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ARTICLE

Butterfly Diversity in Relation to Human-Impact Gradient in Outskirts of Kolkata, West Bengal, India

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ABSTRACT

Anthropogenic activities may affect species diversity and community structure. Butterfly species diversity in relation to human-impact gradient was evaluated in the Baruipur subdivision, outskirts of Kolkata metropolis, West Bengal, India as a model geographic area. Four study sites situated in bird sanctuaries, rural, suburban and urban areas with different levels of anthropogenic disturbances were selected to assess the human impact on butterfly diversity. A total of 80 butterfly species were recorded during the entire study period with the sanctuary (with minimal anthropogenic disturbance) showing the highest species richness (73) followed by rural (62), suburban (54) and urban (36) study sites indicating a strong negative impact of anthropogenic disturbance on butterfly species diversity. Butterfly species diversity varied significantly among different habitats ($p < 0.001$). The relative abundance of butterflies also varied seasonally. It is apparent that the area under the present study is able to sustain diverse butterfly species provided natural habitats are protected from anthropogenic disturbances and steps are taken to increase urban greenery to support butterfly diversity and consequent ecosystem services.

1. Introduction

Butterflies are considered as charismatic species with multiple functional roles, many of which are recognized as ecosystem services for human well-being [1-3]. In almost all types of terrestrial ecosystems, butterflies are common elements involved in pollination, and herbivory, and serve as prey to several predators, thereby playing a crucial role in the maintenance of ecosystem structure and function [4]. Butterflies are a taxonomically well-studied group throughout the world [5] and are indicator taxa in terms of habitat quality and anthropogenic disturbance [6]. More than 18,000 butterfly species have been documented worldwide [7-9] including 1,311 species reported from India [10]. The number of Indian butterflies accounts for one-fifth of the world's fauna [11]. Butterflies are very sensitive to changes in microclimate [12]. Very specific and narrow niche occupancy is exhibited by the early developmental stages of most butterfly species resulting in metapopula-

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tions depending on a network of suitable habitats [13,14]. Therefore, the loss of butterflies from any community would start the "butterfly effect" continuing to affect the entire ecosystem [15]. Minor changes in habitat may lead to migration or local extinction of native butterfly populations [16-18]. Quite significantly, the changes in the land use pattern leading to changes in landscape profile as a part of the ecological succession, are reflected very vividly by the changes in butterfly diversity and distribution [19]. Anthropogenic interferences like urbanization and industrialization along with agricultural intensification cause migration or local extinction of butterflies [18]. Urbanization is generally associated with habitat loss, habitat degradation, and fragmentation, including local extinction of plant and animal species diversity and reduction of resource quality [20-25], and deterioration of habitat quality [26,27]. Perhaps the changes in the environmental variables linked with the urbanization process bring about a shift in the community organization of different species, both plants, and dependent animals. Information on selected taxa along urban to rural gradients has been the focus of many ecological studies [17,28-31] because human modification of the landscape along urban to rural gradients provides information at different spatial scales [32]. Besides urbanization, agricultural intensification also affects biodiversity. Pollen and nectar-feeding insects like butterflies are affected mainly by agricultural intensification [33,34] because their existence is directly affected by pesticides and other agricultural chemicals [35]. As a consequence, both the urbanization process as well as the changing pattern of agricultural practices affects the species organization at the landscape levels. Thus, they are considered to be Umbrella species for conservation planning and management [36]. Butterflies act as a rapid indicator of habitat quality [37] and these are one of the most suitable tools for biodiversity studies [38]. Monitoring species diversity of semi-urban ecosystems can be used as a tool to reduce pollution resulting from rural management processes, urbanization, and industrialization [39]. Habitat alterations are with direct effect on the local faunal composition and their dynamics [40,41]. Therefore, exploration of the butterfly species composition across the urbanization gradient assumes importance for the urban areas across the world for monitoring the environmental quality of the concerned regions. Further, butterflies can act as a role model group from the conservational point of view [42,43].

In the present study, an attempt has been made to explore and analyze the impact of anthropogenic disturbances on butterfly species diversity along urban to rural gradient in Baruipur Subdivision, Kolkata outskirts, West Bengal, India. One of the guiding questions behind the study was whether butterfly diversity will follow the popular 'intermediate disturbance hypothesis' which predicts maximum diversity at a moderate disturbance level. The aim of the study was to highlight the species richness and abundance of the butterflies as shaped by the plant species assemblages along a human impact gradient of four different spatial scales urban, suburban, rural areas, and a sanctuary within Baruipur subdivision, Kolkata as a focal geographical region and prepare a checklist of butterflies for further scientific studies.

2. Material and Methods

2.1 Study Area

The present study was conducted at four different study sites (Site 1, 2, 3, and 4) with different levels of anthropogenic disturbances along four different spatial scales urban, suburban, and rural areas, and a bird sanctuary (Chintamanikar Bird Sanctuary) situated in a suburban area within the Baruipur subdivision, about 30 km south to the Kolkata metropolis, West Bengal, India as a focal geographical region (Figure 1). The level of anthropogenic disturbances was determined based on the population density of the study sites (Table 1) assuming that places with low population density should have a low level of anthropogenic disturbances. The bird sanctuary being a protected area has no human settlement and experiences minimum anthropogenic disturbance. Baruipur subdivision is located in the South 24 Parganas District, the southernmost part of West Bengal, India. The district has a network of rivers and a cluster of islands. South 24 Parganas lies between latitude 20.20° to 22.06°N and 88.20° to 88.60°E. The district is surrounded by North 24 Parganas to the North, Howrah to the North West, East Midnapur to the West, the Bay of Bengal to the South, and East Bangladesh. The region receives an annual rainfall of about 1750 mm to 1770 mm, the temperature varies between 36.3 °C in summer and 13.6 °C in winter, and relative humidity ranges between 71% and 85%. The Baruipur subdivision (22.3597°N 88.4318°E) is in the close vicinity of the Kolkata metropolis on one side while the other side is in contact with the southern part of the district characterized by rural agricultural lands extending up to the Sundarbans. Few large irrigation canals and the Adi Ganga river flows through the subdivision.

The name, geographic location, habitat, and vegetation types of the four study sites are presented in Table 1. The selection of study sites was made based on the range of habitat types with different anthropogenic disturbances and ease of access for observation of butterfly diversity. Site 1, the Chintamanikar Bird Sanctuary is a

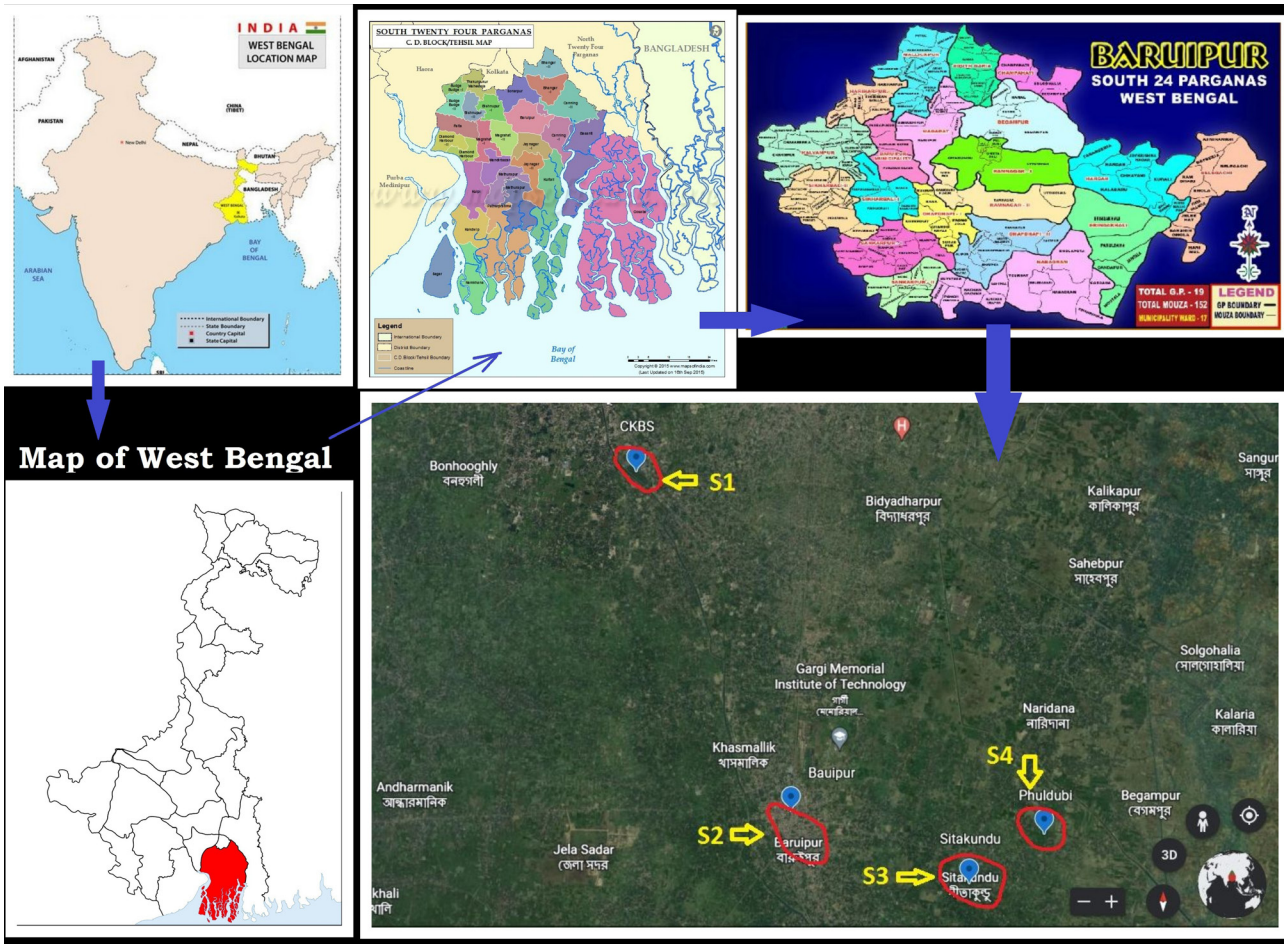

Figure 1. Google image showing the vegetation cover and land use pattern of study sites (S-1, S-2, S-3 and S-4) under present study in Baruipur Sub-division of South 24 Parganas District, West Bengal, India.

Table 1. Name, geographic location, habitat and vegetation types of the four study sites.

Study site	Geographic location	Population density /km^2*	Habitat and vegetation type
Site 1, Chintamanikar Bird Sanctuary	22.4293171°N 88.3984959°E	0	A sanctuary with well wooded areas having bushes and large trees; least anthropogenic disturbances.
Site 2, Adjoining areas of Baruipur Railway Station	22.3688122°N, 88.4312022°E	5,600	Urban area, mostly have bushes with very few large trees; high anthropogenic disturbances.
Site 3, Sitakundu	22.3547905°N, 88.4544858°E	2,640	Suburban area, bush and large trees are in good proportion; moderate anthropogenic disturbances.
Site 4, Phuldubi	22.3638554°N, 88.4930808°E	2,197	Natural rural area, paddy fields and patches of uncultivated lands with natural vegetation having plenty of bushes and scattered trees; least anthropogenic disturbances.

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protected area with natural vegetation having the least anthropogenic disturbances (Figure 2). It is a sanctuary with well-wooded areas having bushes and large trees like Mango (*Mangifera indica*), Bamboo (*Bambusa sp.*), Sacred fig (*Ficus religiosa*), Neem (*Azadirachta indica*), etc. Site 2, the adjoining areas of Baruipur Railway Station mostly have bushes with very few large trees like Mango (*Mangifera indica*), Krishnachura (*Delonix regia*), etc. Being situated in the vicinity of a busy railway station, this area is highly populated and experiences high anthropogenic disturbances (Figure 2). Site 3, Sitakundu is a well-vegetated suburban area with bushes as well as large trees in good proportions (Figure 2). This area experiences moderate anthropogenic disturbances. Site 4, Phuldubi is

a rural area with paddy fields and patches of uncultivated lands with natural vegetation having plenty of bushes and scattered trees (Figure 2). An irrigation canal runs through this area. Being rural in location this area is least affected by anthropogenic disturbances.

2.2 Data Collection and Analysis

Butterflies were observed and recorded directly in the field using the line transect method [44]. A fixed transect was laid in each of the four study sites. Transect length and width were fixed at 1000 m and 20 m respectively. The study was conducted for one year (June 2017 to May 2018) to record butterfly diversity and abundance. Observations were made at a frequency of twice a month for each study site (a total of 24 samples from each study site). Observations were made between 8.30 a.m. and 4.30 p.m. during periods of good weather (no heavy rain or strong winds). This timing was found ideal based on preliminary observations done during different times of the day in the study sites. Butterflies were photographed using a digital camera (Nikon D5200) and identified using suitable keys [11,45-48]. Photographs were used for taxonomic documentation. In critical conditions, where identification was not possible by direct watching or photographs, butterflies were captured by hand net following the method described by Tiple [49], identified using suitable keys, and released in the same habitat with minimal disturbance. Precautions were taken to ensure that the scales present on the wings of the butterflies were minimally affected.

During the data analysis, one complete year was divided into four seasons, season 1 summer (March to May), season 2 monsoon (June to August), season 3 post-monsoon (September to November), and season 4 winter (December to February).

The diversity indices of the butterfly abundance of each study site were analyzed separately using Biodiversity Pro 2.0 Software to calculate different diversity indices [50]. The following diversity indices were considered.

(A) *Shannon-Wiener Index* (*H'*): Species diversity was calculated using the Shannon-Wiener Index [51-53] across seasons and habitats.

$H' = -\Sigma pi \ln pi$ [where, pi is the proportion of the i^{th} species in the total sample]. The number of species (species richness) in the community and their evenness in abundance (or equitability) are the two parameters that define *H'*.

Figure 2. Photographs of study sites S1 (Sanctuary), S2 (Urban), S3 (Suburban) and S4 (Rural).

(B) *Shannon H_{max}*: $H_{max} = Log_{10}(S)$, where H_{max} is the maximum diversity possible.

(C) Pielou's Evenness Index (*J'*): The species' evenness is the proportion of individuals among the species. Evenness of species indicates their relative abundance on-site [52-54]: $J' = H'/ \ln(S)$, where S is the number of species present in the site.

(D) *Margalef's Species Richness* (R): Used to compare the species richness across seasons and habitats. $R = (S-1)/\ln N$, where S is the number of species and N is the number of individuals [52,53].

(E) *Berger-Parker index (1/d)*: $d = N_{max}/N$ (where N_{max} is the number of individuals in the most abundant species, and N is the total number of individuals in the sample). The Berger-Parker index equals the maximum pi value in the dataset, i.e. the proportional abundance of the most abundant type.

(F) *Calculation of ß diversity by Sørensen's Similarity Index* [55]: Shared species statistics and similarity co-efficient calculated between pairs of the six study sites and between the pairs of four prominent seasons:

$$ß = 2C/S_1+S_2$$

S_1 = the total number of species recorded in the first community.

S_2 = the total number of species recorded in the second community.

C = number of species common in both communities.

The variation of the diversity of butterfly species among different study sites was analyzed and compared by ANOVA followed by Tukey's test using SPSS 29 (SPSS IBM, 2022).

3. Results

A total of 80 butterfly species belonging to five families were recorded from the four study sites during the study period (Table 2).

Table 2. List of butterflies with their relative abundance (mean ± SE) in sanctuary (Sa), urban (U), suburban (Su) and rural (R) sites of Baruipur subdivision, India, recorded during study period.

Sl no.	Common name	Scientific name	Sa	U	Su	R
Family 1: Hesperiidae						
1	Common Awl	*Hasora badra*	0.08±0.08	0	0	0
2	Chestnut Bob	*Iambrix salsala*	2.5 ±1.2	1.0±0.69	0	1.42±0.84
3	Common Branded Red Eye	*Matapa aria*	0.58 ±0.26	0	0	0.08±0.08
4	Common Dartlet	*Oriens gola*	0.17±0.17	0	0	0
5	Indian Palm Bob	*Suastus gremius*	0	0	0.50±0.26	0
6	Moore's Ace	*Halpe porus*	0.33±0.22	0	0	0
7	Oriental Dark Palm Dart	*Telicota bambusae*	0	0	0	0.42±0.34
8	Parnara Swift	*Parnara* sp.	2.17±2.17	6.33±6.15	1.75±1.06	5.0±3.24
9	Plain Palm Dart	*Cephrenes acalle*	0.42±0.34	0	0	0.33±0.26
10	Rice Swift	*Borbo cinnara*	0	0	0	0.50±0.26
11	Smaller Dartlet	*Oriens goloides*	0	0	0.58±0.58	0
12	Common Snow Flat	*Tagiades japetus*	0.42±0.19	0	0	0
Family 2: Lycaenidae						
13	Indian Sunbeam	*Curetis thetis*	0.25±0.13	0	0.08±0.08	0.42±0.26
14	Apefly	*Spalgis epius*	0.56±0.23	0	0.08±0.08	0.17±0.11
15	Ciliate Blue	*Anthene* sp.	1.17±0.80	0	0	0
16	Common Cerulean	*Jamides celeno*	0.25±0.25	0	0	0
17	Common Ciliate Blue	*Anthene emolus*	0.17±0.17	0	0.17±0.17	0.67±0.36
18	Common Pierrot	*Castalius rosimon*	2.5±0.86	1.17±0.47	1.33±0.45	3.58±0.71
19	Common Quaker	*Neopithecops zalmora*	13.75±2.55	13.25±1.39	11.67±1.59	14.58±1.94
20	Dark Cerulean	*Jamides bochus*	0.83±0.47	0	0	0
21	Dark Grass Blue	*Zizeeria karsandra*	0.17±0.17	0.33±0.33	0.25±0.25	0
22	Forget Me Not	*Catochrysops strabo*	1.08±0.6	0	0	0.83±0.47
23	Gram Blue	*Euchrysops cnejus*	0.42±0.42	0	0.17±0.17	0.17±0.17
24	Indian Common Lineblue	*Prosotas nora*	0.17±0.17	0	0	0
25	Lime Blue	*Chilades lajus*	0.08±0.08	0	0	0
26	Pale Grass Blue	*Pseudozizeeria maha*	13.17±3.75	8.58±1.71	8.42±2.08	12.08±2.81

Table 2 continued

Sl no.	Common name	Scientific name	Sa	U	Su	R
27	Plains Cupid	*Chilades pandava*	2.0±0.67	2.33±0.60	2.67±0.56	4.42±0.87
28	Pointed Ciliate Blue	*Anthene lycaenina*		0	0.17±0.17	0.17±0.17
29	Tailless Lineblue	*Prosotas dubiosa*	0.17±0.17	0	0.17±0.17	0
30	Tiny Grass Blue	*Zizula hylax*	2.59±1.77	0.92±0.60	0.17±0.17	1.42±1.16
31	Zebra Blue	*Leptotes plinius*	1.33±0.87	0	0.17±0.17	0.83±0.44
32	Common Shot Silverline	*Spindasis ictis*	0.91±0.65	0	0	0
33	Common Silverline	*Spindasis vulcanus*	1.33±0.74	0	0.42±0.42	1.83±0.51
34	Monkey Puzzle	*Rathinda amor*	1.75±0.51	0	0.33±0.26	2.08±0.63
35	Slate Flash	*Rapala manea*	0.08±0.08	0	0	0.42±0.19
36	Yamfly	*Loxura atymnus*	4.08±1.25	0	0	0.08±0.08
Family 3: Nymphalidae						
37	Angled Castor	*Ariadne ariadne*	0.17±0.17	0.92±0.50	0.25±0.18	0.33±0.19
38	Common Castor	*Ariadne merione*	1.25±0.58	5.17±2.07	1.17±0.58	1.17±0.44
39	Blue Tiger	*Tirumala limniace*	6.58±1.93	17.83±3.18	10.08±1.57	12.08±2.14
40	Common Crow	*Euploea core*	15.0±3.81	7.33±1.29	7.83±0.95	12.33±2.0
41	Plain Tiger	*Danaus chrysippus*	1.75±0.66	11.92±2.46	5.50±1.26	6.0±1.64
42	Striped Tiger	*Danaus genutia*	0.67±0.50	0.17±0.17	0.83±0.83	1.42±0.62
43	White Tiger	*Danaus melanippus*	0	0	0	0.50±0.34
44	Common Leopard	*Phalanta phalantha*	2.58±1.53	6.33±2.62	1.67±0.48	4.58±1.47
45	Tawny Coster	*Acraea terpsicore*	0.83±0.52	1.08±0.36	0	0
46	Baron	*Euthalia aconthea*	0.50±0.23	0	0.58±0.23	0.67±0.28
47	Baronet	*Symphaedra nais*	0.08±0.08	0	0	0.08±0.08
48	Chestnut Streaked Sailer	*Neptis jumbah*	3.08±1.74	0	0.17±0.11	2.42±1.03
49	Commander	*Moduza procris*	0.08±0.08	0.08±0.08	0.17±0.11	0.42±0.19
50	Common Sailer	*Neptis hylas*	1.83±1.58	0	0	0
51	Chocolate Pansy	*Junonia iphita*	0.17±0.17	0	0	0
52	DanaidEggfly	*Hypolimnas misippus*	0.25±0.18	0	0.42±0.19	0.33±0.19
53	Great Eggfly	*Hypolimnas bolina*	1.50±0.36	0.33±0.26	0.42±0.29	1.75±0.57
54	Grey Pansy	*Junonia atlites*	2.17±1.13	3.0±0.84	2.17±0.51	3.17±1.17
55	Lemon Pansy	*Junonia lemonias*	0	0	0.08±0.08	0.17±0.11
56	Peacock Pansy	*Junonia almanac*	1.50±0.68	0	2.08±0.54	3.92±1.37
57	Bamboo Treebrown	*Lethe europa*	0.92±0.36	0	0	0
58	Common Bushbrown	*Mycalesis perseus*	0.08±0.08	0	0.25±0.18	0.50±0.23
59	Common Duffer	*Discophora sondaica*	0.08±0.08	0	0	0.17±0.11
60	Common Evening Brown	*Melanitis leda*	0.17±0.17	0	0.08±0.08	0
61	Common Five-Ring	*Ypthima baldus*	2.25±1.07	0.83±0.32	0.42±0.23	1.42±0.66
62	Common Four-Ring	*Ypthima huebneri*	6.5±1.84	3.75±1.02	4.83±1.05	8.42±2.02
63	Common Palmfly	*Elymnias hypermnestra*	0.25±0.13	0.83±0.59	2.42±0.60	1.42±0.38
64	Dark Branded Bushbrown	*Mycalesis mineus*	0.33±0.19	0.58±0.31	0.25±0.18	0.08±0.08
Family 4: Papilionidae						
65	Blue Mormon	*Papilio polymnestor*	0.08±0.08	0	0	0
66	Common Jay	*Graphium doson*	0.17±0.11	1.83±0.72	1.0±0.62	1.33±0.72
67	Common Mime	*Papilio clytia*	0.33±0.19	0	0	0
68	Common Mormon	*Papilio polytes*	11.08±3.11	9.42±2.85	12.0±2.47	13.5±2.65
69	Common Rose	*Pachliopta aristolochiae*	1.0±0.51	0.25±0.18	0.67±0.36	1.0±0.39
70	Lime Swallowtail	*Papilio demoleus*	2.33±0.64	2.50±1.06	6.75±2.89	4.50±0.79
71	Tailed Jay	*Graphium agamemnon*	12.25±2.68	14.33±3.24	8.92±2.39	11.0±2.36

Table 2 continued

Sl no.	Common name	Scientific name	Sa	U	Su	R
Family 5: Pieridae						
72	Grass Yellow	*Eurema* sp.	4.92±0.83	16.75±4.29	10.0±1.95	9.17±1.39
73	Lemon Emigrant	*Catopsilia pomona*	1.42±0.48	2.67±0.72	1.92±0.36	3.42±0.93
74	Mottled Emigrant	*Catopsilia pyranthe*	1.0±0.46	0.17±0.17	0.33±0.23	1.33±0.48
75	Asian Cabbage White	*Pieris canidia*	0.33±0.23	0	0	1.25±0.55
76	Common Gull	*Cepora nerissa*	1.25±0.49	1.33±0.63	1.0±0.43	1.58±0.61
77	Indian Jezebel	*Delias eucharis*	2.67±0.69	4.92±0.77	1.17±0.39	4.83±1.13
78	Indian Wanderer	*Pareronia hippie*	1.25±0.43	0	0	1.33±0.56
79	Psyche	*Leptosia nina*	6.92±1.73	11.42±2.36	9.42±1.17	8.42±1.42
80	Striped Albatross	*Appias* sp.	4.83±1.24	9.75±1.85	8.58±1.91	7.0±1.27

The majority of the Indian butterflies are not enlisted in the IUCN Red list till now. They are enlisted in the Indian Wildlife Protection Act (1972) under several schedules. Two butterfly species Gram blue (*Euchrysops census*) and Striped Albatross (*Appias Libya*) recorded during the present study belong to Schedule II and Schedule IV of the Indian Wildlife Protection Act (1972) respectively. The highest number of species (73) was recorded from Sanctuary followed by rural (62) and suburban (54) areas. The urban area has least number (36) of butterfly species. Sanctuary has 16 unique species (species that were recorded only from a particular study site) while rural and suburban sites have 4 and 2 unique species respectively. No unique species was recorded from the urban site (Figure 3).

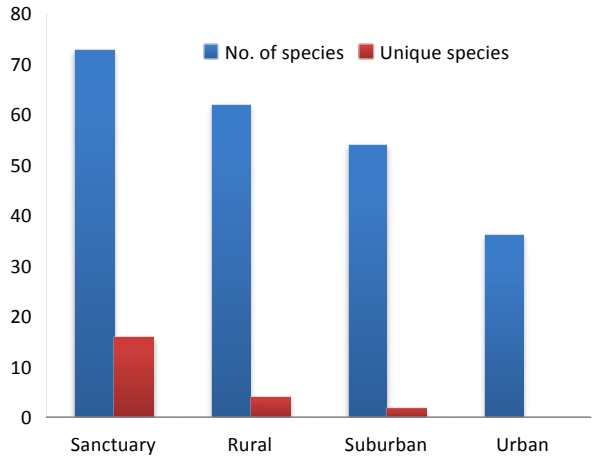

Figure 3. Butterfly species richness and unique species in four study sites.

Among the five families of butterflies, Nymphalidae was the most dominant with 28 species (35%) followed by Lycaenidae (24 species, 30%), Hesperiidae (12 species, 15%), and Pieridae (9 species, 11%). Papilionidae was found to be the least diverse family with only 7 species (9%) (Figure 4). This trend was noticed in all four study sites (Figure 5).

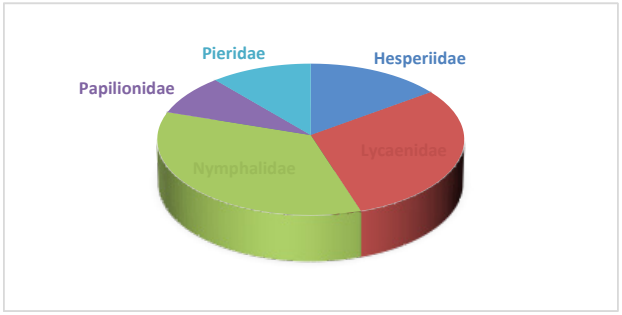

Figure 4. Proportion of different families of butterflies recorded during the study

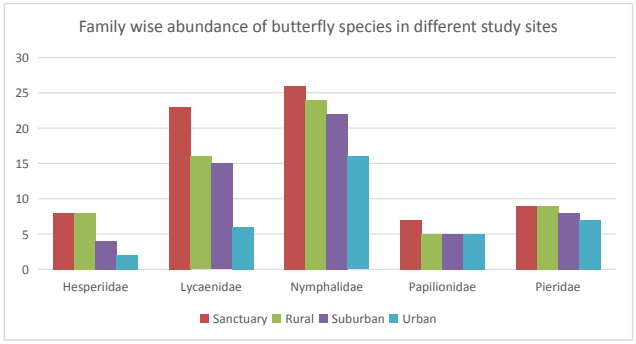

Figure 5. Family wise abundance of butterfly species in different study sites.

Table 3 represents the values of different biodiversity indices. Shannon-Wiener diversity index (H'), Shannon's $H_{max}=Log_{10}(S)$ and Margaleff species richness index (R) which indicates species diversity and richness was highest in Sanctuary followed by rural and suburban habitats whereas the values were minimum for the urban habitat which faces maximum anthropogenic disturbances. This finding clearly indicates that anthropogenic activities have a negative impact on butterfly species diversity and species richness.

Table 3. Values of different diversity indices at four study sites.

Ecological indices	Sanctuary	Rural	Suburban	Urban
Total Abundance (N)	1901	2241	1602	2079
Species Richness (s)	73	62	54	36
Shannon-Wiener diversity index (H') $H'=\sum p_i \ln p_i$	1.517	1.504	1.375	1.327
Shannon's $H_{max}=Log_{10}(S)$	1.863	1.792	1.732	1.556
Margaleff species richness index (R) $R=(s-1)/\ln N$	21.958	18.207	16.538	10.549
Pielou's evenness index (J') $J'=H'/H_{max}$	0.814	0.839	0.794	0.853
Berger-Parker index (1/d)	0.09	0.07	0.08	0.1

Pielou's evenness index (J') which indicates the evenness of species present within a habitat was highest for the urban habitat followed by rural and sanctuary while the value was least for the suburban habitat. Berger-Parker index (1/d) for species dominance was highest for the urban study site and lowest for the rural habitat. This means species dominance was highest in the rural area while minimum dominance was noticed in the urban study site. This indicates species dominance and evenness do not have a direct link with human impact.

Sørensen's Similarity Index which represents beta diversity between different habitats is presented in Table 4. The values indicate that butterfly species composition was different in different habitat types. The maximum similarity was noted between rural and suburban habitats while sanctuary and urban habitats were most dissimilar in terms of species diversity where anthropogenic disturbances are at two extreme ends.

Table 4. ß diversity by Sørensen's Similarity Index (Sørensen's 1948).

Habitat pairs*	No. of shared species	Sorenson's index
S-R	45	0.66
S-U	34	0.62
S-SU	45	0.70
R-U	35	0.71
R-SU	47	0.81
U-SU	33	0.73

*S = Sanctuary, R = Rural, SU = Suburban, U = Urban

Statistical analysis of the data showed significant variation in butterfly species diversity among different habitats ($df = 3$, $F = 6.762$, $p < 0.001$)

Bimodal patterns of peaks were noted during interpretations of the seasonal variations of butterfly abundances (Figure 6). It appears that the butterfly species richness increased twice consistent to the summer (March to May) and the post monsoon (September to November), while decreased in the winter (December to February) and the monsoon period (June to August), conceivably with the variations in the temperature and the humidity of the habitats concerned.

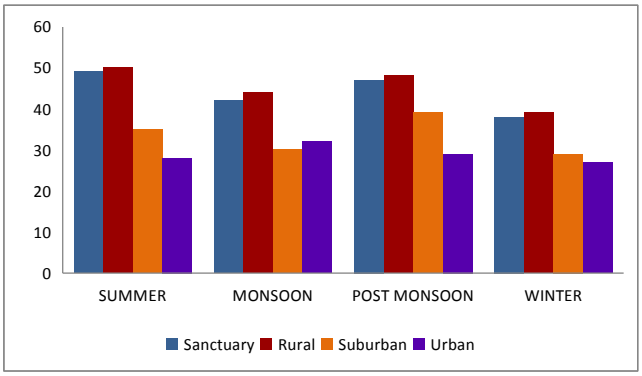

Figure 6. Seasonal variation of butterfly species richness in four study sites

4. Discussion

The spatial variation in butterfly diversity can be attributed to the landscape level heterogeneity and human-impact gradient, while the differences in the temporal scale can be attributed to changes in the climatic conditions both at the local and regional scales [19]. In the present perspective, it may be implicit that the butterfly diversity varied in the four study sites as a matter of the human-impact gradient, landscape differences, and variation in floral composition as well as concentration existing in the sanctuary, urban, suburban, and the rural areas [19]. The highest diversity of plant species was present in the sanctuary and there were minimum anthropogenic disturbances as the area was protected by law and human entry was restricted.

The rural areas although dominated by cultivable lands, there were patches with natural vegetation composed of a variety of plant species that can support the butterfly populations. Rural areas also face minimum anthropogenic disturbances. These might be the reason for higher

butterfly diversity and richness in the sanctuary and rural sites compared to suburban or urban areas. By contrast, the suburban areas represented fewer patches with natural vegetation due to human encroachment, construction works, and other anthropogenic disturbances going on in this area with increasing urbanization. As a result, these areas possessed moderate floral composition and butterfly species diversity. The urban areas were less diverse in terms of vegetation and faced maximum anthropogenic disturbances that resulted in minimum diversity of butterflies.

Observed differences ($p < 0.001$) in the species richness and abundance in the four study sites were prominent which might be a result of the consequent abundance of the host plants in the concerned areas and the degree of anthropogenic disturbances. The variations noted in the species richness in the four study sites provide an inkling of the differences in the host plant availability and the landscape characteristics in the region. Previous reports on the butterfly diversity in the rural undisturbed landscapes compared to the urban and suburban regions showed that the richness increased with the availability of green space and the heterogeneity of the habitats in terms of the available plant species [19,56,57] whereas species richness and general abundance decreased due to increased anthropogenic disturbances [58,59].

The results suggest that it does not follow the 'intermediate disturbance hypothesis' when the anthropogenic disturbance is considered as the 'disturbance component'. Butterfly species diversity was found highest in the least disturbed sanctuary area.

The number of unique species was also highest in the undisturbed and well-wooded sanctuary (16) followed by rural (4) and suburban (2) areas. No unique species was recorded from the urban site. The presence of unique species might be correlated with the presence of some unique plant species in that particular habitat or as stated in previous studies [59] the unique species might be 'disturbance avoiders' while those occurring in all four sites including heavily disturbed urban areas are 'disturbance adaptable' species.

Butterflies were found to be more abundant during summer and post-monsoon seasons compared to monsoon and winter. This might be due to the wide availability of nectar and larval host plants during summer and post-monsoon seasons that increased butterfly diversity and abundance while extreme climatic conditions during monsoon and winter might cause a decline in butterfly population and richness. Similar trends have been reported by earlier studies from this ecoregion [19,58].

Nymphalidae dominated among the five families of butterflies with 28 species (35%). Nymphalidae is polyphagous in nature, can live in a variety of habitats and the species under this family are active fliers [60]. Nymphalidae, therefore, is the best-adapted butterfly family and it dominates in different environmental conditions throughout the country. Hesperiidae (15%), Pieridae (11%), and Papilionidae (9%) were less frequent due to their low ecological tolerance and their preference for relatively less disturbed habitats [60].

The present study, reports 80 butterfly species present in different numbers across the rural-urban gradient of the Baruipur subdivision, West Bengal, India. The number of species recorded during the present study is at par with the observations on the species richness in different parts of India bearing similar landscape patterns [19,61,62]. The butterfly species diversity observed in the present study reflects that the butterflies perform varied functional roles for the sustenance of the ecosystems in the urban as well as the rural areas.

5. Conclusions

Though the present study is only a preliminary observation of the butterfly species diversity of the Baruipur Sub-division, South 24 Parganas, West Bengal, it has some significance as it is the first reporting of butterfly fauna from this region, and these can be used in monitoring ecosystem health, stability and functioning from the present study area. Conservation of these important pollinators is essential for sustainable development [63,64]. Future studies to point out the effect of specific anthropogenic activities like cutting of trees from wooded areas, solid waste disposal, pollution of natural water bodies, and reducing greenery for urbanization, on butterfly species diversity and community structure should be carried out to facilitate conservation measures. In addition, further investigation into the biodiversity of this region covering more study areas may generate awareness among the local people and government authorities to save wildlife and their habitats.

Author Contributions

The idea and experimental design of the present study was conceived by Dr. Sudipta Mandal. Kaiyum Baskh Mollah carried out the field work with observations and recording the data. Analysis of data, drafting and compilation was done by both the authors.

Conflict of Interest

As authors of the article we declare no conflict of interest.

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