Abundance and diversity gradient of butterflies from urban to rural habitats in Udaipur district, Rajasthan, India

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ABSTRACT : Rapid expansion of urbanization and industrialization are major reasons for biodiversity decline in urban area. Urbanization causes habitat fragmentation, alteration and lack of vegetation due to cutting of trees and human settlements and causes negative impact on butterflies diversity, abundance and evenness. The present study focuses on uncovering the significant gaps related to butterfly biodiversity in the study area and how the urbanization is affecting the overall ecology of butterflies in the urban, sub-urban and rural areas of district Udaipur. Study area has been divided in four categories on basis of percentage of vegetation and its composition in the study areas as Urban Site 1 (US1) with 5% - 8% vegetation followed by Urban Site 2 (US2) with 20% - 30% vegetation, Sub Urban Site (SUS) with almost 40% - 50% vegetation and Rural Area Site (RAS) which consists of almost 90% - 95% vegetation including herbs, shrubs, trees and crop plants. During the present study total 69 species of butterflies were recorded together from all four study areas. The minimum number of butterfly diversity, abundance and evenness was recorded in Urban Site 1 (US1) (Shanon-Wiener Diversity Index=2.132, Simpson Diversity Index=0.8496, Brillion Index=1.993, Menhinick's Index=0.9864, Margalef's Index=2.201, Chao-1Index=12, Equability-J Evenness Index= 0.8578) and maximum butterfly diversity, abundance and evenness was recorded in Rural Area Site (RAS) (Shanon-Wiener Diversity Index=3.663, Simpson Diversity Index=0.9638, Brillion Index=3.556, Menhinick's Index=1.831, Margalef's Index=8.863, Chao-1Index=92, Equability-J Evenness Index=0.8807). Overall Beta Diversity of the four study areas was recorded with the help of different indexes like Whittaker Beta Diversity Index=0.864, Cody's Beta Diversity Index=35 and Mourelle Index=0.315 of study area. The present study concludes that Rural Area Site (RAS) is rich in butterfly diversity and shows high abundance due to present of high density and variety of vegetation in this site.

Key Words: Urbanization, diversity, abundance, evenness, vegetation.

Butterflies are very beautiful and charming invertebrate and are key species of an ecosystem playing there important role in various ways in terrestrial ecosystems (Robbins and Opler, 1997). Simultaneously they act as a good bio-indicator in analysing the health of various ecosystems. In the present time, natural habitats and plant species including herbs, shrubs and trees are rapidly declining due to rapid expansion and infrastructural developments in the urban and surrounding sub-urban and rural areas and establishment of various industrial areas in the same. These developments are one of the main causes for decline in vegetation and rich biodiversity of the local areas (Blair, 1997, Bliar and Launer, 1997; Clak *et al.,* 2007 and Tiple *et al.,* 2007). Urbanization is becoming major threat and responsible factor for reduction in overall global biodiversity (Wilcove *et al.,* 1998) and leads to overall modification and alteration in the habitats of different faunal species including insects. Butterfly richness and abundance are signs of good environmental health condition, while opposite of the same is an indicator of polluted and poor quality ecosystem (Dwari and Mondal, 2015). Butterflies and their larval stages usually feed upon host plants and show host-specific relationship and co-evolutionary process. The overall species richness and abundance of butterflies heavily depends upon variety of plant species including herbs, shrubs and cultivated plants (Padhye *et al.,* 2001). Most of the butterflies prefer particular habitats only and show periodic and seasonal variations in their life cycle throughout year (Kunte, 1997). Butterflies link different food chain and are important key connectors in the food webs in an ecosystem, while playing an important role of food resource to different faunal species including birds, reptiles, spiders and predatory insects. They are very sensitive and susceptible towards the changes in climate and environmental conditions even at micro level with respect to temperature, humidity, pollution and availability of host plants in an ecosystem (Thomas *et al.,* 1998 and Kunte, 2000). Many species of animals, including butterflies and insects are rapidly declining and are becoming rare and even some species are facing risk due to loss of vegetation and high pollution of different types and enormous anthropogenic activities like urbanization, industrialization, construction of roads and buildings, habitat destruction, deforestation, forest fires, illegal collection of specimen and excessive use of insecticide and pesticides occurring in the vicinity of

these natural habitats leading to decline in biodiversity in various ecosystems of the Earth (Ramesh *et al.,* 2010 and Rosin *et al.,* 2010).

Study on butterflies has been started during 18th century and almost 19,238 species are discovered worldwide presently (Heppner, 1998) and discovery of new species of butterflies is appearing to be a continuous and constant process throughout different continents of the world (Green and Huang, 1998; Barua *et al.,*2004; Ambrose and Raj 2005; Alphonsa, 2006; Chandra *et al.,* 2007 and Parag and Omkaar 2009). Entomologists and other related enthusiasts has documented around 1504 butterflies species widely distributed throughout in the Indian subcontinent which includes 100 endemic and threatened butterfly species as per IUCN Red list of threatened animals (Singh and Pandey, 2004 and Tiple, 2011). Very few studies have been conducted on butterflies in the southern part of the state Rajasthan particularly district Udaipur. Total 40 butterfly species were recorded in native vegetation and *Prosopis juliflora* dominated area of Udaipur district, Rajasthan (Choudhary and Chishty, 2020) which mainly belongs to four families of insects namely Papillionidae (12 species), Lycanidae (10), Nymphalidae (15) and Hespridiae (3).

Materials and Methods

Study Area : Udaipur is located in southern part of Rajasthan in Aravalli ranges, between 24°34'16.5720''N latitude and 73°41'29.5584''E longitude. Udaipur city area is surrounded by Aravalli hill ranges with elevation range of 558 meter to 767 meter above sea level. The study area is specified by three remarkable seasons summer (March-June), Monsoon (July-October) and winter (November- February) with an average annual precipitation of 540-580mm. The average temperature of study areas is 6.8°C in winter season and a maximum temperature of upto 44°C in summer season. Urban area of Udaipur consist of different types of microhabitats which has a rich potential of enhancing biodiversity due to presence of numerous number of seasonal and perennial water bodies, agricultural land, fragmented forest areas including Sajjangarh Wildlife Sanctuary and rich floral species.

Study area has been divided in four categories on basis of percentage of vegetation and its composition in the study areas as Urban Site 1 (US1) with 5% - 8% vegetation followed by Urban Site 2 (US2) with 20% - 30% vegetation, Sub Urban Site (SUS) with almost 40% - 50% vegetation and Rural Area Site (RAS) which consists of almost 90% - 95% vegetation including herbs, shrubs, trees and crop plants.

Regular surveys were conducted to search for butterfly during the time period of August, 2017 to December, 2019. Data was collected twice a month using line transect, point count and quadrates methods from different localities of four study areas. Different study sites were divided in almost equal size of two lines transects and two quadrates. Length of transect was kept approximately 500 meter long and 5 meter wide where butterflies were easily identified by without capturing the specimen. Size of each quadrate was kept 200 meter wide and 200 meter long. For observation the study site was visited twice a day during time periods 8:00 am - 11:00 am and 4:00 pm - 7:00 pm. Identification of butterflies was done by using standard field guide and literature (Evans, 1932; Wynter-blyth, 1957; Gay *et al.,* 1992 ; Haribal, 1992; Kunte, 2000 and Kehimar, 2008).

Statistical Analysis : Alpha and Beta Diversity Indexes were calculated using software's SPSS and PAST and butterfly diversity, species richness, abundance and evenness was calculated using following formula:-

1.   Simpson's Diversity Index - It is generally used for biodiversity measuring in the study area.

Simpson's diversity index = 1-D

where D=Dominance

2.   Shannon Diversity Index : It is used for the comparison of two or more study areas or sites in the biological community.

$$H_s = \sum_{i=1}^{S} Pi \ln Pi$$

where P_i i is the proportion of individuals found in the ith species represented in natural logarithm.

Brillouin Diversity Index : The index calculates and reflect the species abundance in the study area.

$$H_B = \frac{\ln(N!) - \sum \ln(ni!)}{N}$$

where N = Total number of individuals in the community, n_i = The number of individuals in the ith species

Menhinick's Richness Index: The ratio of the number of taxa/species to the square-root of sample size.

$$D_{mn} = \frac{S}{\sqrt{N}}$$

where N = Total number of individuals in sample size, S = Number of species in sample

Margalef's richness index:

Margalef's Richness index $= \dfrac{(S-1)}{\ln(n)}$

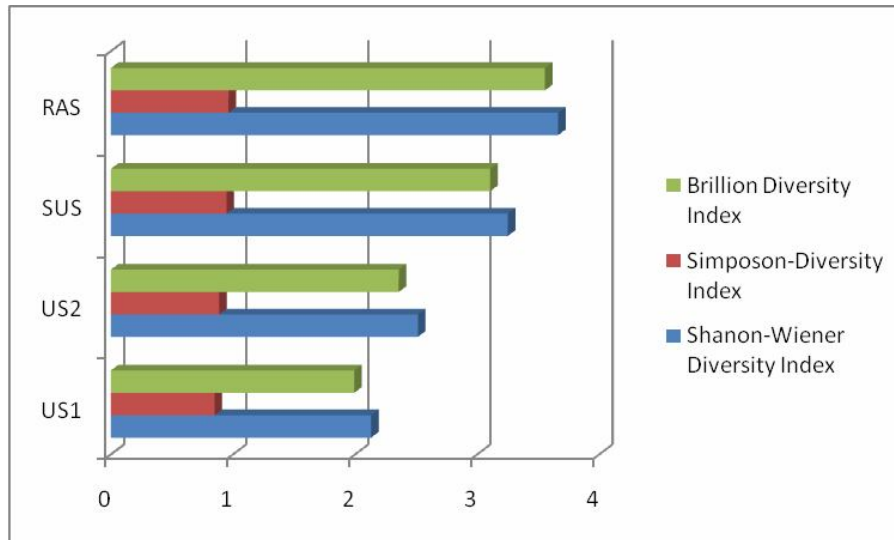where S = the number of taxa/species, n =the number of individuals.

Fig.-1 : Comparative analyses of various abundance estimates for butterflies in different study sites in the study area of Udaipur (RAS = Rural Area Site, SUS = Sub Urban Site, US2 = Urban Site 2, US1 = Urban Site 1).

Fig.-2 : Comparative analyses of various rihnss estimates for butterflies in different study sites in the study area of Udaipur (RAS = Rural Area Site, SUS = Sub Urban Site, US2 = Urban Site 2, US1 = Urban Site 1).
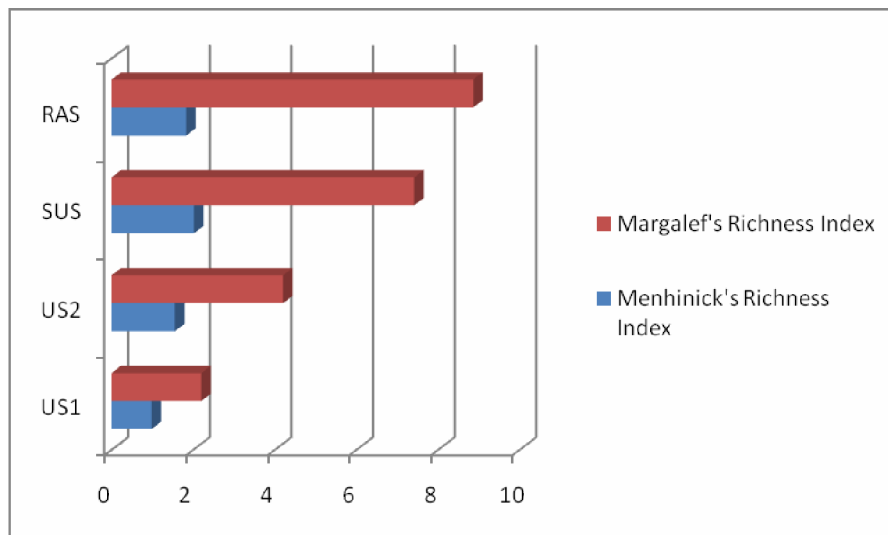
Equitability J : Shannon diversity divided by the logarithm of number of taxa. This measures the evenness with which individuals are divided among the taxa present. This indices used for a calculated of equitability comparison of the Shannon- Weiner index and used for against the distribution of individuals between the observed species, they are widely distributed.

$$J = \frac{H}{Log(S)}$$

where S= Total number of species in sample size, H= Shanon-weiner index

1. Chao-1- This index uses for the estimate of

species richness in different habitat or area, proposed by (Chao, 1984).

$$S_{max} = S_{obs} + (a^2/2b)$$

where S_{obs} = Actual number of species present in sample, a = Number of species represented by a single individuals, b= Number of species represented by two individuals.

Beta Diversity Indices

Beta diversity calculates the species diversity with transects and it is mainly applicable on the analysis of environmental gradients. It is calculated on the basis of two different variables, the number of selective habitats

Table-1 : Butterflies recorded from different sites in the study area of Udaipur.

Common name and families	Zoological Name	Urban Site 1 (US1)	Urban Site 2 (US1)	Sub Urban Site (SUS)	Rural Area Site (RAS)
Papillionidae					
1 Tailed Jay	*Graphiumagamemnonagamemnon* (Linnaeus, 1758)	-	+	+	+
2 Indian Common mormon	*Papiliopolytesromulus* (Cramer, 1775)	-	-	+	+
3 Lime butterfly	*Papiliodemoleus* (Linnaeus, 1758)	+	+	+	+
4 Malabar Raven	*Papiliodravidarum* (Wood-Mason, 1880)	-	+	+	+
Pieridae					
5 Small grass yellow	*Euremabrigitta* (Cramer, 1780)	+	+	+	+
6 Common grass yellow	*Euremahecabe* (Linnaeus, 1758)	-	+	+	+
7 Indian Spotless grass yellow	*Euremalaetalaeta* (Boisduval, 1836)	-	-	+	+
8 Oriental Mottled Emigrant	*Catopsiliapyranthepyranthe* (Linnaeus, 1758)	-	+	+	+
9 Common Emigrant	*Catopsiliapomonapomona* (Fabricius, 1775)	-	+	+	+
10 Common gull	*Ceporanerissa* (Fabricius, 1775)	-	-	-	+
11 Indian Little orange tip	*Colotisetrida* (Boisduval, 1836)	-	-	+	+
12 Caper white	*Belenoisaurota* (Fabricius, 1793)	-	-	-	+
13 White orange tip	*Ixias marianne* (Cramer, 1779)	-	-	-	+
14 Yellow Orange tip	*Ixias pyrene* (Fabricius, 1764)	-	+	+	+
15 Common/ Indian Jezebel	*Delias eucharis* (Drury, 1773)	-	-	+	+
16 Oriental Psyche	*Leptosianinanina (Fabricius,1793)*	-	-	+	+
17 Western Striped Albatross	*Appiaslibythea* (Fabricius, 1775)	-	+	+	+
18 White Arab	*Colotisvestalis* (Butler, 1876)	-	-	-	+
19 Modest Small Salmon Arab	*Colotisamatamodesta* (Butler, 1876)	-	-	+	+
20 Dakhan Large Salmon Arab	*Colotisfaustafulvia* (Wallace, 1867)	-	-	-	+
21 Blue Spotted Arab	*Colotisprotractus* (Butler, 1876)	-	-	-	+
22 Red Line Small grass yellow	*Euremabrigitta rubella* (Wallace, 1867)	-	+	+	+
23 Indian Orange Albatross	*Appiasgalba* (Wallace, 1867)	-	-	+	+
24 Sahyadri Albatross	*Appiaswardii* (Moore, 1884)	-	+	+	-
Lycaenidae					
25 Indian Tiny grass blue	*Zizulahylaxhylax* (Fabricius, 1775)	+	-	-	+
26 Grass Jewel	*Freyeriatrochylus* (Freyer, 1845)	+	-	-	+
27 Zebra blue	*Leptotespliniusplinius* (Fabricius, 1793)	-	-	+	+
28 Gram blue	*Euchrysopscnejuscnejus* (Fabricius, 1798)	+	-	+	+
29 Pea blue	*Lampidesboeticus* (Linnaeus, 1767)	-	-	-	+
30 Striped pierrot	*Tarucusnara* (Kollar, 1848)	-	-	+	-
31 Spotted pierrot	*Tarucuscallinara* (Butler, 1886)	-	-	+	-
32 Black spotted pierrot	*Tarucusbalkanicanigra* (Bethune-Baker, 1918)	-	-	-	+
33 Lesser grass blue	*Zizinaotis* (Fabricius, 1787)	-	-	+	+
34 Indian cupid	*Cupidolacturnus* (Godart, 1824)	-	-	-	+

35 Small cupid	*Chiladesparrhasiusparrhasius* (Fabricius, 1793)	-	-	+	+
36 Indian Lime blue	*Chiladeslajuslajus* (Stoll, 1780)	-	-	-	+
37 Pale grass blue	*Pseudozizeeriamaha* (Kollar, 1884)	-	-	+	+
38 Indian Common silverline	*Spindasisvulcanusvulcanus* (Fabricius, 1775)	-	+	+	+
39 Bright Babul Blue	*Azanusubaldus* (Stoll, 1782)	-	+	+	+
40 Common Pierrot	*Castaliusrosimon* (Fabricius, 1775)	-	-	+	+
41 Angled Pierrot	*Caletadecidia* (Hewitson, 1876)	-	-	-	+
42 Oriental Plains Cupid	*Chiladespandavapandava* (Horsfield, 1829)	-	+	+	+
43 Dark Pierrot	*Tarucusananda* (de Niceville, 1884)	-	-	-	+
44 Common Acacia blue	*Surendraquercetorum* (Moore, 1858)	+	+	+	+
45 Indian Peacock Royal	*Tajuriacippuscippus* (Fabricius, 1798)	-	-	+	+
Nymphalidae					
46 Danaid eggfly	*Hypolimnasmisippus* (Linnaeus, 1764)	-	+	+	+
47 Oriental Great eggfly	*Hypolimnasbolinajacintha* (Drury, 1773)	+	+	+	+
48 Blue pansy	*Junoniaorithya* (Linnaeus, 1758)	-	-	+	+
49 Peacock pansy	*Junoniaalmana* (Linnaeus, 1758)	+	+	+	+
50 Yellow pansy	*Junoniahierta* (Fabricius, 1798)	-	-	-	+
51 Painted lady	*Vanessa cardui* (Linnaeus, 1758)	-	-	-	+
52 Grey pansy	*Junoniaatlites* (Linnaeus, 1763)	+	-	+	+
53 Lemon pansy	*Junonialemonias* (Linnaeus, 1758)	+	+	+	+
54 Common evening brown	*Melanitisleda* (Linnaeus, 1758)	-	-	+	+
55 Dark evening brown	*Melanitisphedima* (Cramer, 1780)	-	+	-	-
56 Common castor	*Ariadne merione* (Cramer, 1777)	+	+	+	+
57 Common leopard	*Phalantaphalantha* (Drury, 1773)	-	-	+	+
58 Plain tiger	*Danauschrysippus* (Linnaeus, 1758)	+	+	+	+
59 Striped tiger	*Danausgenutia* (Cramer, 1779)	-	+	+	+
60 Blue tiger	*Tirumala limniace* (Cramer, 1775)	-	+	+	+
61 Indian common crow	*Euploea core core* (Cramer, 1780)	-	-	+	+
62 Indian Extra Lascar	*Pantoporiasandakadavidsoni* (Eliot, 1969)	-	-	+	+
63 Chocolate pansy	*Junoniaiphita* (Cramer, 1779)	-	-	-	+
64 Common four ring	*Ypthimahuebneri* (Kirby, 1871)	-	-	-	+
Hesperiidae					
65 Brown Awl	*Badamia exclamations* (Fabricius, 1775)	-	-	-	+
66 Common small flat	*Sarangesadasaharadasahara* (Moore, 1866)	-	-	+	+
67 Indian Pale palm dart	*Telicota colon colon* (Fabricius, 1775)	-	-	-	+
68 Indian Bush Hopper	*Ampittiadioscoridesdioscorides*	-	-	+	-
69 Spotted small flat	*Sarangesapurendra* (Moore, 1882)	-	-	+	+
Total number of species recorded in different study sites		12	24	48	64

Note: + means species present in study area, - means species absent in study area

within a region and the replacement of species by another disconnected part of same habitat.

Whittaker's Beta Diversity Index

$$\beta w = (S/\alpha) - 1$$

where S= the total number of species recorded in study area, α=Average of species richness of the sample

Cody's Beta Diversity Index

$$\beta c = g\ (H) + I(H)/2$$

where g (H) = Number of species recorded in study area, I (H) = the number of species absent along transect

Mourelle Index

$$B_{me} = \frac{g(H) + l(H)}{2a(N-1)}$$

Results and Discussion

During the present study total 69 species of butterflies were observed in the study areas, which belongs to five families viz. Papillionidae(4), Pieridae (20), Lycanidae (21), Nymphalidae (19) and Hesperiidae (5). Out of them only 12 species of butterflies were observed in Urban Site 1 (US1) followed by 24 species observed in Urban Site 2 (US2), 48 species in Sub Urban Site (SUS) and maximum butterfly species were observed and recorded from Rural Area Site (RAS) (Table-1). Various diversity indexes were utilized during the present study to calculate the abundance and richness of butterfly species in the study areas. Shanon-Wiener Diversity Index showed maximum butterfly diversity in RAS (3.663), followed by SUS (3.251), US2 (2.515) and US1 (2.132). Similarly Simposon-Diversity Index showed maximum butterfly diversity in RAS (0.9638), followed by SUS (0.947), US2 (0.887) and US1 (0.8496).

Abundance estimation of butterflies of different areas was done through using Brillion Diversity Index which showed minimum abundance of butterflies was observed in US1 (1.993) followed by US2 (2.358), SUS (3.107) and maximum abundance was recorded in RAS (3.556). Butterfly richness was calculated through Menhinick's richness index, Margalef's richness index and Chao-1 richness indices. Value of Menhinick's index was obtained 0.9864 in US1 followed by 1.556 in US2, 2.019 in SUS and 1.831 in RAS. Margalef's Richness Index value was calculated to be 2.201 (US1) followed by 4.203 (US2), 7.417 (SUS) and maximum richness calculated was 8.863 (RAS). According to Chao-1 species richness indices; minimum richness were observed in US1 (12), followed by US2 (45), SUS (83) and maximum richness observed was in RAS (92). Spe-

cies evenness was calculated by using Equitability-J Index and following values of species evenness was obtained 0.8578 in US1 followed by 0.7914 in US2, 0.8399 in SUS and maximum evenness 0.8807 was observed in RAS. Fig.-1 and Fig.-2 shows comparative analyses graphically shown for butterfly abundance and richness respectively in different study sites of the study area Udaipur depicting both maximum abundance and richness for butterflies for RAS and minimum for US1.

Over all beta diversity of butterflies of study area was calculated from Whittaker's Beta Diversity Index, Cody's Beta Diversity Index and Mourelle Index. Value of different Beta Diversity Indices obtained was 0.86486 for Whittaker's Beta Diversity Index, 35 for Cody's Beta Diversity Index and 0.31 Mourelle Index inclusively for all study areas.

The present study represents total 69 butterfly species belonging to five families observed and recorded during the study period. Present study is important in understanding the relationship between urbanization and its effects on butterfly diversity, density and abundance. Butterfly richness, abundance and diversity was observed and recorded lowest in the urban area due to lack of flowering plants, natural vegetation and abundance of various anthropogenic activity centres and pollution. While maximum butterfly richness, abundance and diversity was recorded in the rural areas due to high density of plant community including flowering plant and crops and less anthropogenic disturbances. Different plant species and crop plants prove to be a suitable habitat for survival and sustainability of butterflies as they are direct good sources of food, nectar and shelter to them which is supported by different indices of abundance and richness and hence indicate that vegetation is important for the survival and existence of butterflies.

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