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RESEARCH

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Alteration in butterfly community structure along urban–rural gradient: with insights to conservation management

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Abstract

Background Ecosystem services rendered by the butterflies are important for the sustenance of community interaction. Butterfly species have also coevolved with the host and nectaring plants. In the adult condition, they mostly rely on nectar, while in the larval condition, they feed on the leaves of their host plants. Butterfly species are sensitive to changes in environmental parameters and are considered excellent indicators of ecosystem health. The study of species diversity and richness indices aids in better ecosystem management. The present study's goal was to determine butterfly diversity in the urban–rural gradient of Purulia district, West Bengal, India, a part of the Chota Nagpur Plateau. We aim to complement crucial information on butterfly conservation management in Purulia, West Bengal, India, and other similar geographical areas with the findings of this study.

Results It was found that out of 3809 sampled butterflies, the individual contribution of the family Nymphalidae was the highest (51.24%), followed by Lycaenidae (18.40%), Pieridae (17.32%), Papilionidae (9.74%), and Hesperiidae (3.12%). A total of 54 butterfly species were observed in the urban–rural gradient, out of which the urban region contained 49 species, the suburban region had 32 species, and the rural region had 30 species. Significant differences were observed in butterfly abundance for the sites, seasons, and families during the study period. PERMANOVA and ANOSIM for species abundance and species presence-absence data show that all three sites are significantly different. Results Both PCoA and NMDS revealed clear differences among sites (groups) in terms of species abundance and presence-absence data. According to the findings of this study, the urban region has the highest species richness, followed by the suburban and rural regions. We discovered that urban areas have the highest butterfly abundance, followed by suburban and rural areas. Numerous butterfly species prefer the bushes dominated by *Lantana camara* in the urban region with the highest species richness. Aside from this invasive weed, the site also contains *Tridax procumbens*, *Catharanthus roseus*, *Synedrella nodiflora*, and *Ocimum americanum*, which are well known for being butterfly nectaring plants. In the case of the suburban region, members of the Lycaenidae family contributed the highest percentage after Nymphalidae, which was dominated by *Tridax procumbens* and *Sphagneticola trilobata*, which was preferred by the members of the Lycaenidae family observed during the survey, this site also contained *Ixora coccinea*, *Catharanthus roseus*, and *Lantana camara*. This site, in terms of nectaring plants, remains homogeneous in a rural region.

Conclusions Out of 3809 butterfly individuals, the family Nymphalidae contributed the most, followed by Lycaenidae, Pieridae, Papilionidae, and Hesperiidae. Both species richness and butterfly abundance were highest in urban regions, followed by sub-urban and rural regions. The current study has shown that this particular geographic location

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can sustain a variety of butterfly species. However, it is important to note that conservation planning is necessary not only for the butterfly species but also for the nectaring plant species that contribute to the diversity of these insects. The conservation of butterfly species can also lead to the achievement of ecosystem services they provide.

Keywords Butterfly, Conservation, PCoA, NMDS

Background

Both intrinsic and anthropocentric values have a link with the study of biological diversity (Mukherjee et al., 2015a, 2015b). Biological diversity is important for the functional aspects of the species that contribute human welfare. For a region the study of species diversity allows assessment of the functional roles of the species. In case of urban ecosystems assessment of species diversity can be applied for as a tool for the reduction of the human misapplication and pollution in several areas including urban, industrial, rural and managed areas (Wilson, 1997). In urban ecosystems assessment of species diversity are requisite for perception of the effect of humancentric development and sustenance of ecosystem. In many studies insect diversity has been highlighted because of their dominance in both terrestrial and aquatic ecosystems and stipulation of ecosystem services such as pollination, pest control, nutrient decomposition, and maintenance of ecosystem species (Losey & Vaughan, 2006). Among insects butterflies maintain a crucial role in food webs such as herbivores (Rusman et al., 2016), pollinators (Atmowidi et al., 2007; Mukherjee et al., 2015a, 2015b), serving as host for parasitoids (Van Nouhuys & Hanski, 2002), and helps in prey-predator relationship (Hammond & Miller, 1998; Rusman et al., 2016). Several butterfly species perform as indicators of biological systems including environmental health and ecological changes (Hill, 1999; Kocher & Williams, 2000; Koh & Sodhi, 2004; Thomas, 2005; Posha & Sodhi, 2006; Koh, 2007; Attaullah et al., 2018), because butterfly fauna can be very delicate to climate change and habitat fragmentation (Kunte, 2000). Predominantly butterfly fauna contribute in maintaining floral community structure in tropical regions (Bonebrake et al., 2010; Samanta et al., 2017). It is reported that 1318 butterfly species is found throughout the Indian subcontinent (Varshney & Smetacek, 2015). Over the previous few decades numerous anthropogenic activities and changes in climatic condition has negative effect in butterfly diversity (Clark et al., 2007; Di Mauro et al., 2007). By the studies of butterfly diversity are critical to determine the consequences of urbanization on butterfly communities and other aspects of conservation (Blair, 1999; Clark et al., 2007; Di Mauro et al., 2007; Mukherjee et al., 2015a, 2015b; Saikia et al., 2009; Singh & Pandey, 2004). Butterfly diversity has a positive impact on the diversity of various plant communities (Mukherjee et al., 2016; Murugesan et al., 2013). Biotic and abiotic factors additionally effects the population of butterfly species, marking the bioindication potential of this group (Pollard, 1988). For important ecosystem services that are carried out by butterfly species and to encourage the conservation management the goal of the present study was to determine the butterfly diversity in urban–rural gradient of Purulia district, West Bengal India, a part of the Chota Nagpur Plateau. The results of the study are supposed to be serving as a supplement the important information on the conservation management and increasing the ecological roles of the butterfly species in Purulia, West Bengal, India and similar geographical areas.

Materials and methods

Study area

The present survey was done around three central point in Purulia, West Bengal, India, such as urban region-Leprosy mission campus and adjacent areas in the Wilcox road (23.32939 N, 86.33786 E), rural region- Surulia (23.32201 N, 86.39566 E), and suburban region—Sidho-Kanho-Birsha University campus and its outskirts (23.36126 N, 86.33990 E) designated as site 1, site 2 and site 3, respectively. The coordinates of the central points of the study sites were collected from Google Maps (https://maps.google.com/).

Sampling period and time

The survey was carried out for a period of one year in between July 2020 and June 2021. We considered June–August as monsoon, September–November as post monsoon, December–February as winter and March–May as summer. Every study sites were visited once in a month and transect was monitored from 7 AM to 2 PM when the butterflies were most active.

Sampling techniques

In every study sites three transect paths were selected (1000 m each) and the butterfly species were counted on either side of the paths (distance of 5 m). The survey was done by using Pollard walk method with required modification (Pollard & Yates, 1993) and the butterflies were photographed by using Camera (Nikon Coolpix P600) and in some critical conditions butterflies were captured by hand net (Mukherjee et al., 2021) and identified with suitable keys (Evans, 1932; Kehimkar, 2008; Kunte, 2000; Wynter-Blyth, 1957). After identification butterflies were released without noticeable harm.

Biodiversity indices

Shannon–Wiener index (SWI), Pielou's index (PI) and Simpson's index (SI) were calculated for measuring species richness, evenness and dominance of the community. The Shannon–Wiener index is calculated by the following equation $H_s = H_s = \Sigma\ p_i \ln p_i$, where H_s represents the value of Shannon index and *pi* denotes the proportion *i*th species in the community (Shannon & Wiener, 1963). Rare species with a few number provide less to the index. Pielou's index (Pielou, 1969) of species evenness, represents how closely species present in the community numerically. It can be calculated by the equation $E = H_s/H\text{max}$, where E is the evenness, H_s is the value of Shannon index and Hmax is the ln(S), where S is the number of species in the community. Simpson's index (Simpson, 1964), is calculated by the following formula $\lambda = \Sigma\ pi^2$ where λ is the Simpson's index and p_i is the proportion of *i*th species in the community. If the value of Simpson's index is high meaning that one or few species dominate the community.

Statistical analyses

One way Analysis of Variance (ANOVA) was performed for Shannon–Wiener index, Pielou's index and Simpson's index followed by Tukey HSD test to check whether there was significant difference between them were present or not. Two way ANOVA were performed for butterfly abundance considering seasons and sites as categorical variables. Two way ANOVA also performed for butterfly family abundance as dependent variable considering family—sites and family—seasons as categorical variables followed by Tukey HSD test (Zar, 2010). One way Permutational multivariate analysis of Variance (PERMANOVA) and one way Analysis of similarities (ANOSIM) were performed for both species abundance data and species presence-absence data by using Bray–Curtis and Jaccard index, respectively, followed by pairwise test. Principal coordinate analysis (PCoA) and Non metric multidimensional scaling (NMDS) were also performed for both species abundance and presence-absence data by using Bray–Curtis and Jaccard index, respectively (Xu et al., 2018). All the analyses were performed by using PAST 4.07 (Hammer et al., 2001) and R v. 3.6.3 (R studio team, 2020).

Results

Total 54 species belonging to family Nymphalidae, Pieridae, Papilionidae, Lycaenidae and Hesperiidae found during the present study (Table 1). *Ypthima huebneri, Hypolimnas bolina* and *Danaus chrysippus* were most abundant in site 1, site 2, and site 3, respectively (Table 1). Shannon–Wiener index (SWI) was highest for site 1 (3.50 ± 0.04), followed by site 3 (3.200 ± 0.03) and site 2 (3.038 ± 0.05), respectively (Fig. 1). Pielou's index (PI) for evenness was observed highest for site 3 (0.983 ± 0.004) followed by site 2 (0.951 ± 0.009) and site 1 (0.936 ± 0.016), respectively (Fig. 2). Simpson's index (SI) of dominance maintain a negative relationship with Shannon–Wiener index (SWI), so it was lowest for site 1 (0.032 ± 0.001) followed by site 3 (0.042 ± 0.001) and site 2 (0.05 ± 0.002), respectively (Fig. 3). Results of one way ANOVA for the indices such as Shannon–Wiener index (SWI) ($F = 27.34$, $p < 0.05$), Pielou's index (PI) ($F = 4.856$, $p < 0.05$), and Simpson's index (SI) ($F = 20.09$, $p < 0.05$) for three sites demonstrated that there was significant difference between the mean values were present. Tukey HSD test revealed that in case of Shannon–Wiener index (SWI) all study sites were significantly different from each other ($p < 0.05$) (Table 2). For Pielou's index (PI) difference between Site 3–Site 1 was significant ($p < 0.05$) but in case of Site 2–Site 1 and Site 3–Site 2 difference was not significant ($p > 0.05$) (Table 3). In terms for Simpson's index difference between all sites were significant ($p < 0.05$) (Table 4). One way PERMANOVA by using Bray–Curtis index showed that significant difference were found in three sites (groups) in terms of species abundance (Permutation = 9999, $F = 14.2$, $p = 0.0001$). Pair wise results for one way PERMANOVA for species abundance data revealed significant difference between Site1–Site2, Site2–Site3, and Site3–Site1, respectively (Table 5). In case of presence- absence data the results of one way PERMANOVA by using Jaccard index also demonstrated that significant difference were found in three sites (groups) (Permutation = 9999, $F = 19.04$, $p = 0.0001$). Pair wise results for one way PERMANOVA in case of presence-absence data also revealed that between Site1–Site2, Site2–Site3, and Site3–Site1 significant difference were found (Table 6). In case of one way ANOSIM R value closer to 1 signify the difference between groups. Results of One way ANOSIM for species abundance data showed significant difference between sites (groups) were present (Permutation = 9999, $R = 0.8154$, $p = 0.0001$). For species presence-absence data the one way ANOSIM analysis also revealed significant difference among sites (groups) (Permutation = 9999, $R = 0.8495$, $p = 0.0001$). Pair wise results for one way ANOSIM for species abundance by using Brey–Curtis index demonstrated significant difference between Site1–Site2, Site2–Site3, and Site3–Site1 (Table 7). In case of presence-absence data by using Jaccard index

Table 1 List of butterfly species during the present survey in Purulia, West Bengal, India, with their relative abundance (mean ± SE) in site 1 (urban), site 2 (rural) and site 3 (suburban)

Sl No.	Common name	Scientific name	Family	Relative abundance (Site 1)	Relative abundance (Site 2)	Relative abundance (Site 3)
1	Plain Tiger	*Danaus chrysippus* (Linnaeus,1758)	Nymphalidae	6.24 ± 0.48	7.48 ± 0.40	9.69 ± 0.60
2	Striped Tiger	*Danaus genutia* (Cramer, 1779)	Nymphalidae	3.37 ± 0.44	1.67 ± 0.43	0
3	Blue Tiger	*Tirumala limniace* (Cramer, 1775)	Nymphalidae	2.82 ± 0.47	0.93 ± 0.51	2.20 ± 0.47
4	Lemon Pansy	*Junonia lemonias* (Linnaeus, 1758)	Nymphalidae	4.59 ± 0.29	7.22 ± 0.82	6.69 ± 0.62
5	Grey Pansy	*Junonia atilites* (Linnaeus, 1763)	Nymphalidae	1.72 ± 0.34	1.08 ± 0.36	2.25 ± 0.38
6	Peacock Pansy	*Junonia almana* (Linnaeus, 1758)	Nymphalidae	3.61 ± 0.20	4.48 ± 1.02	6.03 ± 0.68
7	Yellow Pansy	*Junonia hierta* (Fabricius, 1798)	Nymphalidae	0	0.60 ± 0.24	0.97 ± 0.35
8	Blue Pansy	*Junonia orithya* (Linnaeus, 1764)	Nymphalidae	0	0	0.65 ± 0.28
9	Chocolate Pansy	*Junonia iphita* (Cramer, 1779)	Nymphalidae	3.50 ± 0.33	0	0
10	Palmfly	*Elymnias hypermnestra* (Linnaeus, 1763)	Nymphalidae	0.62 ± 0.22	0	0
11	Common Crow	*Euploea core* (Cramer, 1780)	Nymphalidae	4.35 ± 0.24	7.34 ± 0.80	7.02 ± 0.50
12	Brown king Crow	*Euploea klugii* (Moore & Horsfield, 1857)	Nymphalidae	0.25 ± 0.11	0	0
13	Common Four Ring	*Ypthima huebneri* (Kirby, 1871)	Nymphalidae	7.63 ± 0.74	0	0.09 ± 0.09
14	Tawny Coaster	*Acraea terpsicore* (Drury, 1773)	Nymphalidae	1.71 ± 0.30	1.64 ± 0.40	2.33 ± 0.30
15	Common Leopard	*Phalanta phalantha* (Cramer, 1777)	Nymphalidae	3 ± 0.32	0	0
16	Common Lascar	*Pantoporia hordonia* (Stoll, 1790)	Nymphalidae	0	0	0.18 ± 0.12
17	Common Bushbrown	*Mycalesis perseus* (Fabricius, 1775)	Nymphalidae	2.80 ± 0.69	2.37 ± 0.43	1.22 ± 0.40
18	Common Evening brown	*Melanitis leda* (Linnaeus, 1758)	Nymphalidae	1.27 ± 0.44	0.75 ± 0.46	0.33 ± 0.14
19	Angled Castor	*Ariadne ariadne* (Linnaeus, 1763)	Nymphalidae	0.40 ± 0.15	2.16 ± 0.74	0
20	Common Castor	*Ariadne merione* (Cramer, 1779)	Nymphalidae	0	0.87 ± 0.34	0
21	Great Eggfly	*Hypolimnas bolina* (Linnaeus, 1758)	Nymphalidae	4.49 ± 0.29	8.26 ± 0.87	6.36 ± 0.57
22	Common Sailer	*Neptis hylas* (Linnaeus, 1758)	Nymphalidae	2.30 ± 0.38	2.25 ± 0.30	1.76 ± 0.25
23	Common Emigrant	*Catopsilia pomona* (Fabricius, 1775)	Pieridae	5.34 ± 0.53	8.15 ± 0.57	5.56 ± 0.31
24	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus, 1758)	Pieridae	2.90 ± 0.19	4.14 ± 0.34	4.04 ± 0.23
25	Pioneer	*Belenois aurota* (Fabricius, 1793)	Pieridae	0.53 ± 0.17	0	0
26	Common Gull	*Cepora nerissa* (Fabricius, 1775)	Pieridae	1.55 ± 0.36	0	0
27	Common Grass Yellow	*Eurema hecabe* (Linnaeus, 1758)	Pieridae	3.21 ± 0.33	6.43 ± 0.59	4.24 ± 0.25
28	Indian Wanderer	*Pareronia hippia* (Fabricius, 1787)	Pieridae	1.04 ± 0.27	0	0
29	Psyche	*Leptosia nina* (Fabricius, 1793)	Pieridae	2.24 ± 0.26	1.41 ± 0.22	1.95 ± 0.20
30	Common Mormon	*Papilio polytes* (Linnaeus, 1758)	Papilionidae	2.95 ± 0.30	6.14 ± 0.56	3.90 ± 0.31
31	Lime butterfly	*Papilio demoleus* (Linnaeus, 1758)	Papilionidae	2.81 ± 0.13	3.84 ± 0.42	3.07 ± 0.20
32	Common Jay	*Graphium doson* (Felder & Felder, 1864)	Papilionidae	0.46 ± 0.13	0	0
33	Tailed Jay	*Graphium agamemnon* (Linnaeus, 1758)	Papilionidae	0.79 ± 0.19	0	0
34	Common Rose	*Pachliopta aristolochiae* (Fabricius, 1775)	Papilionidae	1.45 ± 0.19	0.60 ± 0.23	3.99 ± 0.28
35	Plains Cupid	*Luthrodes pandava* (Semper, 1890)	Lycaenidae	1.63 ± 0.26	0	2.55 ± 0.25
36	Indian Cupid	*Everes lacturnus* (Godart, 1824)	Lycaenidae	0.29 ± 0.11	0	0
37	Lesser Grass Blue	*Zizina otis* (Fabricius, 1787)	Lycaenidae	2.69 ± 0.26	4.85 ± 0.55	3.68 ± 0.29
38	Pale Grass Blue	*Pseudozizeeria maha* (Kollar, 1844)	Lycaenidae	2.02 ± 0.34	4.39 ± 0.47	3.20 ± 0.27
39	Tiny grass Blue	*Zizula hylax* (Fabricius, 1775)	Lycaenidae	0.76 ± 0.30	1.11 ± 0.47	0.95 ± 0.30
40	Common Hedge Blue	*Acytolepis puspa* (Horsfield, 1828)	Lycaenidae	0.23 ± 0.08	0	0
41	Lime Blue	*Chilades lajus* (Stoll, 1780)	Lycaenidae	2.10 ± 0.26	1.58 ± 0.22	0
42	Gram Blue	*Euchrysops cnejus* (Fabricius, 1798)	Lycaenidae	0.39 ± 0.12	0	6.30 ± 0.30
43	Pea Blue	*Lampides boeticus* (Linnaeus, 1767)	Lycaenidae	0	0	2.04 ± 0.46
44	Common Pierrot	*Castalius rosimon* (Fabricius, 1775)	Lycaenidae	4.13 ± 0.50	5.42 ± 0.36	3.44 ± 0.41
45	Striped Pierrot	*Tarucus nara* (Kollar, 1848)	Lycaenidae	0.82 ± 0.20	0	0.56 ± 0.21
46	Common Cerulean	*Jamides celeno* (Cramer, 1775)	Lycaenidae	0.92 ± 0.25	0	0
47	Common Ciliate Blue	*Anthene emolus* (Godart, 1824)	Lycaenidae	0.48 ± 0.18	0	0

Table 1 (continued)

Sl No.	Common name	Scientific name	Family	Relative abundance (Site 1)	Relative abundance (Site 2)	Relative abundance (Site 3)
48	Continental Swift	*Parnara ganga* (Evans, 1937)	Hesperiidae	0.60 ± 0.25	1.05 ± 0.41	1.39 ± 0.50
49	African Straight Swift	*Parnara bada* (Moore, 1878)	Hesperiidae	0.66 ± 0.20	1.14 ± 0.40	1.27 ± 0.42
50	Small-Branded Swift	*Pelopidas mathias* (Fabricius,1798)	Hesperiidae	0.76 ± 0.30	0.51 ± 0.25	0
51	Obscure Branded Swift	*Pelopidas agna (Moore, 1866)*	Hesperiidae	0.12 ± 0.08	0	0
52	Rice Swift	*Borbo cinnara* (Wallace, 1866)	Hesperiidae	0.49 ± 0.21	0	0
53	Common Red Eye	*Matapa aria* (Moore, 1865)	Hesperiidae	0.10 ± 0.06	0	0
54	Palm bob	*Suastus gremius* (Fabricius, 1798)	Hesperiidae	0.79 ± 0.28	0	0

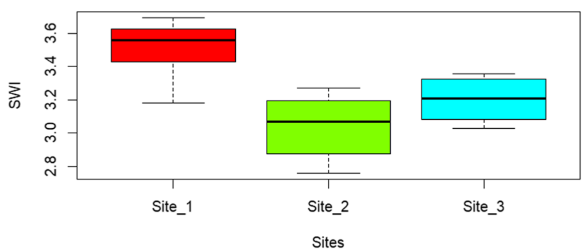

Fig. 1 Box plot showing Shannon–Wiener index of three sites, marking that Site 1 has highest species richness followed by Site 3 and Site 2

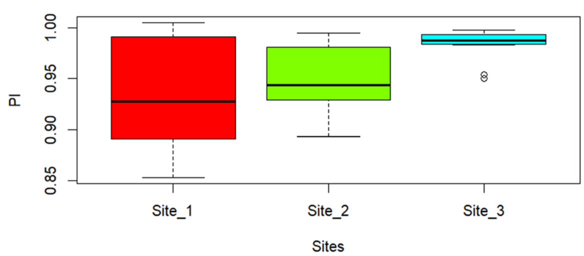

Fig. 2 Box plot showing Pielou's index of evenness of three sites, marking that Site 3 has highest species evenness followed by Site 2 and Site 1

also demonstrated significant difference between Site1–Site2, Site2–Site3, and Site3–Site1 (Table 8). Two way ANOVA by considering butterfly abundance as dependent variables and study sites and seasons as categorical variables showed that there was significant difference were found in case of sites ($F = 112.683$, $p < 0.05$), seasons ($F = 51.309$, $p < 0.05$) and with both sites and seasons cumulatively ($F = 9.242$, $p < 0.05$). Tukey HSD test for seasons revealed that difference in butterfly abundance between post monsoon–monsoon, summer–monsoon, winter–monsoon, summer–post monsoon, winter–post monsoon and Winter–Summer were significant ($p < 0.05$) (Table 9). For study sites, site 2–site1 and site 3–site 1 significant difference were found in terms of butterfly abundance ($p < 0.05$), but in case of site 3–site 2 difference was not significant ($p > 0.05$) (Table 10). It also found that butterfly abundance were highest in post monsoon in all three sites (Fig. 4). By considering abundance as dependent variable and butterfly families and sites as categorical variables the results of two way ANOVA revealed that significant difference were found in terms of abundance in family ($F = 201.25$, $p < 0.05$), sites ($F = 38.42$, $p < 0.05$) and cumulative interaction of sites-family ($F = 12.23$, $p < 0.05$). Tukey HSD test for butterfly families proved that significant difference was found between Lycaenidae–Hesperiidae, Nymphalidae–Hesperiidae, Papilionidae–Hesperiidae, Pieridae–Hesperiidae, Nymphalidae–Lycaenidae, Papilionidae–Lycaenidae, Papilionidae–Nymphalidae, Pieridae–Nymphalidae, and Pieridae–Papilionidae ($p < 0.05$), but significant difference was not observed between Pieridae–Lycaenidae ($p > 0.05$) (Table 11). In case of study sites Tukey HSD test revealed that significant difference was observed for abundance of the butterfly families in site 2–site 1 and site 3–site 1 ($p < 0.05$), but no significant difference was observed between site 3–site 2 ($p > 0.05$) (Table 12). It was found that the abundance of family Nymphalidae was highest in all three sites (Fig. 5). Two way ANOVA for dependent variable abundance of butterfly family and categorical variables families and seasons showed significant difference in family ($F = 131.563$, $p < 0.05$), seasons ($F = 11.424$, $p < 0.05$) and cumulative interaction between seasons and family ($F = 2.342$, $p < 0.05$). Tukey HSD test for butterfly families revealed that significant difference for abundance were present between Lycaenidae–Hesperiidae, Nymphalidae–Hesperiidae, Papilionidae–Hesperiidae, Pieridae–Hesperiidae, Nymphalidae–Lycaenidae, Papilionidae–Lycaenidae, Papilionidae–Nymphalidae, Pieridae–Nymphalidae, and Pieridae–Papilionidae ($p < 0.05$), but difference between Pieridae–Lycaenidae was not significant ($p > 0.05$) (Table 13). For seasons Tukey HSD test revealed that

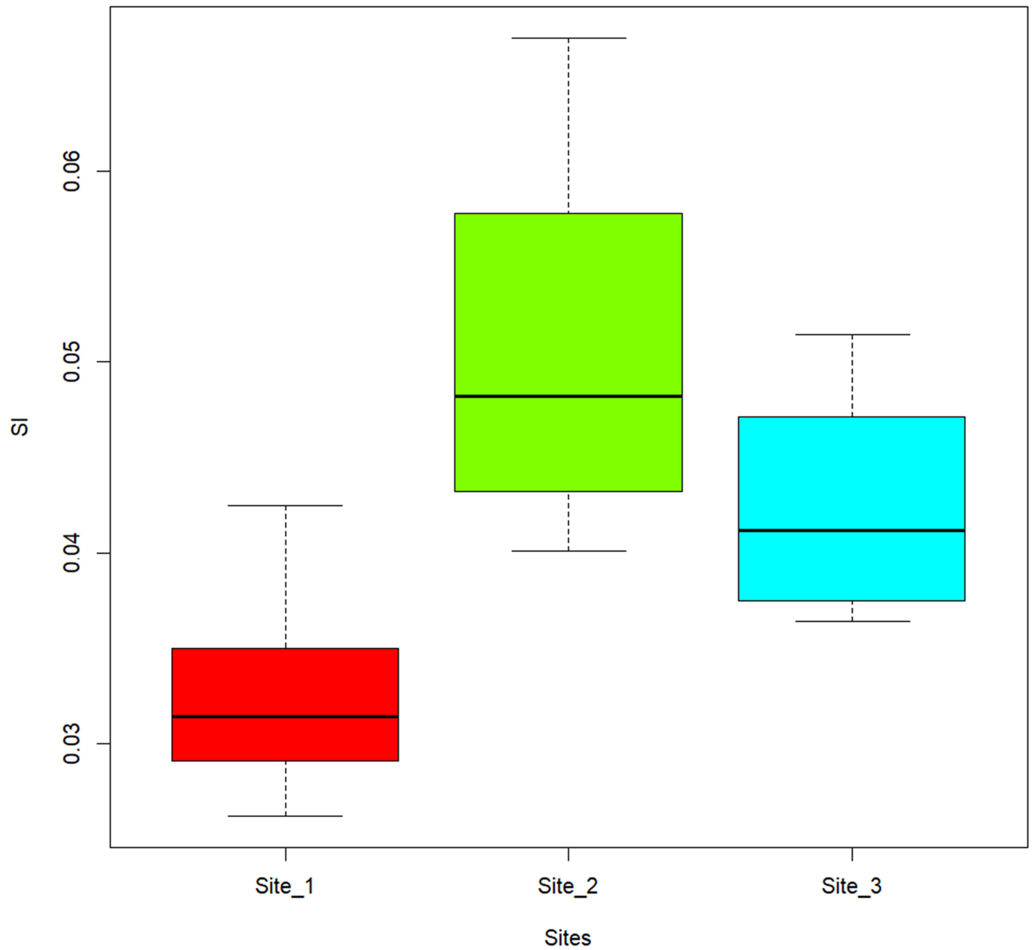

Fig. 3 Box plot showing Simpson's index of three sites, marking that Site 1 has lowest species dominance followed by Site 3 and Site 2

Table 2 Results of Tukey HSD test for Shannon–Wiener index

Sites	Difference	Lower	Upper	*p* adjusted
Site 2–Site 1	−0.4693333	−0.67093891	**−0.2677278**	0.0000001
Site 3–Site 1	−0.3070000	−0.50860558	**−0.1053944**	0.0001077
Site 3–Site 2	0.1623333	−0.03927225	**0.3639389**	0.0433101

Values are marked bold at $p < 0.05$ level of significance

Table 3 Results of Tukey HSD test for Pielou's index

Sites	Difference	Lower	Upper	*p* adjusted
Site 2–Site 1	0.01521667	−0.032802384	0.06323572	0.5876299
Site 3–Site 1	0.04690000	−0.001119051	**0.09491905**	0.0120241
Site 3–Site 2	0.03168333	−0.016335718	0.07970238	0.1132173

Values are marked bold at $p < 0.05$ level of significance

Table 4 Results of Tukey HSD test for Simpson's index

Sites	Difference	Lower	Upper	*p* adjusted
Site 2–Site 1	0.017843333	0.0090300916	**0.0266565751**	0.0000011
Site 3–Site 1	0.009681667	0.0008684249	**0.0184949084**	0.0044857
Site 3–Site 2	−0.008161667	−0.0169749084	**0.0006515751**	0.0178065

Values are marked bold at $p < 0.05$ level of significance

Table 5 Results of pairwise test for one way PERMANOVA by using Bray–Curtis index

Sites	F value	*p* value
Site1–Site2	**13.41**	0.0001
Site2–Site3	**10.71**	0.0001
Site3–Site1	**18.06**	0.0001

Values are marked bold at $p < 0.05$ level of significance

Table 6 Results of pairwise test for one way PERMANOVA by using Jaccard index

Sites	F value	*p* value
Site1–Site2	**17.61**	0.0001
Site2–Site3	**15.48**	0.0002
Site3–Site1	**24.46**	0.0001

Values are marked bold at $p < 0.05$ level of significance

Table 7 Results of pairwise test for one way ANOSIM by using Bray–Curtis index

Sites	R value	*p* value
Site1–Site2	**0.8827**	0.0001
Site2–Site3	**0.7886**	0.0001
Site3–Site1	**0.9187**	0.0001

Values are marked bold at $p < 0.05$ level of significance

Table 8 Results of pairwise test for one way ANOSIM by using Jaccard index

Sites	*R* value	*p* value
Site1–Site2	**0.8845**	0.0001
Site2–Site3	**0.774**	0.0001
Site3–Site1	**0.9459**	0.0001

Values are marked bold at $p < 0.05$ level of significance

significant difference were found between summer -monsoon, summer-post monsson and winter–post monsoon ($p < 0.05$), but in case of post monsoon–monsoon, winter–monsoon and Winter–Summer difference in terms of abundance of butterfly families were not significant ($p > 0.05$) (Table 14). It was revealed that abundance of family Nymphalidae was highest in all seasons (Fig. 6). PCoA for species abundance by using Bray–Curtis index proved that the three sites were dissimilar with each other (Fig. 7). In case of presence-absence data principal coordinate analysis (PCoA) by using Jaccard index demonstrated that all the sampling from three sites were dissimilar from each other

Table 10 Results of Tukey HSD test for Sites

Sites	Difference	Lower	Upper	*p* adjusted
Site 2–Site 1	− 59.91667	− 70.956163	**− 48.87717**	0.0000000
Site 3–Site 1	− 54.66667	− 65.706163	**− 43.62717**	0.0000000
Site 3–Site 2	5.25000	− 5.789497	16.28950	0.4717573

Values are marked bold at $p < 0.05$ level of significance

(Fig. 8). Results of one way PERMANOVA justify the results of PCoA in terms of both species abundance and species presence-absence data. As showed by the one way ANOSIM the results of NMDS also showed the sites (groups) were significantly different from each other for both species abundance and presence-absence data with fair stress values 0.1791 and 0.2015, respectively (Figs. 9, 10).

Discussion

During the present survey 54 butterfly species belongs to Nymphalidae, Pieridae, Papilionidae, Lycaenidae and Hesperiidae were observed. Out of 54 species, site 1, site 2, and site 3 contained 48, 30 and 32 species, respectively. Total 3809 individual butterflies were observed during this period, in which contribution of the family Nymphalidae was highest with 51.24% followed by Lycaenidae (18.40%), Pieridae (17.32%), Papilionidae (9.74%), and Hesperiidae (3.12%). 1728 individuals were observed in site 1 where Nymphalidae emerged as the most dominant family with 54.57% contribution followed by Pieridae, Lycaenidae, Papilionidae and Hesperiidae with 17.07%, 16.37%, 8.56% and 3.41% contribution. Out of 1009 individuals in site 2, Nymphalidae, Pieridae, Papilionidae, Lycaenidae and Hesperiidae contributed 49.55%, 19.92%, 10.50%, 17.14% and 2.87%, respectively. Site 3 observed with 1072 individuals in which Nymphalidae contributed 47.48% that was highest in that site during the study period and other families such as Pieridae, Papilionidae, Lycaenidae and Hesperiidae contributed 15.85%,

Table 9 Results of Tukey HSD test for seasons

Seasons	Difference	Lower	Upper	*p* adjusted
Post monsoon–monsoon	20.66667	6.585447	**34.747887**	0.0024574
Summer–monsoon	− 40.66667	− 54.747887	**− 26.585447**	0.0000002
Winter–monsoon	− 15.44444	− 29.525664	**− 1.363224**	0.0278731
Summer–post monsoon	− 61.33333	− 75.414553	**− 47.252113**	0.0000000
Winter–post monsoon	− 36.11111	− 50.192331	**− 22.029891**	0.0000015
Winter–Summer	25.22222	11.141002	**39.303442**	0.0002655

Values are marked bold at $p < 0.05$ level of significance

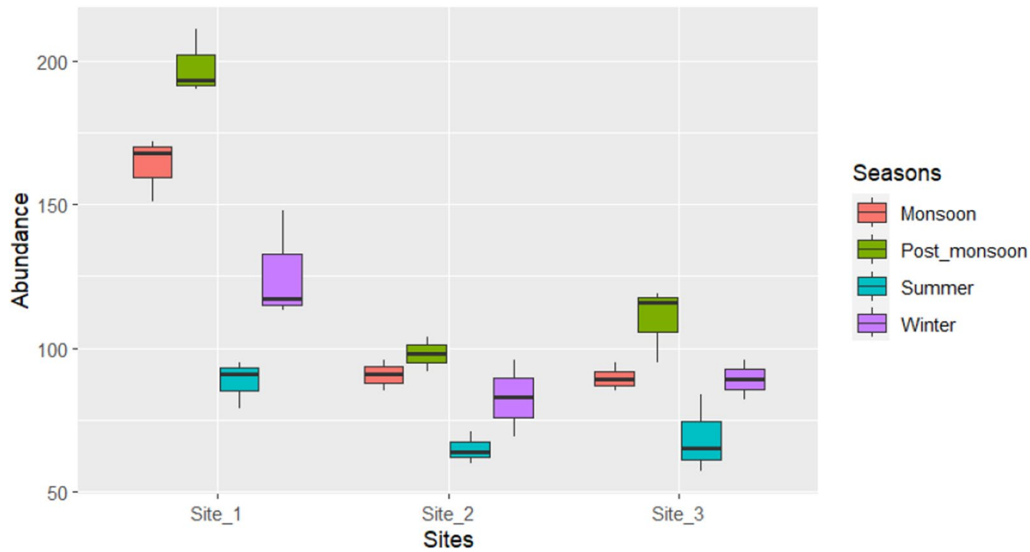

Fig. 4 Box plot of two categorical variables namely Sites and Seasons and one dependent variable butterfly abundance indicating that butterfly abundance highest in post monsoon season in all three sites

Table 11 Results of Tukey HSD test for butterfly families

Family	Difference	Lower	Upper	*p* adjusted
Lycaenidae–Hesperiidae	16.2222222	10.824287	**21.620157**	0.0000000
Nymphalidae–Hesperiidae	50.9722222	45.574287	**56.370157**	0.0000000
Papilionidae–Hesperiidae	7.0555556	1.657621	**12.453490**	0.0037378
Pieridae–Hesperiidae	15.2500000	9.852065	**20.647935**	0.0000000
Nymphalidae–Lycaenidae	34.7500000	29.352065	**40.147935**	0.0000000
Papilionidae–Lycaenidae	−9.1666667	−14.564602	**−3.768732**	0.0000570
Pieridae–Lycaenidae	−0.9722222	−6.370157	4.425713	0.9875736
Papilionidae–Nymphalidae	−43.9166667	−49.314602	**−38.518732**	0.0000000
Pieridae–Nymphalidae	−35.7222222	−41.120157	**−30.324287**	0.0000000
Pieridae–Papilionidae	8.1944444	2.796510	**13.592379**	0.0004367

Values are marked bold at $p < 0.05$ level of significance

Table 12 Results of Tukey HSD test for sites

Sites	Difference	Lower	Upper	*p* adjusted
Site 2–Site 1	−11.983333	−15.568609	**−8.398058**	0.0000000
Site 3–Site 1	−10.966667	−14.551942	**−7.381391**	0.0000000
Site 3–Site 2	1.016667	−2.568609	4.601942	0.7808548

Values are marked bold at $p < 0.05$ level of significance

10.91%, 22.85% and 2.89%, respectively. Assessment of butterfly diversity furnishes information about difference in species richness, and abundance with proper information about vegetation along the landscape (Harrington & Stork, 1995; Öckinger & Smith, 2006; Öckinger et al., 2006, 2009). Difference in diversity of the butterfly species on spatial scale assigned by the heterogeneous landscape but in case of temporal scale difference in diversity accredited by the climatic condition both at regional and local scale (Mukherjee et al., 2015a, 2015b). It is assumed that difference in butterfly diversity during the present study in urban, suburban and rural region in Purulia because of landscape difference. Urban region where the species richness was highest consists of bushes dominated by *Lantana camara*, that is preferred by the numerous butterfly species (Mukherjee & Hossain, 2022; Mukherjee et al., 2015a, 2015b, 2021, 2024) apart from this invasive weed the site also contain *Tridax procumbens, Catharanthus roseus, Synedrella nodiflora and Ocimum americanum* well known for being the nectaring plant of the butterfly species (Mukherjee et al., 2015a, 2015b; Mukherjee & Hossain, 2021). In case of

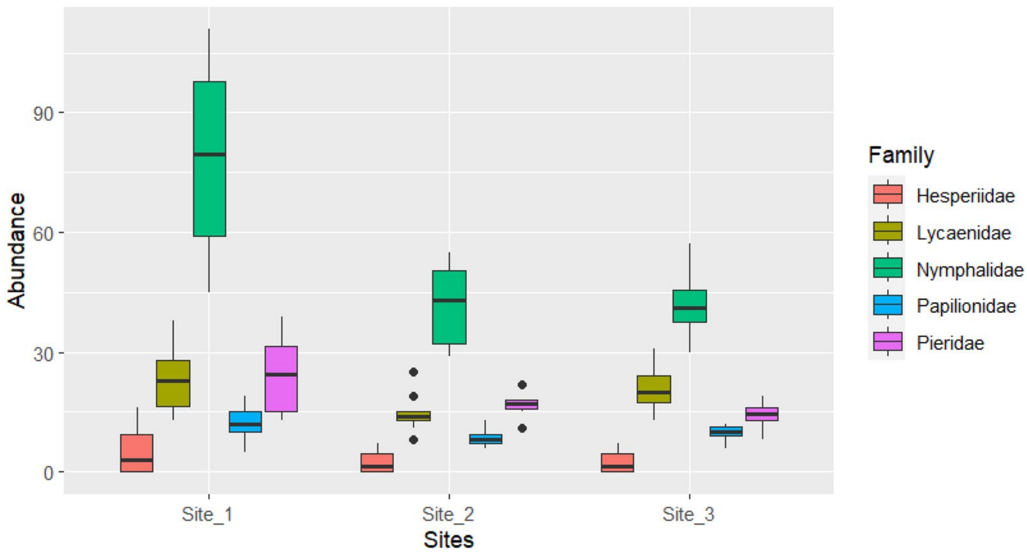

Fig. 5 Box plot of two categorical variables namely Sites and Family and one dependent variable butterfly abundance (family) indicating that the abundance of Nymphalidae family highest in all three sites

Table 13 Results of Tukey HSD test for butterfly families

Family	Difference	Lower	Upper	*p* adjusted
Lycaenidae–Hesperiidae	16.1666667	9.4924619	**22.840871**	0.0000000
Nymphalidae–Hesperiidae	50.9166667	44.2424619	**57.590871**	0.0000000
Papilionidae–Hesperiidae	7.0000000	0.3257952	**13.674205**	0.0346932
Pieridae–Hesperiidae	15.1944444	8.5202396	**21.868649**	0.0000000
Nymphalidae–Lycaenidae	34.7500000	28.0757952	**41.424205**	0.0000000
Papilionidae–Lycaenidae	−9.1666667	−15.8408715	**−2.492462**	0.0019687
Pieridae–Lycaenidae	−0.9722222	−7.6464270	5.701983	0.9944563
Papilionidae–Nymphalidae	−43.9166667	−50.5908715	**−37.242462**	0.0000000
Pieridae–Nymphalidae	−35.7222222	−42.3964270	**−29.048017**	0.0000000
Pieridae–Papilionidae	8.1944444	1.5202396	**14.868649**	0.0078031

Values are marked bold at $p < 0.05$ level of significance

Table 14 Results of Tukey HSD test for seasons

Seasons	Difference	Lower	Upper	*p* adjusted
Post monsoon–monsoon	4.133333	−1.4838129	9.750480	0.2277741
Summer–monsoon	−8.133333	−13.7504796	**−2.516187**	0.0013518
Winter–monsoon	−3.088889	−8.7060351	2.528257	0.4840021
Summer–post monsoon	−12.266667	−17.8838129	**−6.649520**	0.0000004
Winter–post monsoon	−7.222222	−12.8393684	**−1.605076**	0.0057321
Winter–Summer	5.044444	−0.5727018	10.661591	0.0952204

Values are marked bold at $p < 0.05$ level of significance

suburban region where members of Lycaenidae family contributed major percentage after Nymphalidae dominated by *Tridax procumbens*,and *Sphagneticola trilobata* that preferred by the members of Lycaenidae family observed during the survey, besides this plants this sites also contained *Ixora coccinea, Catharanthus*

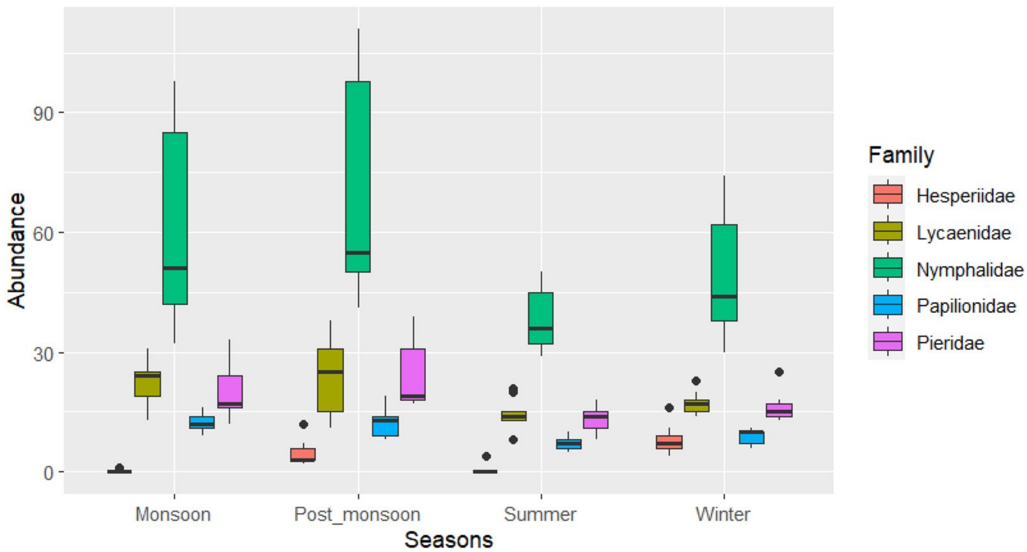

Fig. 6 Box plot of two categorical variables namely Seasons and Family and one dependent variable butterfly abundance (family) indicating that the abundance of Nymphalidae family highest in all seasons

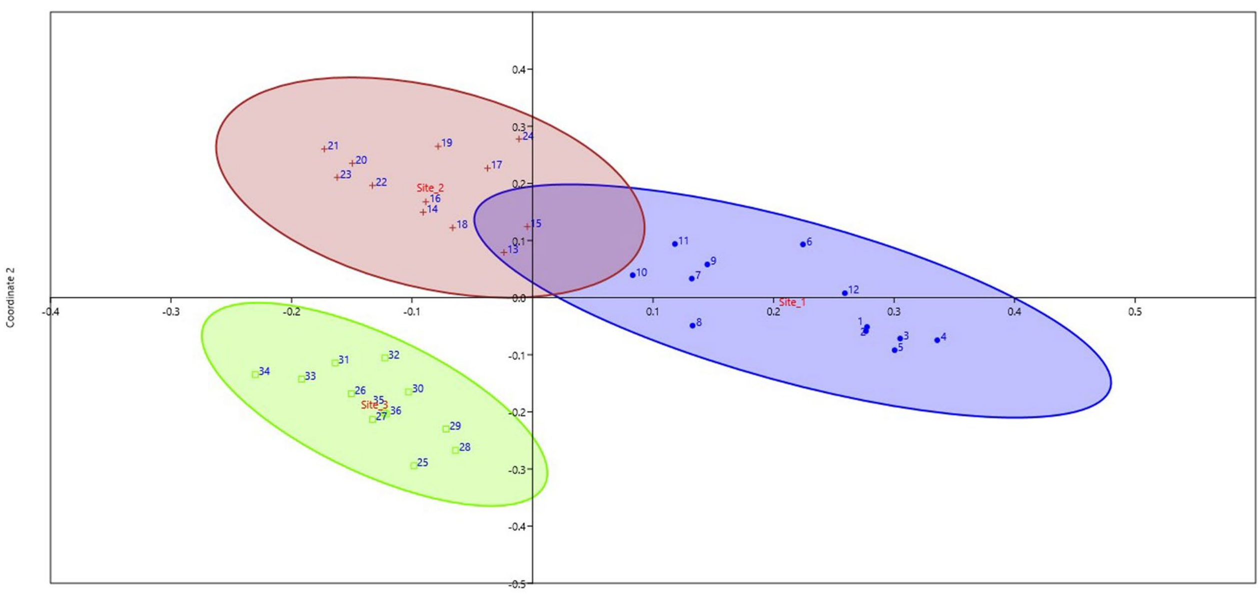

Fig. 7 Results of Principal coordinate analysis for species abundance data by using Bray–Curtis index showing that the three groups (sites) are different from each other

roseus, and *Lantana camara*. In contrast of urban and suburban regions rural region is dominated by mostly woody plants and some areas were covered by cultivable lands, in case of nectaring plants that are preferred by butterfly species remained homogenous with less richness contained mainly *Lantana camara* and *Tridax procumbens*. Differences in species richness and abundance were profound in three sites because of differing abundance of nectaring plants. Species richness variation in urban, suburban, and rural regions furnish with the information about the host plant abundance and landscape characteristics. The results of present study that demonstrated the diversity was higher in suburban area than rural areas support previous records (Blair & Launer, 1997; Hogsden & Hutchinson, 2004; Kitahara & Sei, 2001; Mukherjee

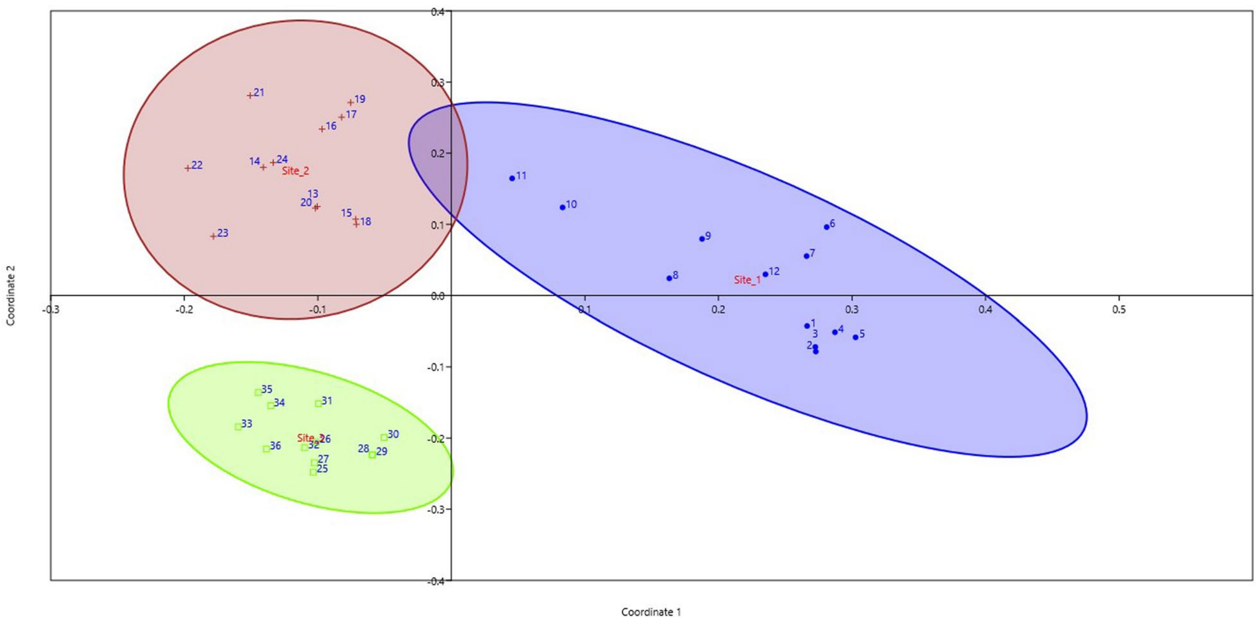

Fig. 8 Results of Principal coordinate analysis for species presence-absence data by using Jaccard index showing that the three groups (sites) are different from each other

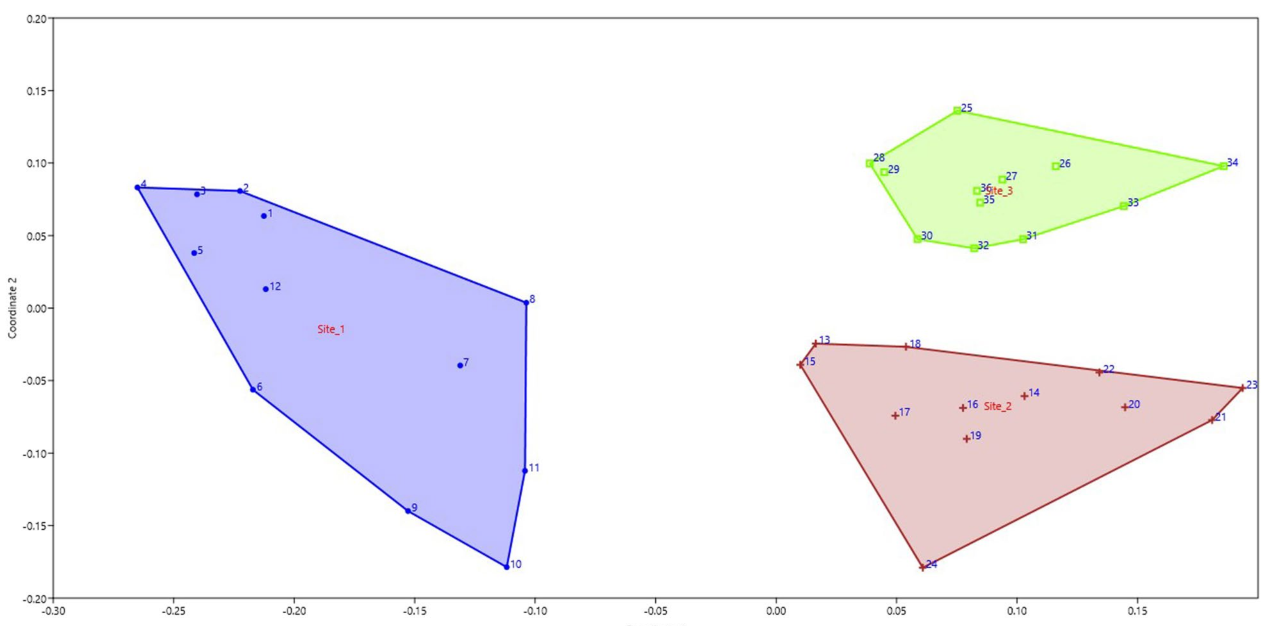

Fig. 9 Results of Non metric multidimensional scaling for species abundance data by using Bray–Curtis index showing that the three groups (sites) are different from each other with stress value 0.1791

et al., 2015a, 2015b). But the present study also demonstrated higher diversity of butterfly species in urban regions followed by suburban and rural regions. During the present study, it was observed that family Nymphalidae was dominant followed by Lycaenidae, Pieridae, Papilionidae and Hesperiidae, respectively. The above observation followed the previous observation in different parts in the West Bengal (Biswas et al., 2019; Pahari et al., 2018). But in suburban regions of Kolkata Lycaenidae found to be most dominant family

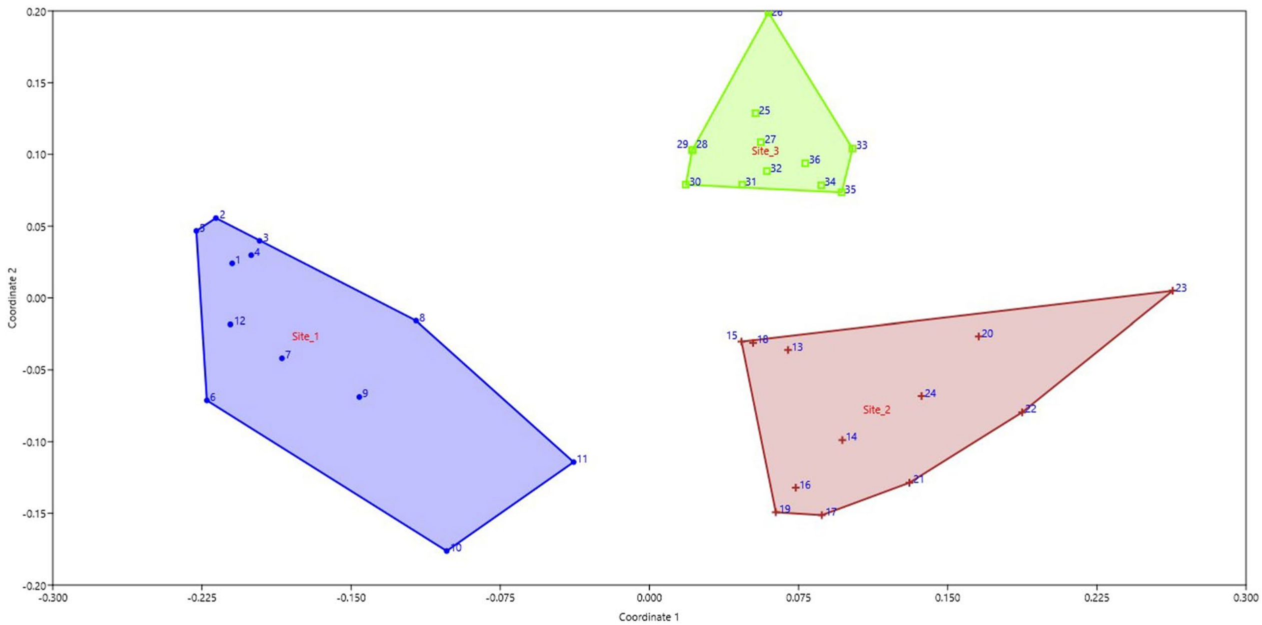

Fig. 10 Results of Non metric multidimensional scaling for species presence-absence data by using Brey–Curtis index showing that the three groups (sites) are different from each other with stress value 0.2015

(Mukherjee et al., 2015a, 2015b). The species richness value during the present survey was lower than the richness values for the Kolkata and Midnapore (Biswas et al., 2019; Mukherjee et al., 2015a, 2015b) but higher than the Baghmundi region (Samanta et al., 2017). From the observed 54 butterfly species not a single species is globally threatened according to IUCN red list. *Euchrysops cnejus* and *Cepora nerissa* fall under Wildlife (Protection) Act 1972 in Schedule II category. *Euchrysops cnejus* found in higher abundance in site 3 (suburban) and lower abundance in site 1 (urban), but not a single individuals of this species found in site 2 (rural). In case of *Cepora nerissa* suburban and rural region did not contain a single individuals but urban region found with this species with fewer numbers. *Danaus chrysippus, Junonia lemonias, Junonia atilites, Junonia almana, Euploea core, Acraea terpsicore, Mycalesis perseus, Melanitis leda, Hypolimnas bolina, Neptis hylas, Catopsilia pomona, Catopsilia pyranthe, Eurema hecabe, Leptosia nina, Papilio polytes, Papilio demoleus, Pachliopta aristolochiae, Zizina otis, Pseudozizeeria maha, Zizula hylax, Castalius rosimon, Parnara ganga* and *Parnara bada* were found in all the three study sites, in which *Danaus chrysippus, Junonia lemonias, Junonia almana, Euploea core, Hypolimnas bolina, Catopsilia pomona,* and *Castalius rosimon* were found with higher relative abundance than the other butterfly species. All three sites were dominated by family Nymphalidae. Representation of family Pieridae (percentage wise) was highest at rural region or site 3. Lycaenidae representatives dominate the sub urban region and in case of Papilionidae and Hesperiidae representatives they were found in highest abundance (percentage wise) in sub urban and urban regions, respectively. The species found during the present study were similar in observation of butterfly species in different part of India (Roy et al., 2012; Saikia, 2014). The present study revealed that leastways 54 butterfly species found in varying numbers along the urban–rural gradient of Purulia, West Bengal, India. By assessing diversity of butterfly species it can be speculated that butterflies make an important part for performing various functional roles that nourish in the ecosystem in urban, sub urban and rural regions (Mukherjee et al., 2015a, 2015b). Vegetation availability and associated factors that helps in maintaining population stability and assemblages of butterfly species probably the important contributors for the variation observed during the present study (Mukherjee et al., 2015a, 2015b). Regardless of the variation in the different landscape, the observation of butterfly diversity in the sites of the present survey demonstrated that conservation management is necessary for the nourishment of ecosystem services that are governed by butterfly species. The butterfly abundance is highest in post monsoon season that is in between the months of September–November and lowest in summer that is between the March–May. Species found in the urban area and also the abundance of butterflies were highest at urban region. The present study revealed that urban area in Purulia can nourish various butterfly species and by conserving the species we also have benefits from the ecosystem services that are done by the butterfly species.

Conclusions

The present survey deals with the diversity of butterfly species in urban, suburban and rural region in Purulia, West Bengal, India and before the present survey there was no such records were found for butterfly diversity in urban–rural gradient in Purulia. Butterfly species are sensitive to subtle switching of landscape function, loss of vegetation and pattern of land use for that reason apart from butterfly species conserve the other species that support the butterfly diversity is also necessary. During the present survey, it was found that butterfly abundance were highest in post monsoon and lowest in summer and in case of family of butterflies Nymphalidae dominate in all three sites and all seasons. It was also found that both in terms of species abundance and species presence-absence the study sites were significantly different. Shannon–Wiener index was highest for urban region followed by suburban and rural region. This type of studies can give us information about species richness, abundance and vegetation that maintain the butterfly diversity in urban–rural gradient. It can also generate interests among people for conserving butterfly species by enrich them with informations that conserving the butterfly species is necessary for sustainable development.

Abbreviations

ANOVA	Analysis of variance
PERMANOVA	Permutational multivariate analysis of variance
ANOSIM	Analysis of similarities
PCoA	Principal coordinate analysis
NMDS	Non metric multidimensional scaling

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Author contributions

SSM and AH have a major contribution in Conceptualizing the idea, writing the manuscript. SSM made the practical part and analysed and interpreted the data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets for current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Authors declare that they have no competing of interests.

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