	R	
47		Common Rose	*Pachliopta aristolochiae*	0.03	VR	
48		Crimson Rose	*Pachliopta hector*	0.91	C	Schedule I
49		Common Jay	*Graphium doson*	1.48	C	
50		Common Bluebottle	*Graphium sarpedon*	1.92	VC	
51	Pieridae	Common Emigrant	*Catopsilia pomona*	3.93	VC	
52		Mottled Emigrant	*Catopsilia pyranthe*	5.06	VC	
53		Indian Cabbage White	*Pieris canidia*	1.61	C	
54		Common Grass Yellow	*Eurema hecabe*	4.94	VC	
55		Small Grass Yellow	*Eurema brigitta*	2.96	VC	
56		Tree Yellow	*Gandaca harina*	1.75	VC	
57		Common Jezebel	*Delias eucharis*	0.67	NR	
58		Psyche	*Leptosia nina*	2.29	VC	
59		Clouded Yellow	*Colias croceus*	2.56	VC	
60		Common Gull	*Cepora nerissa*	2.44	VC	Schedule II
61		Common Albatross	*Appias albina*	2.72	VC	
62		Striped Albatross	*Appias libythea*	4.09	VC	Schedule IV
63		Chocolate Albatross	*Appias lyncida*	2.39	VC	Schedule II
64	Riodinidae	Punchinello	*Zemeros flegyas*	0.08	R	
65	Hesperidae	Chestnut Bob	*Iambrix salsala*	0.27	NR	
66		Dark Small-branded Swift	*Pelopidas mathias*	0.20	R	
67		Small Banded Swift	*Pelopidas mathias*	0.12	R	
68		Grass Demon	*Udaspes folus*	0.13	R	
69		Brown Awl	*Badamia exclamationis*	0.10	R	
70		Commom Banded Awl	*Hasora chromus*	0.27	NR	
71		Indian Skipper	*Spialia galba*	0.55	NR	
72		Common Snowflat	*Tagiades japetus*	0.27	NR	

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

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 diversity index (Ds)	Simpson's index of diversity (D)
3.96	0.92	0.98	0.02

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

Family	Shannon diversity index (H')	Shannon H_{max}	Pielou's evenness index (J')	Simpson's diversity index (Ds)	Simpson's index of diversity (D)	Simpson's reciprocal index (Dr)
Nymphalidae	3.17	3.34	0.94	0.95	0.05	21.11
Lycaenidae	2.44	2.98	0.93	0.90	0.10	9.87
Papilionidae	1.72	2.67	0.88	0.80	0.20	4.95
Pieridae	2.47	3.35	0.96	0.91	0.09	10.94
Riodinidae	0.00	0.70	0.00	0.00	1.00	1.00
Hesperiidae	1.94	2.06	0.93	0.84	0.16	6.04

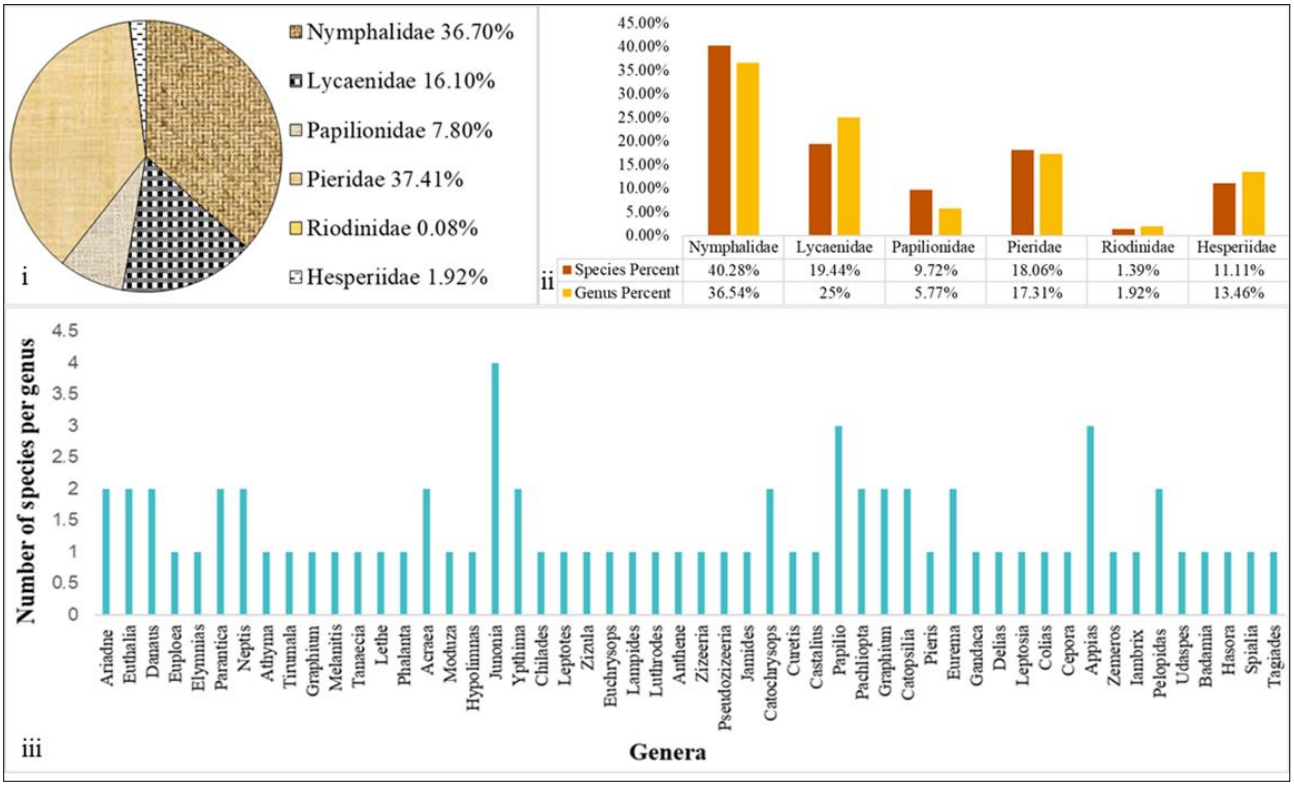

Fig 2: Percentage composition (i), genus to species proportion (ii) of butterflies of six families, and species richness (iii) of the recorded butterfly genera of the study site

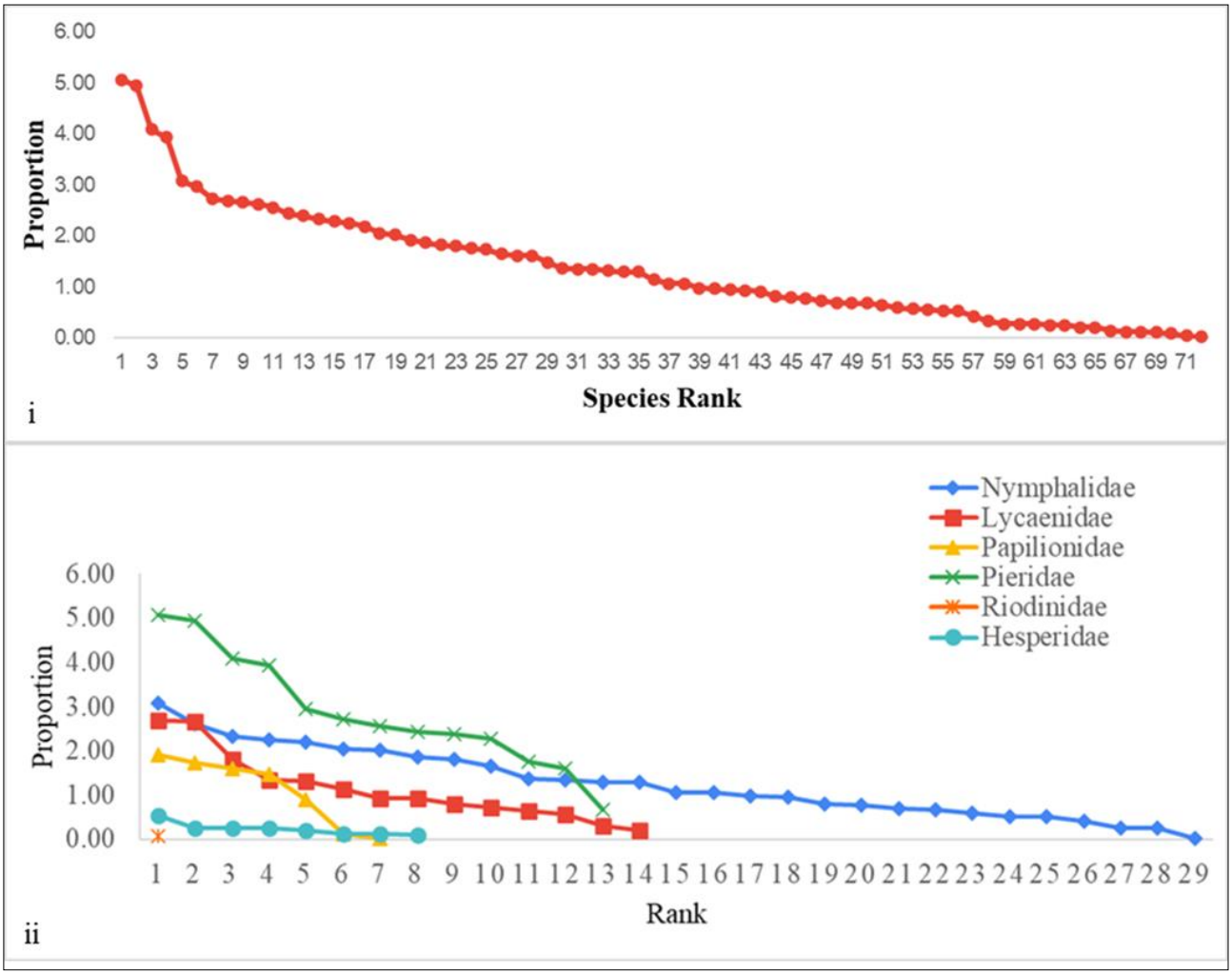

Fig 3: Rank abundance curve of 72 species of butterfly (i) and rank abundance curve of six families of butterfly (ii) in the study area

Discussion

Butterflies are considered as one of the best-known enigmatic insects for their beauty of wing coloration and pattern, their diversity and adaptation in different habitat and environment, and also for their role as an effective ecological indicator of terrestrial ecosystem (Venkataramana, 2010) [48]. Hence, butterflies are the targeted taxa selected for the estimation of biodiversity, which is essential for the assessment of ecosystem conservation and for monitoring of the health of environment (Simonson *et al*., 2001) [42]. Most of the butterfly species' larval stages are greatly host-specific, occupying a narrow niche and thereby forming metapopulations in their preferred habitats. Butterfly diversity and their distribution are adversely affected by anthropogenic activities and urbanization which may often lead to local extinction of butterfly species or sometimes depletion of butterfly population (Patra, 2022) [37]. In earlier studies it was found that a minor change or alteration of their habitat might cause migration or local extinction of native butterfly populations (Kunte, 1997; Blair, 1999; Mennechez *et al*., 2003) [22, 6, 27]. For this reason, shaping of landscape profile by altering the land use pattern in course of ecological succession are depicted easily by the changes in diversity, abundance and distribution of butterfly population (Mukherjee *et al*., 2015) [31].

The present survey-based study on butterfly diversity and abundance in Alipore Zoological Garden, Kolkata was conducted for the first time. Butterfly species richness and evenness is comparable to the earlier studies conducted on the urban areas of India (Sarma *et al*., 2012; Arya *et al*., 2014; Kumar 2014) [40, 1, 19]. A total count of 72 butterfly species belonging to six families were recorded from the study site. In this regard, previous studies carried out in different areas of Kolkata, showed variations in the number of butterfly species with respect to the current study. A total number of 33 butterfly species were reported from Mudialy Ecological Park (Chowdhury and Chowdhury, 2007) [9], 96 species from urban Kolkata (Mukherjee *et al*., 2015) [31], 57 species from the campus of Ramakrishna Mission Vivekananda Centenary College, Rahatra (Bhattacharya *et al*., 2018) [4], 74 butterfly species from East Calcutta Wetland (Chowdhury and Soren, 2011) [10], 33 butterfly species from the Lake Town area (Chowdhury, 2022) [8], 21 species from Rammohan College Campus (Mitra *et al*., 2023) [28]. Butterfly species recorded in the present study was found consistent with some of the earlier studies as well as contradicts with some of the earlier findings. These variations in species richness might be due to variation in the study period, the sample area size and the type of vegetation of the sampled area. If the present study area was dominated by nectar plants and host plants of butterfly species, then it might have a positive impact on the diversity and abundance of butterfly.

In the study area, all the noted butterfly species belonged to six families which was found similar with the earlier studies carried out in East Calcutta wetland (Chowdhury and Soren, 2011) [10]. Although only four butterfly families with relatively less species richness were recorded from Rammohan College campus (Mitra *et al*., 2023) [28]. Few prior studies documented five butterfly families from different region of Kolkata (Mukherjee *et al*., 2015; Mukherjee *et al*., 2016; Bhattacharya *et al*., 2018; Chowdhury, 2022) [31, 30, 4, 8]. This variation in family composition and species richness among different areas of Kolkata was probably due to dissimilar habitats and availability of nectar plants (Kunte, 2000) [23].

In the present study if the number of species were considered then it was noticed that Nymphalidae followed by Pieridae dominated among all the recorded families. This finding was similar with that of previous research reports conducted in Lake Town area (Chowdhury, 2022) [8] and Rammohan College Campus of Kolkata (Mitra *et al*., 2023) [28]. While studies carried out in other region of Kolkata showed that Nymphalidae was the dominant family followed by Lycaenidae (Chowdhury and Soren, 2011; Mukherjee *et al*., 2016; Bhattacharya *et al*., 2018) [10, 30, 4]. On contrary, Mukherjee *et al*. (2016) [30] reported that Lycaenidae was the dominant family in the butterfly community followed by Nymphalidae in their study area, Kolkata city.

In the current study, under the Nymphalidae family, 29 species of butterfly were found from the study site. While 27 species were recorded under Nymphalidae family from Kolkata city (Mukherjee *et al*., 2015) [31], 18 species from Kolkata metropolis (Mukherjee *et al*., 2016) [30], 19 species from Vivekananda centenary college campus (Bhattacharya *et al*., 2018) [4], 24 species from East Calcutta wetlands (Chowdhury and Soren, 2011) [10], 12 species from Rammohan College campus (Mitra *et al*., 2023) [28], 10 species from Lake Town area (Chowdhury, 2022) [8].

Again, under the Pieridae family, 13 species of butterfly were found from the study site. While under this family, 11 species from East Kolkata Wetlands (Chowdhury and Soren, 2011) [10], 9 species from Kolkata metropolis, 12 species from Kolkata city (Mukherjee *et al*., 2015) [31], 6 species from Vivekananda centenary college campus (Bhattacharya *et al*., 2018) [4], 5 species from Rammohan College campus (Mitra *et al*., 2023) [28], 7 species from Lake Town area (Chowdhury, 2022) [8] were documented previously.

When the number of individuals were considered, it was observed that the family Pieridae was found to be dominating the butterfly family of the study site butterfly community, followed by Nymphalidae. A similar trend of finding was reported in the earlier studies conducted in Lake Town area (Chowdhury *et al*., 2022) [8] and Rammohan college campus of Kolkata (Mitra *et al*., 2023) [28]. On the other hand, a discrete pattern of results was obtained from a number of studies conducted in several areas of Kolkata where in some cases, Nymphalidae dominated the sampled area, followed by Lycaenidae (Chowdhury and Soren, 2011; Mukherjee *et al*., 2016; Bhattacharya *et al*., 2018) [10, 30, 4] while in other areas, Lycaenidae dominated the study site followed by Nymphalidae (Chowdhury, 2022; Mitra *et al*., 2023) [8, 28].

Variations observed in these findings might be due to the variation in the nature of habitat of sampling area or its size (Nair *et al*., 2014) [33], type of vegetation (Ockinger and Smith, 2006; Ockinger *et al*., 2006) [36, 35], presence of species-specific larval host plant, prevalent climatic conditions (Bhusal and Khanal, 2008) [5]. Moreover, human interferences provide a negative impact on habitat, broadly on the ecosystem and this anthropogenic effect is a crucial factor for the alteration of the dominance of butterfly family.

Fig 4: Photographs of different butterfly species recorded in the study area.
1. *Catopsilia pyranthe*, 2. *Ariadne merione*, 3. *Danaus genutia*, 4. *Castalius rosimon*, 5. *Acraea terpsicore*, 6. *Junonia atlites*, 7. *Tirumala limniace*, 8. *Junonia iphita*, 9. *Euploea core*

Fig 5: Photographs of different butterfly species recorded in the study area. 10. *Eurema hecabe*, 11. *Graphium doson* 12. *Luthrodes pandava*, 13. *Appias libythea*, 14. *Junonia almanac*, 15. *Danaus chrysippus*, 16. *Ypthima huebneri*, 17. *Elymnias hypermenstra*, 18. *Chilades Laius*

Conclusion

The present study on the butterfly diversity and abundance at Alipore Zoological Garden will act as baseline information about the health of the ecosystem as butterflies are well recognized indicator species of the ecosystem. The information gathered from this study can serve as a precious reference information for future researches. These reports are greatly needed to determine the anthropogenic effect on the study area because these charismatic creatures are sensitive to minor changes in the environment. The current study area was large in size provided with dense vegetation and gardens of flowering plants and also with host plants which supported the butterfly diversity of this area. Current observations on the butterfly diversity of Alipore Zoological Garden reflected that the sampled site was a healthy green patch within the heavily populated urbanized city, Kolkata. For this reason, maintenance of these green patches along with the butterfly fauna is recommended for long-term sustenance of ecosystem services. Moreover, further studies on butterfly communities covering more study areas within the Kolkata city may effectively inform about the health of Kolkata and impart the need of implementation of better conservation efforts for the busiest city.

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