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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, abun-dance and evenness.The present study focuses on uncovering the significant gaps related to but-terfly 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 studytotal 69 species of butterflies were recorded together from all four study areas. The minimum number of butterfly diversity, abundance and evenness was rec-orded in Urban Site 1 (US1) (Shanon-Wiener Diversity Index=2.132, Simpson Diversity In-dex=0.8496, Brillion Index=1.993, Menhinick's Index=0.9864, Margalef's Index=2.201, Chao-1 Index=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-1 Index=92, Equability-J Evenness Index=0.8807). Overall Beta Diversity of the four study areas wasrecordedwith 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 higha-bundance due to present of high densityand variety of vegetation in this site.

Key words: Urbanization, Diversity, Abundance, Evenness, Vegetation.

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INTRODUCTION

Butterflies are very beautiful and charming invertebrateand are key species of an ecosystem playing thereimportant role in various ways in terrestrial ecosystems (Robbins and Opler 1997).Simultane-

ously they act as agood bio-indicator in analyzing the health of various ecosys-tems. 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 sur-rounding 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 and Launer 1997, Claket al. 2007,Tipleet al. 2007). Urbanization is becoming major threat and responsible factor for reduction in overall global biodiversity (Wilcoveet 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 con-dition, while opposite of the sameis 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 abun-dance of butterflies heavily depends upon variety of plant species including herbs, shrubs and cultivated plants (Padhyeet al. 2001). Most of the butterflies prefer particular habitats only and show periodic and sea-sonal variationsin their life cycle throughout year (Kunte1997). 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 includ-ing birds, rep-tiles, 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, humidi-ty, pollution and availability of host plants in an ecosystem (Thomas et al. 1998,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 dif-ferent types and enormous anthropogenic activities like urbanization, industrialization, construc-tion of roads and build-ings, 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 todecline in biodiversity in various ecosystems of the Earth (Ramesh et al. 2010,Rosin et al. 2012).

Study on butterflies has been started during 18th century and almost 19,238 species are discov-ered worldwide presently (Heppner 1998) anddiscovery of new species of butterflies is appearing to be a continuous and constant process throughout different continents of the world (Green and Huang 1998,Ba-ruaet al.2004, Ambrose and Raj 2005,Alphonsa 2006, Chandra et al. 2007, Parag and Omkar 2009). Ento-mologists and other related enthusiasts has document-ed around 1504 but-terflies species widely distributed throughoutin the Indian subcontinent which includes 100 en-demic and threatened butterfly species as per IUCN Red list of threatened animals (Singh and Pandey 2004,Tipleet al. 2007). Very few studies have been conducted on butterflies in the south-ern part of the state Rajasthan particularly district Udaipur. Total 40 butterfly species were rec-orded in native vegetation and Prosopisjuliflora dominated area of Udaipur district, Rajasthan (Choudhary and Chishty 2020) which mainly belongs to four families of insects namely Papil-lionidae (12 species), Lycanidae (10), Nymphalidae (15) and Hespridiae (3).

MATERIALS AND METHODS

Study area

Udaipur is located inSouthern 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 hillranges 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 540-580 mm. 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 numer-ous 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 com-position 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 linestransects 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 eachquadratewas 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 -7:00pm. 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 usingsoft ware's SPSS and PAS Tandbutterfly 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.

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

where P_i= i is the proportion of individuals found in the i^{th} species represented in natu-ral logarithm.

3. **Brillouin Diversity Index-**The index calculates and reflect the species abundance in the study area.

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

Where N = Total number of individuals in the community, n_i = The number of indi-viduals in the i^{th} species

4. 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

5. Margalef'sRichness Index:

$$\text{Margalef" srichress Index} = \frac{(S-1)}{\text{In } (n)}$$

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

6. 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 indi-viduals between the observed species, they are widely distributed.

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

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

7. Chao-1- This index uses for the estimate of species richness in different habitat or area, proposed by (Chao 1984).

$$\hat{S}_{max} = S_{obs} + (a^2/2b)$$

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 in-dividuals.

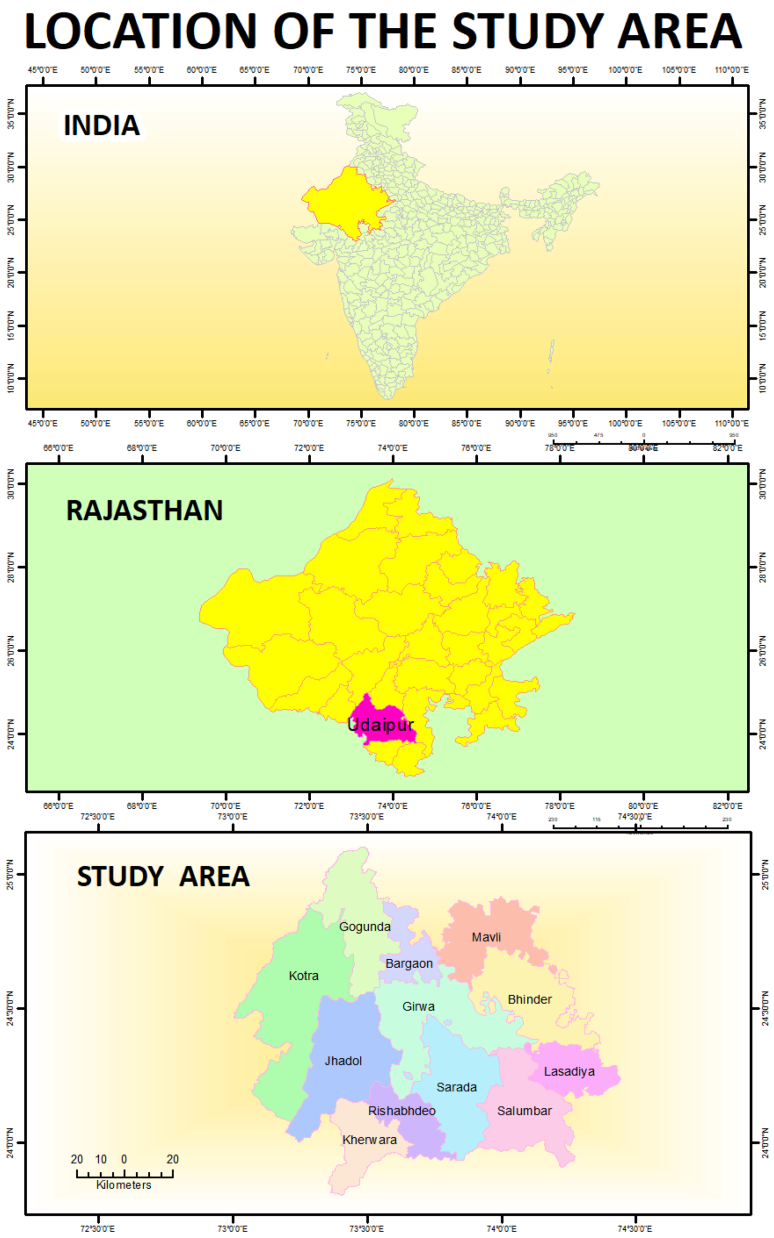

Fig. 1. Geographic location of different study sites in Udaipur district.

Beta Diversity Indices

Beta diversity calculates the species diversity with transects and it is mainly applicable on the analysis of environ-mental gradients. It is calculated on the basis of two different variables, the number of selective habitats within a region and the replacement of species by another disconnected part of same habitat.

1. Whittaker's Beta Diversity Index

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

Where S= the total number of species recorded in

Table 1. Continued.

	Common name and families	Zoological name	Urban SIte-1 (USI	Urban Site-2 (US2)	Sub Urban Site (SUS)	Rural Area Site (RAS)
	Papillionidae					
1.	Tailed Jay	*Graphiumagamemnonagamemnon* (Linnaeus 1758)	-	+	+	+
2.	Indian Common mormon	*Paptlio polytesromudus* (Cramer 1775)	-	-	+	+
3	Lime butterfly	*Papilio demoleus*(Linnaeus 1758)	+	+	+	+
4	Malabar Raven	*Papilio dravidarum* (Wood-Mason1880)	-	+	+	+
	Pieridae					
5	Small grass yellow	*Eurema brigitta* (Cramer 1780)	+	+	+	+
6	Common grass yellow	*Eurema hecabe* (Linnaeus 1758)	-	+	+	+
7	Indian Spotless grass yellow	*Eurema laetalaeta* (Boisduval 1836)	-	-	+	+
8	Oriental Mottled Emigrant	*Catopsilia pyranthe pyranthe* (Linnaeus1758)	-	+	+	+
9	Common Emigrant	*Catopsilia pomona pomona* (Fabricius1775)	-	+	+	+
10	Common gull	*Cepora nerissa* (Fabricius 1775)	-	-	-	+
11	Indian Little orange tip	*Colotis etrida* (Boisduval 1836)	-	-	+	+
12	Caper white	*Belenois aurota* (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	*Leptosia nina nina* (Fabricius1793)	-	-	+	+
17	Western Striped Albatross	*Appias libythea* (Fabricius 1775)	-	+	+	+
18	White Arab	*Colotis vestalis* (Butler 1876)	-	-	-	+
19	Modest Small Salmon Arab	*Colotis amatamodesta* (Butler 1876)	-	-	+	+
20	Dakhan Large Salmon Arab	*Colotis faustafulvia* (Wallace 1867)	-	-	-	+
21	Blue Spotted Arab	*Colotis protractu* (Butler 1876)	-	-	-	+
22	Red Line Small grass yellow	*Euremabrigitta rubella* (Wallace 1867)	-	+	+	+
23	Indian Orange Albatross	*Appias galba* (Wallace 1867)	-	-	+	+
24	Sahyadri Albatross	*Appias wardii* (Moore 1884)	-	+	+	-
		Lycaenidae				
25	Indian Tiny grass blue	*Zizula hylax hylax* (Fabricius 1775)	+	-	-	+
26	Grass Jewel	*Freyeria trochylus* (Freyer, 1845)	+	-	-	+
27	Zebra blue	*Leptote splinius splinius* (Fabricius, 1793)	-	-	+	+
28	Gram blue	*Euchrysops cnejus cnejus* (Fabricius1798)	+	-	+	+
29	Pea blue	*Lampides boeticus* (Linnaeus 1767)	-	-	-	+
30	Striped pierrot	*Tarucus nara* (Kollar 1848)	-	-	+	-
31	Spotted pierrot	*Tarucus callinara* (Butler 1886)	-	-	+	-
32	Black spotted pierrot	*Tarucus balkanicanigra* (Bethune-Baker 1918)	-	-	-	+
33	Lesser grass blue	*Zizinaotis* (Fabricius 1787)	-	-	+	+
34	Indian cupid	*Cupidolacturnus* (Godart 1824)	-	-	-	+
35	Small cupid	*Chilades parrhasius parrhasius* (Fabricius 1793)	-	-	+	+
36	Indian Lime blue	*Chilades lajus lajus* (Stoll 1780)	-	-	-	+
37	Pale grass blue	*Pseudozizeeriamaha* (Kollar 1884)	-	-	+	+
38	Indian Common silverline	*Spindasis vulcanus vulcanus* (Fabricius 1775)	-	+	+	+

Table 1. Continued.

	Common name and families	Zoological name	Urban Site 1 (US1)	Urban Site 2 (US2)	Sub Urban Swite (SUS)	Rural Area Site (RAS)
39	Bright Babul Blue	*Azanusubaldus* (Stoll 1782)	-	+	+	+
40	Common Pierrot	*Castaliusrosimon* (Fabricius 1775)	-	-	+	+
41	Angled Pierrot	*Caletadecidia* (Hewitson 1876)	-	-	-	+
42	Oriental Plains Cupid	*Chilades pandava pandava* (Horsfield1829)	-	+	+	+
43	Dark Pierrot	*Tarucus ananda* (de Niceville 1884)	-	-	-	+
44	Common Acacia blue	*Surendra quercetorum* (Moore 1858)	+	+	+	+
45	Indian Peacock Royal	*Tajuria cippus cippus* (Fabricius 1798)	-	-	+	+
Nymphalidae						
46	Danaideggfly	*Hypolimnas misippus* (Linnaeus 1764)	-	+	+	+
47	Oriental Great eggfly	*Hypolimnas bolinajacintha* (Drury,1773)	+	+	+	+
48	Blue pansy	*Junonia orithya* (Linnaeus 1758)	-	-	+	+
49	Peacock pansy	*Junoniaalmana* (Linnaeus 1758)	+	+	+	+
50	Yellow pansy	*Junonia hierta* (Fabricius 1798)	-	-	-	+
51	Painted lady	*Vanessa cardui* (Linnaeus 1758)	-	-	-	+
52	Grey pansy	*Junonia atlites* (Linnaeus 1763)	+	-	+	+
53	Lemon pansy	*Junonia lemonia*s (Linnaeus 1758)	+	+	+	+
54	Common evening brown	*Melanitis leda* (Linnaeus 1758)	-	-	+	+
55	Dark evening brown	*Melanitis phedima* (Cramer 1780)	-	+	-	-
56	Common castor	*Ariadne merione* (Cramer 1777)	+	+	+	+
57	Common leopard	*Phalanta phalantha* (Drury 1773)	-	-	+	+
58	Plain tiger	*Danaus chrysippu*s (Linnaeus 1758)	+	+	+	+
59	Striped tiger	*Danaus genutia* (Cramer 1779)	-	+	+	+
60	Blue tiger	*Tirumala limniace* (Cramer 1775)	-	+	+	+
61	Indian common crow	*Euploea core core* (Cramer 1780)	-	-	+	+
62	Indian Extra Lascar	*Pantoporiasandakadavidsoni* (Eliot1969)	-	-	+	+
63	Chocolate pansy	*Junonia iphita* (Cramer 1779)	-	-	-	+
64	Common four ring	*Ypthimahuebneri* (Kirby 1871)	-	-	-	+
Hesperiidae						
65	Brown Awl	*Badamia exclamations* (Fabricius 1775)	-	-	-	+
66	Common small flat	*Sarangesa dasahara dasahara* (Moore1866)	-	-	+	+
67	Indian Pale palm dart	*Telicota colon colon* (Fabricius 1775)	-	-	-	+
68	Indian Bush Hopper	*Ampittia dioscorides dioscorides*	-	-	+	-
69	Spotted small flat	*Sarangesa purendra* (Moore 1882)	-	-	+	+
	Total number of species recorded in different study sites		12	24	48	64

study area, α = Average of spe-cies richness of the sample

2. 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

3. Mourelle Index

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

RESULTS AND DISCUSSION

During the present study total 69 species of butterflieswere observed in the study areas,which belongs

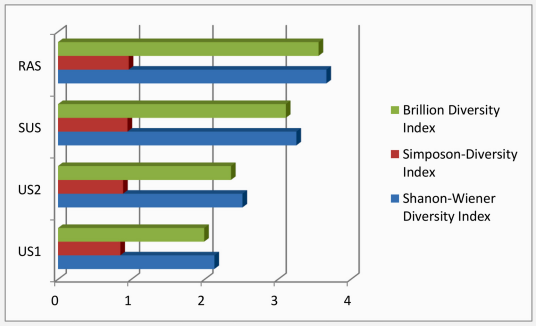

Fig. 2. Comparative analyses of various abundance estimates for butterflies in different study sites in the study area of Udaipur (RAS = Rural Area Site, SUS = Sub Urban Site, US2 = Urban Site 2, US1 = Urban Site 1).

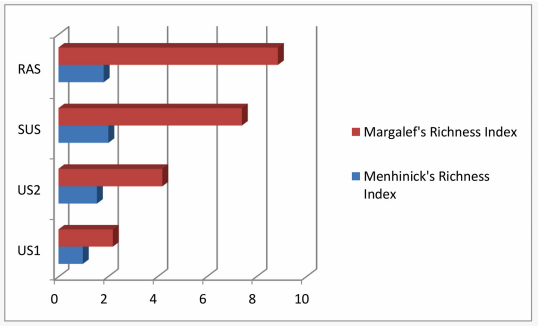

Fig. 3. Comparative analyses of various richness estimates for butterflies in different study sites in the study area of Udaipur (RAS = Rural Area Site, SUS = Sub Urban Site, US2 = Urban Site 2, US1 = Urban Site 1).

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 fromRural Area Site (RAS) (Table 1). Various diversity indexes were utilized during the present study to calculate the the abundance and richness of butterfly species in the study areas. Shannon-Wiener Diversity Indexshowed maximum butterfly diversity in RAS (3.663), followed by SUS (3.251),US2 (2.515) and US1 (2.132). Similarly Simpson-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 richnesscalculatedwas 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). Species 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. Figs. 1-3 shows comparative analyses graphically shown for butterfly abundance and richness respectively in different study sites of the study area Udai-pur 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 Diversi-ty Index, Cody's Beta Diversity Index and Mourelle Index. Value of different Beta Diversity Indices obtainedwas 0.86486 forWhittaker's Beta Diversity Index, 35 forCody's Beta Diversity Index and 0.31 Mourelle Indexinclusively for all study areas.

Butterflies importance in agriculture

Butterflies show wide range of food choices and host specific relationship with plant to complete its life cycle. They plays important role in all ecosystems including forest, agricultural land and gardens. They pollinate various cropping plants all around year. They are excellentpollinator which helps incross pollination and hence increase production of crops all around world. Butterf-ly diversity and abundance are important part of agro ecosystem; they primarily cre-

ates link be-tween plants and animals in food chains. Butterfly and other insects performs dual roles as a pol-linator and control pests in agro ecosystem. In present time excessive use of pesticides and chemical in agricultural become limiting factors for butterflies survival and distribution. They are very sensitive to change in environment so its study helpful in deter-mine changes in environment and habitats.

Butterflies play an important role in pollination of plants and are equally important to agriculture in same manner. Besides being important aesthetically they play significant role in biodiversity conservation by playing a vital role in the ecosystem. Butterflies help in migration of pollen grains which induces genetic variation in plant species including cultivated crops allowing them to maintain their sustainability. Seasonal crop like wheat, mustard, coriander, maize,Jowar increase butterflies abundance due to availability of nectar and host plant for development of larval stages. Butterflies are useful and as well as adverse impact on cropping plant. Due to cross pol-lination leads to increase genetic variation and crop production in agricultural ecosystems.

CONCLUSION

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 therelationship betweenurban-izationand its effects on butterfly diversity, density and abundance. Butterfly rich-ness, abundance and diversity was observed andrecorded lowest in the urban area due to lack of flowering plants, natural vegetation and abundance of various anthropogenic activity centers 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 cropsand less anth-ropogenic disturbances. Different plant species and crop plantsprove to bea suitable habitat for survival and sustainability of butterflies as they are direct good sources of food, nectar and shel-ter to themwhich 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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