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Butterfly diversity throughout Midnapore urban area in West Bengal, India

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Abstract: Butterflies have always attracted attention due to their unique colourations. As most butterflies are highly specific in their niche utilisation, abundance of the species in a locality may advocate status of ecosystem functioning and environmental health. In recent times, different anthropogenic activities and unscientific management of nature have resulted in a decline of butterfly communities at a rapid rate. The objective of the present study is to study butterfly diversity in and around Midnapore Town, West Bengal, India. A total of 82 butterfly species belonging to six families were recorded during the two years of the study period. Of the six families Nymphalidae is the most abundant family comprising 42.54% of the total population followed by Lycaenidae (22.5%), Pieridae (19.03%), Papilionidae (8.58%), Hesperiidae (7.24%), and Riodinidae (0.11%). Different diversity indices, Lorenz curve, Whittaker plot, and Gini index show high diversity in the butterfly community structure. As Midnapore Town is the connecting area between the plains of Bengal and Chota Nagpur Plateau, the present study may be the baseline for further ecological, environmental, and conservation studies.

Keywords: Chota Nagpur Plateau, diversity indices, Lepidoptera, Lorenz curve, Nymphalidae, plains of Bengal.

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Author contributions: DP, SR, SKG collected the field data, SP prepared the map of study area, SJB and AH participated in planning and guiding the study, evaluation of results and performed statistical analysis. All authors participated in preparing the final version of the manuscript.

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INTRODUCTION

Butterflies play a pivotal roles for stability in food webs as: herbivores (Rusman et al. 2016), pollinators (Atmowidi et al. 2007; Mukherjee et al. 2015), host of parasitoids (van Nouhuys & Hanski 2002), and prey of predators (Hammond & Miller 1998; Rusman et al. 2016). Numerous butterfly species act as biological indicators of environmental health and ecological changes (Hill 1999; Kocher & Williams 2000; Koh & Sodhi 2004; Thomas 2005; Posha & Sodhi 2006; Koh 2007) as they can be very sensitive to habitat fragmentation and climate change (Kunte 2000). Butterflies contribute to a large extent in maintaining the community structure of flora in the tropical regions (Bonebrake et al. 2010; Samanta et al. 2017).

Empirical studies show that the Indian subcontinent hosts about 1,318 species of butterflies (Varshney & Smetacek 2015). Over the last few decades, however, various anthropogenic activities and sudden climatic change conditions have led to modification of the habitat structure and function which in turn negatively influenced butterfly diversity (Clark et al. 2007; Di Mauro et al. 2007). Therefore, the diversity studies of butterflies are critical to determine the effects of urbanization on butterfly communities and other aspects of biodiversity conservation (Blair 1999; Singh & Pandey 2004; Clark et al. 2007; Di Mauro et al. 2007; Saikia et al. 2009; Mukherjee et al. 2015). Butterfly diversity indirectly also reflects the diversity of various plant communities (Murugesan et al. 2013; Mukherjee et al. 2016). Pollard (1988) reported that biotic and abiotic factors also influence butterfly populations, indicating the bio-indication potential of the group. There are numerous reports by various investigators on butterfly diversity from different parts of India (Bhaskaran & Eswaran 2005; Eswaran & Pramod 2005; Tiple & Khurad 2009; Nimbalkar et al. 2011; Tiple 2011; Kunte et al. 2012; Majumder et al. 2012; Tiple 2012; Harsh 2014).

Midnapore is the headquarters of the district West Midnapore of the state of West Bengal in India. It is in the junction of the plains of Bengal and Chota Nagpur Plateau. The plains of Bengal are enriched mostly with agricultural fields where as the Chota Nagpur Plateau is mostly tropical deciduous forestland. Since no systematic study of diversity of butterfly fauna was ever conducted in and around Midnapore Municipality area there is no documentation, the present investigation was carried out to explore the status of butterfly fauna in Midnapore Municipal area.

MATERIALS AND METHODS

Study Area

The study was conducted in and around Midnapore Municipality area of West Midnapore District of West Bengal, India. The study area (22.262^{0}N & 87.654^{0}E; elevation about 1,035m) is situated on the banks of river Kangasabati on one side and the other side consists of sparse to highly dense forest, chiefly of *Shorea robusta*, which connects with Dalma Hills and is the entry point of Bengal-Jharkhand hill range of Chota Nagpur Plateau. This range is often used as an elephant corridor, though the town is not affected by elephants. Several adjacent areas like Gopegarh Heritage Park, Banks of Kasai River adjacent to the railway track, Vidyasagar Park, Khudiram Park, area adjacent to Aniket Bandh, Pakhibagan, Vidyasagar University Campus, area adjacent to government Silkworm Centre, Police Line field, and Ramakrishna Ashram field were the main points of study area (Figure 1).

Methods

The survey of butterflies was done using Pollard walk method (Pollard et al. 1975; Pollard 1977). The surveys of butterflies were carried out in most of the designated areas during day time mostly on sunny days (07.00 to 10.00 h). Occasional surveys were also undertaken during early morning and even after 16.00h in search of the butterflies that love shadows during summer months. The study areas were mainly divided into 12 sites and conducted on regular basis through random visit and photographs of most of the species were taken all over the year. The line transect method was used principally for assessing the butterfly communities (Hossain & Aditya 2016). We refrained from collection of live specimens or use of nets so as not to put these insects under stress or harm them accidentally during the investigation. Most of the species were identified through photographs taken from different angle so as to make a positive identification. Photographs were taken using Canon 600D +(55-250) mm f/4-5.6 lens and a Nikon L820 point & shoot camera. Identification of specimen was done following the keys of Evans (1932), Wynter-Blyth (1957), Kehimkar (2008), and Kunte (2012). Further, help was also taken from www.ifoundbutterflies.org.

Biodiversity indices

Different dominance indices and information statistic indices were analysed with the help of Microsoft Excel 2010 software to understand the community structure

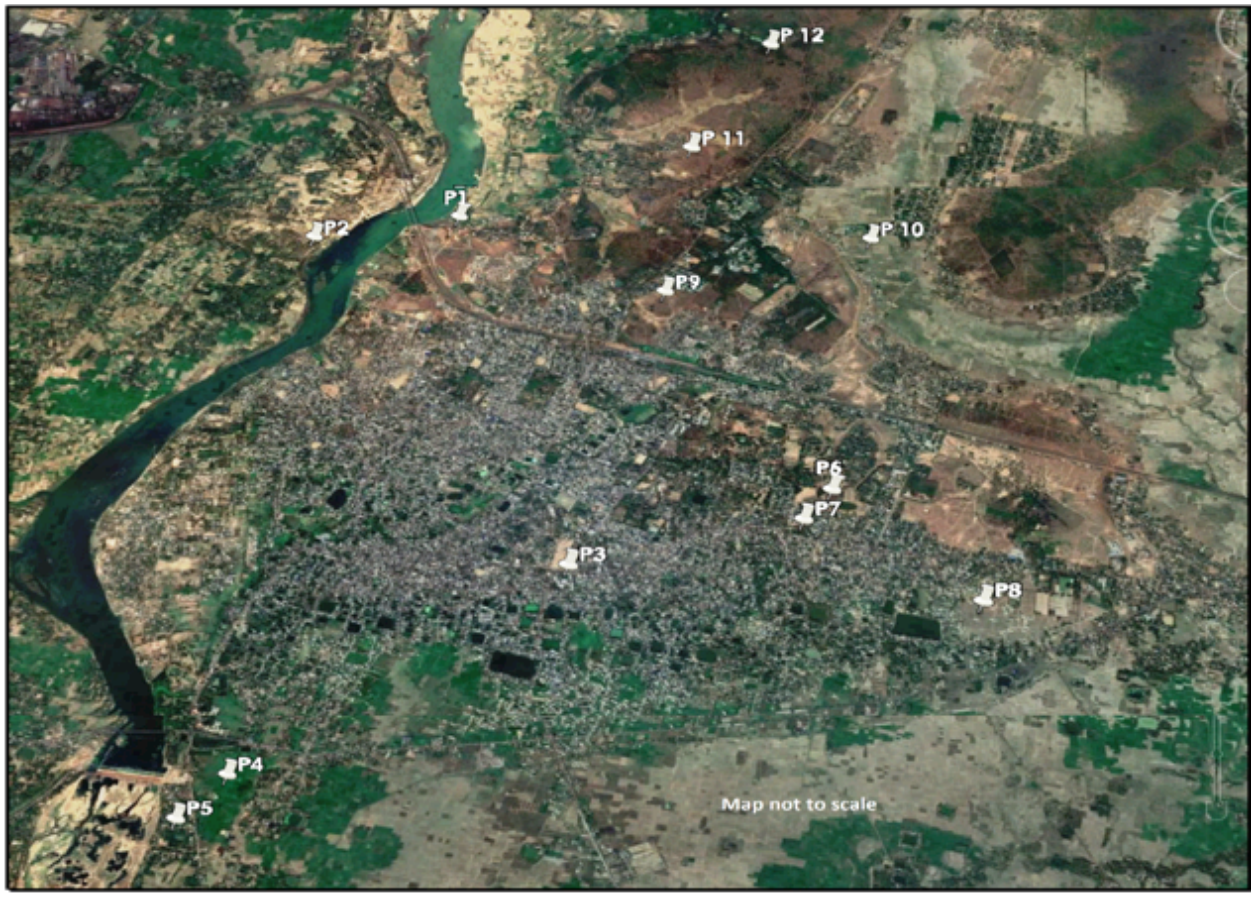

Figure 1. Satellite view of twelve sites of the study area. The sites are as follows: Banks of Kasai river adjacent to railway track (P1), Vidyasagar park (P2), Midnapore College campus (P3) Khudiram park (P4), area adjacent to Aniket Bandh (P5), Policeline Field (P6), Pakhibagan (P7), Ramakrishna ashram field (P8), Vidyasagar University Campus (P9), area adjacent to government Silkworm Centre (P10) and Gopegarh Heritage Park (P11 and P12).

of the butterflies in the study area. Species richness was analysed through Shanon index (Shannon & Weaver 1963) whereas, species abundance was analysed through Simpson index (Simpson 1964) and evenness was studied through Pielou index (Mulder et al. 2004). A rank abundance curve or Whittaker plot was used to show relative abundance of different species. The plot simultaneously represents species richness and species evenness. Lorenz curve was used to show inequality in the population distribution of different species in the community (Damgaard & Weiner 2000).

Species Richness

Shanon index is an important information-statistic index, used in measuring species richness in a community. Rare species with very few individuals can contribute some value to this biodiversity index. The index is calculated through the following equation:

$H_s = -\Sigma\, p_i \ln p_i$

where, H_s is the value of Shanon index and pi is the proportion of i^{th} species in the community.

Species Abundance

Simpson's index is the measures of probability that two individuals randomly selected from a community will belong to the same species. Simpson's index was calculated using the protocol given by Simpson 1964 (Simpson 1964):

$\lambda = \Sigma\, p_i^2$

where, λ is the value of Simpson index and p_i is the proportion of i^{th} species in the community.

Species Evenness

Species evenness denotes how close the species are in a community numerically. Statistically it is well-defined as a degree of species diversity which quantifies how equal the community is. Evenness of species in a community can be represented by Pielou's index (Pielou

1969), as follows:

$E = H_s / H_{max}$ where, E is the evenness, H_s is the value of Shanon index and H_{max} is equal to ln(s) (Where, S=number of species in the community)

Whittaker plot and Lorenz curve

Whittaker plot or rank-abundance curve is a graphical representation used in ecology to display relative species abundance. In the rank abundance curve, the X-axis is denoted as abundance rank and Y-axis is denoted as relative abundance. Further, it is used to visualize species richness and evenness simultaneously (Whittaker 1965). Lorenz curves were used to demonstrate phenomena such as disproportionate distribution of species abundance in a community. This curve was also used to demonstrate degree of inequality in abundance in a community. Quantitative comparison of rank abundance curves of different families of butterflies can demonstrate the unequal distribution of species.

SHE analysis

SHE analysis scrutinizes the relationship between species richness (S), diversity as measured by Shanon index or the information (H) and evenness (E) in the samples. The most obvious advantage of this analysis is that it allows to interpret variations in the diversity (Magurran 1988). SHE analysis fundamentally can shed light on the species abundance and distribution (Buzas & Hayek 1998). The SHE analysis (McAleece et al. 1997) provides the variations in the species richness, abundance and evenness in the sample size (N) or throughout the months (N, over time) abundance for an area (Mukherjee et al. 2015) in a nutshell. The analysis for SHE was conducted using PAST software (Hammer et al. 2001).

RESULTS AND DISCUSSION

During the present study period overall 82 species of butterflies were recorded in the field with a total of 5,107 individuals belonging to six families. The list of the butterflies along with their occurrence and time of appearance has been listed in Table 1. Of the butterfly species recorded, most are 'common' and 'generalist' species (Sarma et al. 2012), and not a single species is threatened globally as per the IUCN Red List 2018, however, there are many species which were declared legally protected, viz., Gram Blue *Euchrysops cnejus*, Pointed Ciliate Blue *Anthene lycaenina*, Common Gull *Cepora nerissa* under Schedule II, and Striped Albatross *Appias libythea* under Schedule IV of the Wildlife Protection Act, 1972. The study shows higher species richness when compared with other empirical studies (Jana et al. 2013; Samanta et al. 2017; Pahari et al. 2018) on butterfly diversity in the nearby urban and forested areas except Kolkata's suburban areas which shows 91 species (Mukherjee et al. 2015).

Satellite overview of the marked study area have been represented in Figure 1. During the study period we found that family Nymphalidae is the dominant species comprising 2,173 number of individuals which constitutes 42.54% of the total population followed by Lycaenidae comprising 1,153 numbers of individuals and 22.5%, followed by Pieridae (971 individuals and 19.03%), Papilionidae (438 and 8.58%), Hesperiidae (370 and 7.24%), and Riodinidae (2 and 0.11%) (Figure 2). Previous study support Nymphalidae as the most dominant family in the semi-urban areas of Howrah and Haldia (Pahari et al. 2018) whereas, Lycaenidae as the most dominant family in the suburban areas of Kolkata, West Bengal (Mukherjee et al. 2015).

Papilio polytes which belongs to family Papilionidae was found to be the most abundant while *Papilio crino* was the least. In the family Pieridae, *Catopsilia pomona* was more predominant than other species but we found only a single species of *Ixias marianne*. In the family Nymphalidae we found that *Danais chrysippus* was the most common species while *Lethe europa* was the least.

The Shanon-Weaver index for the studied community with a value of 4.01 shows that the community is a natural one with high species richness. As the value of Simpson index increases, the species abundance decreases. The value of Simpson's index ranges between 0 and 1 and the more the index value inclined to 0 the more the species abundance in the community. The value of Simpson's

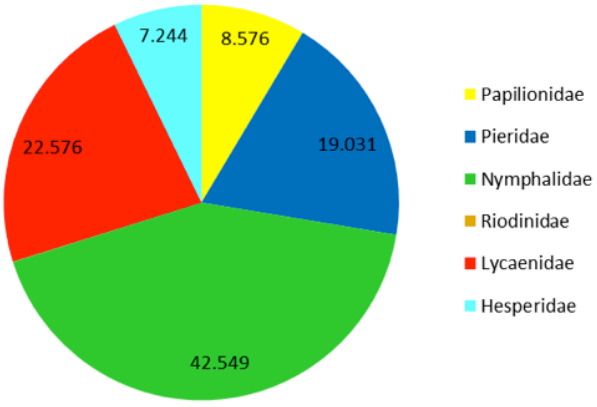

Figure 2. Family wise composition (%) of Butterfly species in the study area.

Table1. Butterfly species, their abundance and season of occurrence in the study area.

	Common name	Scientific name	Total number of species found during study period (2013–2015)	Season	Observed time (M/N/A)
Family: Papilionidae					
1	Common Rose	*Atrophaneura aristolochiae* (Fabricius)	78	Feb–Nov	M, N
2	Common Mormon	*Papilio polytes* (Linnaeus)	126	Jan-Dec	M, N
3	Blue Mormon	*Papilio polymnestor* (Cramer)	12	Aug-Nov	M, N
4	Common Jay	*Graphium doson* (Felder)	63	Jan-Dec	N
5	Tailed Jay	*Graphium agamemnon* (Linnaeus)	44	May-Nov	N
6	Lime Butterfly or Common Lime	*Papilio demoleus* (Linnaeus)	81	Jan-Dec	M, N, A
7	Common Mime	*Chilasa clytia* (Linnaeus)	19	Aug-Oct	N, A
9	Common-banded Peacock	*Papilio crino* (Fabricius)	4	Jul-Aug	A
10	Spot bar Swordtail	*Graphium nomius* (Esper)	11	Jun-Oct	M, A
Family: Pieridae					
11	Common Albatross	*Appias albino* (Boisduval)	59	Mar-Nov	M
12	Common Emigrant	*Catopsilia pomona* (Fabricius)	196	Jan-Dec	M, N, A
13	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus)	171	Jan-Dec	M, A
14	Common Grass Yellow	*Eurema hecabe* (Linnaeus)	124	Jan-Dec	M, N, A
15	Small Grass Yellow	*Eurema brigitta* (Cramer)	49	Jun-Oct	
16	Pioneer	*Belenois aurota* (Fabricius)	6	Jul-Aug	A
17	Common Gull	*Cepora nerissa* (Fabricius)	63	Mar-Dec	M, N
18	Common Jezebel	*Delias eucharis* (Drury)	97	Jan-Dec	M, A
19	White Orange tip	*Ixias marianne* (Cramer)	1	Sept	M,A
20	Yellow Orange tip	*Ixias pyrene* (Linnaeus)	15	Apr-Oct	M, A
21	Psyche	*Leptosia nina* (Fabricius)	104	Jan-Dec	M, N, A
22	Common Wanderer	*Pareronia valeria* (Cramer)	86	Jun-Dec	N
Family: Nymphalidae					
23	Common Castor	*Ariadne merione* (Cramer)	43	Mar-Oct	M, A
24	Angled Castor	*Ariadne ariadne* (Moore)	119	Jan-Dec	M, N, A
25	Tawny Coster	*Acraea violae* (Fabricius)	143	Feb-Nov	M, A
26	Plain Tiger	*Danais chrysippus* (Linnaeus)	211	Jan-Dec	M, N, A
27	Stripped Tiger	*Danais genutia* (Cramer)	82	Feb-Nov	M, N, A
28	Common Crow	*Euploea core* (Cramer)	131	Jan-Dec	M, N, A
29	Blue Tiger	*Tirumala limniace* (Cramer)	64	Mar-Nov	M, A
30	Common Leopard	*Phalanta phalantha* (Drury)	37	Mar-Dec	N
31	Baronet	*Symphaedra nais* (Forster)	34	Mar-Sept	M, A
32	Common Baron	*Euthalia aconthea* (Cramer)	27	Mar-Oct	A
33	Common Sailor	*Neptis hylas* (Linnaeus)	18	Feb-Nov	M, N
34	Chestnut-streaked Sailor	*Neptis jumbah* (Moore)	19	Feb-Nov	M, N, A
35	Great Eggfly	*Hypolimnas bolina* (Linnaeus)	49	Jan-Dec	N, A
36	Peacock Pansy	*Junonia almanac* (Linnaeus)	94	Jan-Dec	N, A
37	Blue Pansy	*Junonia orithya* (Linnaeus)	66	Mar-Oct	M, N, A
38	Yellow Pansy	*Junonia hierta* (Fabricius)	47	Jan-May	M, A
39	Lemon Pansy	*Junonia lemonias* (Linnaeus)	138	Jan-Dec	N, A
40	Grey Pansy	*Junonia atlites* (Linnaeus)	161	Jan-Dec	N, A
41	Chocolate Pansy	*Junonia iphita* (Cramer)	39	Apr, Oct	N
42	Common Palmfly	*Elymnias hypermnestra* (Linnaeus)	50	Dec- May	N, A

	Common name	Scientific name	Total number of species found during study period (2013–2015)	Season	Observed time (M/N/A)
43	Common Evening brown	*Melanitis leda* (Linnaeus)	182	Jan-Dec	M, A
44	Common Bush Brown	*Mycalesis perseus* (Fabricus)	163	Jan-Dec	A
45	Dark Branded Bushbrown	*Mycalesis mineus* (Linnaeus)	43	Oct-Mar	N, A
46	Common Fourring	*Ypthima huebneri* (Kirby)	121	Jan-Deb	M, A
47	Common Fivering	*Ypthima baldus* (Fabricus)	33	May-Oct	N
48	Bamboo Tree brown	*Lethe europa* (Fabricus)	3	Mar	M
49	Commander	*Moduza procris* (Cramer)	56	Jun-Nov	M, N
Family: Riodinidae					
50	Double-banded Judy	*Abisara bifasciata* (Moore)	2	Dec-Mar	N
Family: Lycaenidae					
51	Ape Fly	*Spalgis epius* (Westwood)	9	Mar-Nov	M, N
52	Common Pierrot	*Castalius rosimon* (Fabricius)	144	Jan-Dec	M, N
53	Common Cerulean	*Jamides celens* (Cramer)	49	Jul-Oct	M, N
54	Common Lineblue	*Prosotas nora* (Felder)	33	Jan-Oct	M, N
55	Common Quacker	*Neopithecops zalmora* (Butler)	31	Jul-Nov	N, A
56	Common Silverline	*Spindasis vulcanus* (Fabricius)	67	Jun-Nov	M, N
57	Dark Cerulean	*Jamides bochus* (Stoll)	5	Mar-Apr	A
58	Dark Grassblue	*Zizeeria karsandra* (Moore)	167	Jan-Dec	M, N, A
59	Falcate Oakblue	*Mahathala ameria* (Hewitson)	8	Apr-Nov	M, N
60	Gram Blue	*Euchrysops cnejus* (Fabricius)	96	Jan-Dec	M, N, A
61	Indian oakblue	*Arhopala atrax* (Hewitson)	12	Jun-Jul	
62	Lesser Grassblue	*Zizina otis* (Fabricius)	17	Jul-Oct	M, N
63	Lime Blue	*Chilades lajus* (Stoll)	121	Feb-Nov	M, N, A
64	Tailless Lineblue	*Prosotas dubiosa indica* (Evans)	5	Jul	N
65	Oriental Grass Jewel	*Freyeria putli* (Stoll)	4	Mar-Aug	
66	Pale Grass Blue	*Pseudozizeeria maha* (Kollar)	109	Mar-Oct	
67	Plains Cupid	*Chilades pandava* (Horsfield)	38	May-Sep	M, N, A
68	Rounded Pierrot	*Tarucus nara* (Kollar)	146	Mar-Oct	N, A
69	Slate Flash	*Rapala manea* (Hewitson)	64	Mar-Dec	M
70	Zebra Blue	*Leptotes plinius* (Fabricius)	17	May-Jul	M, A
71	Pea Blue	*Lampides boeticus* (Linnaeus)	11	Oct-Nov	N
Family: Hesperiidae					
72	Brown Awl	*Badamia exclamationis* (Fabricius)	14	Jun-Aug	N, A
73	Chestnut Bob	*Lambrix salsala* (Moore)	78	Jan-Dec	M, N
74	Common branded Awl	*Hasora chromus* (Cramer)	2	Aug	M
75	Common snow Flat	*Tagiades japetus* (Stoll)	13	Nov-Jan	M
76	Forest Hopper	*Astictopterus jama* (Felder and Felder)	1	Oct	M
77	Indian Grizzle Skipper	*Spialia galba* (Fabricius)	29	May-Jul	M, A
78	Moore Ace	*Halpe porus* (Mabille)	2	Jul-Aug	N
79	Indian Palm Bob	*Suastus gremius* (Fabricius)	74	Jan-Dec	M, N
80	Tree Flitter	*Hyarotis adrastus* (Stoll)	52	Sep-Feb	M
81	Common Redeye	*Matapa aria* (Moore)	82	Feb-Nov	M, N, A
82	Grass Demon	*Udaspes tolus* (Cramer)	23	Aug-Dec	M, N, A

M—morning (05.00–10.59) | N—noon (11.00–15.59) | A—afternoon: (16.00–19.00).

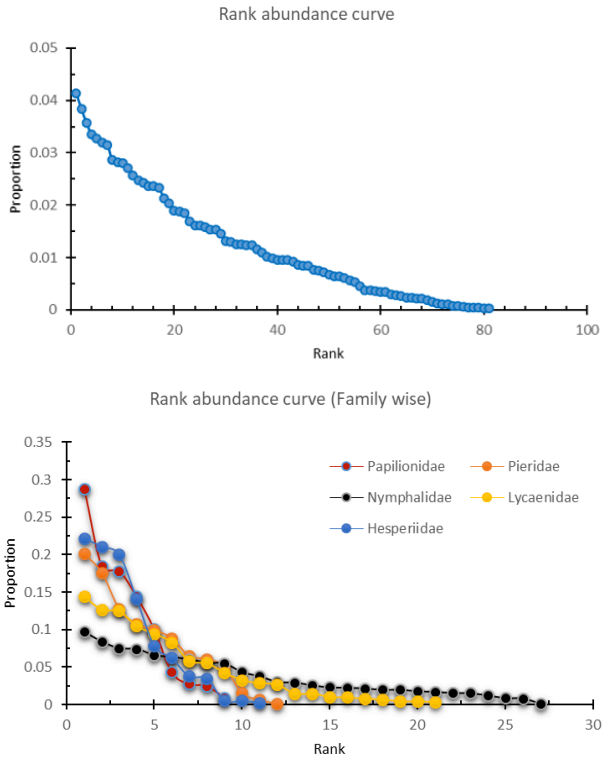

Figure 3. A. Whittaker plot of rank-abundance of the butterfly community B. Family wise rank-abundance curve

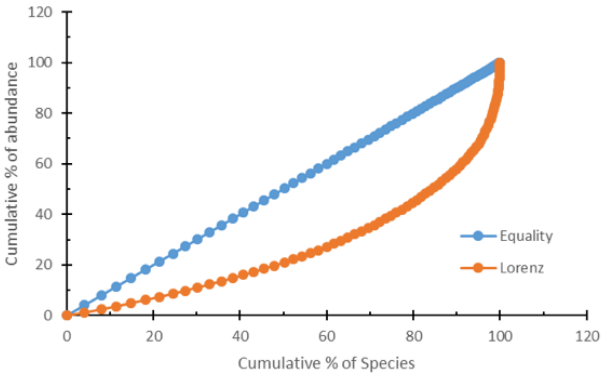

Figure 4. Lorenz curve showing inequality in species richness and abundance.

Table 2. Values of different biodiversity indices.

Shanon Index	Simpson Index	Pielou Index	Lorenz Curve	
4.01	0.02	0.91	Lorenz Area	Gini Index
			13.46	0.2692

index in this study is 0.021 that shows an intuitive high proportion to species abundance. As we know the value of Pielou's index ranges between 0 and 1 and the more the index value reaches 1 the more the evenness in the community. The species evenness (E=0.91) calculated for the studied community shows high evenness (Table 2).

The rank abundance curve for the community has a relatively low steep inclination in Whittaker plot showing high evenness as the high-ranking species have much lower abundances than the low-ranking species. A low gradient dictates high evenness among the different species (Figure 3 A). The rank-abundance curve when compared family wise (Figure 3 B) shows that family Nymphalidae has the highest species evenness, whereas family Papilionidae has the lowest species evenness. In Lorenz curve (Figure 4) a perfectly equal species abundance would be one in which every species has the same population size. The Gini coefficient is the ratio of the area between the line of equality and Lorenz curve. It ranges between 0 and 1. The higher the Gini coefficient, the more unequal the population distribution (Gini 1936). In the present study (Table 2) the Gini coefficient value is 0.269 that supports the species richness and species abundance demonstrated through the Shanon and Simpson index.

Observations on SHE graphs of monthly variations in richness and abundance of butterfly species clearly indicate log series pattern of distribution, where S will increase, H will remain constant and E will decrease (Figure 5) (Hayek & Buzas 1997; Buzas & Hayek 2005; Magurran 2004). It seems that the butterfly abundance increased in winter and post monsoon and decreased in summer and monsoon. This may be due to the changes in the temperature in this lateritic soil area and high precipitation in the monsoon may cause destruction of the habitats as well as food supply of most of the species concerned.

CONCLUSION

The present report on the butterflies in and around Midnapore Municipality area is the first of its kind. There are no such records on the studies of butterflies earlier from the region. Butterflies are susceptible to subtle changes in landscape, land use patterns and vegetation loss, therefore, utmost care should be taken to preserve not only butterflies but also the species that support them. Percentage-wise distribution of the family Riodinidae was the lowest so it might be that the habitat of the study areas and climate of the region was not suitable for the family in the present investigation

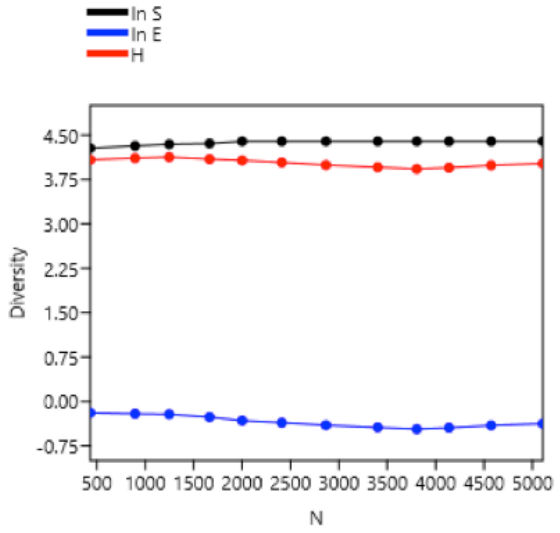

Figure 5. Graphical representation of SHE analysis, obtained from PAST 3.20 software, calculated from the data of relative abundances of 82 butterfly species in 12 months (samples) of two consecutive years in and around Midnapore urban area.

which warrants independent investigations. During our study we encountered that butterflies were abundant during post monsoon and monsoon while at other times (winter and summer) their population dwindled which may be due to less rainfall in winter, scorching heat and long dry spells during summer. The Shanon-Weaver index for the studied community shows high species richness. Simpson's index shows an intuitive high proportion to species abundance. The species evenness (E=0.91) calculated through Pielou's index shows high evenness. A low gradient in rank-abundance curve dictates high evenness among the different species. Gini coefficient (0.269) in the present study supports well about the species richness and species abundance demonstrated through the Shanon and Simpson index. SHE analysis indicate log series distribution of the butterfly species throughout the year in the studied area. Such studies can generate or inculcate interest among students, locals and authorities to save or conserve these pollinators and their habitat, also its conservation is essential for sustainable development.

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Images 1–18. Photographs of some representative butterfly species in their habitats. © Debarun Patra and Soumyajit Roy.
1—*Pachliopta aristolochiae* | 2—*Papilio polytes* | 3—*Delias eucharis* | 4—*Graphium agamemnon* | 5—*Papilio demoleus* | 6—*Papilio clytia* | 7—*Euthalia nais* | 8—*Papilio crino* | 9—*Graphium nomius* | 10—*Neptis hylas* | 11—*Neptis jumbah* | 12—*Belenois aurota* | 13—*Hypolimnas bolina* | 14—*Junonia iphita* | 15—*Junonia lemonias* | 16—*Junonia orithya* | 17—*Junonia almanac* | 18—*Junonia hierta*.

Images 19–36. Photographs of some representative butterfly species in their habitats. © Debarun Patra and Soumyajit Roy.
19–*Spalgis epius* | 20—*Badamia exclamationis* | 21—*Lambrix salsala* | 22—*Jamides celens* | 23—*Prosotas nora* | 24—*Castalius rosimon* | 25—*Neopithecops zalmora* | 26—*Matapa aria* | 27—*Tagiades japetus* | 28—*Zizina labradus* | 29—*Mahathala ameria* | 30—*Euchrysops cnejus* | 31—*Udaspes tolus* | 32—*Spialia galba* | 33—*Zizina otis* | 34—*Chilades lajus* | 35—*Suastus gremius* | 36—*Chilades pandava.*

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