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Comparative study of diversity and seasonal abundance of butterflies in two different sites (Chatra Villas Garden and Abheda), Kota, Rajasthan, India

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Abstract
Butterflies are the most important "bioindicators" representing the overall health of the ecosystem (Pollard, 1991). Butterflies are dependent on different types of vegetation for their life. They are facing threats due to habitat loss and climate change that varies with seasons. Chatra villas garden is endowed with butterflies diversity due to lush green vegetation. Comparatively Abheda is lower in species richness and abundance of butterflies due to habitat loss and lesser variation in vegetation. Study of these bioindicators is crucial for patronage efforts, monitoring of ecosystem and overall understanding the health of the ecosystem. Number of species of butterflies is decreasing day by day due to increase use of pesticides, deforestation and climate change that ultimately results in loss of habitat of butterflies. The study was carried out in March 2022 to February 2023. For the sampling of butterflies "Line Transect Method" was used. The Microsoft excel was used for analyzing the data and for making the graphs. Maximum abundance (205) and species richness (19) was reported in Chatra villas garden. While in Abheda 191 individuals and 11 species of butterflies was reported. Shannon diversity index of Chatra villas garden (H= 2.288) is more than the Abheda (H= 1.883). The highest Simpson's diversity index was at the Chatra villas garden (D= 0.8651) than Abheda (D= 0.176). The species richness Margalef's index (R) of Chatra villas garden (R= 3.381) was higher than the Abheda (R= 1.903). Pielou's eveness index (e) of Chatra villas garden was (e= 0.777) lesser than Abheda (e= 0.785). Nymphalidae family was the dominant family in both Chatra villas garden (36.84%) and in Abheda (54.54%).The least dominant family in Chatra villas garden was Hesperiidae (5.26%) while in Abheda, Lycaenidae (18.18%) was the least dominant family. *Danaus chrysippus* (Plain tiger butterfly) and *Eurema brigitta* (Brush bordered yellow) was the most dominant species in C.V garden. While in the Abheda *Zizula hylax* (Tiny grass blue) was the most dominant species followed by *Danaus chrysippus*.

Keywords: Chatra villas garden, abheda, diversity indices, species richness, relative dominance, seasonal abundance

Introduction
Butterflies are the most important "bioindicators" representing the overall health of the ecosystem (Pollard, 1991) [25]. Butterflies are dependent on different types of vegetation for their life. They are facing threats due to habitat loss and climate change that varies with seasons. As the butterfly population is declining day by day. So the study of their diversity, richness, evenness and abundance help us to track the population changes. Due to anthropogenic activities the shocks and the pressure on the ecosystem result into changes in environment in which living organisms (including butterflies) are unable to adapt. The species richness and kinds of butterflies also determined by habitat type. Therefore, observation of butterfly population helps in monitoring the environmental changes and the condition of habitats for biodiversity.

These Lepidopterans are able to detect the minute climatic variations. The diversity of species is affected by climatic changes such as temperature, rainfall patterns and harsh atmospheric conditions such as heat waves, persistent dry weather or persistent rainfall. The study of these bioindicators is crucial for patronage efforts, monitoring of ecosystem and overall understanding the health of ecosystem. The diversity of butterflies in the whole world is 18,000 species (IUCN, 2020).

Out of that India accounts 1379 butterfly species (Das *et al*. 2023).

Present study will help us to explore the diversity and seasonal abundance of two different sites. The result of present study will uncover the health of ecosystem and provide the baseline data which is focusing on the need to protect the habitat loss in order to conserve the biodiversity of butterflies.

Materials and Methods

Study area: For the biodiversity study of butterflies in Kota, two sites were selected- Chatra villas garden and Abheda (near water body).

Site 1 Chatra villas garden is located at Nayapura Kota just adjacent to Kishore Sagar Talab. The geographical coordinates lies between latitude 25.20°N and longitude 75.85 °E (Fig 1). Area covered by C.V garden is 62.1 acres. The Chatra villas garden is enriched with unique flora and fauna. Different plant species present in Chatra villas garden are *Leucophyllum frutescens, Lantana camara, Nuphar advena, Hamelia patens, Phlox, Crinum asiaticum, Langerstroemia indica, Parthenium hysterophorus, Azadirachta indica, Murraya paniculata, Tridex procumbens, Mangifera indica, Nelumbo nucifera, Acacia arabica, Calotropis procera, Hibiscus rosasinensis, Psidium guajava etc.*

Fig 1: Map of C.V garden, Nayapura, Kota (Rajasthan).

Site 2 is Abheda, which is situated near the Chambal river of Kota, Rajasthan. The geographical coordinates of Abheda Mahal lies between latitude 25.20 °N and longitude 75.79 °E (Fig 2). Abheda Mahal is located about 8 km from the main Kota city. This area is covered by grass and various plant species like *Allamanda cathartica, Bougainvillea glabra, Calotropis procera, Hibiscus rosasinensis, Lantana camara, Acacia catechu, Eicchornia crassipes, Ficus benghalensis, Parthenium hysterophorus and Azadirachta indica etc.*

Fig 2: Map of Abheda (near the Chambal river of Kota, Rajasthan)

Method of sampling, collection of butterflies and identification: The sampling was done by "Line Transect Method" during March 2022 to February 2023. Regular visits and collections were done between 7 am to 11 am and in evening 4 pm to 6 pm with the help of Aerial net. Data was collected regularly every month and insects were photographed using Nikon Z611. The insects were identified based on their wings color, pattern, shapes, sizes, with the help of entomological experts, and available literature.

Statistical analysis: Alpha diversity is used and the data of identified species were analyzed for richness and abundance by using various diversity indices.

Shannon–Wiener diversity index (H)
It is alpha diversity index and it depends upon species richness and species evenness. High value of 'H' indicate greater diversity.
Shannon–Wiener diversity index (Shannon, 1949) was calculated as-

$$H = - \sum Pi \, In \, Pi$$

Where Pi = S / N, S = number of individuals of one species, N = total number of all individuals in the sample, In = logarithm to base e.

Simpson's Index (D): Simpson's index denotes the alpha diversity of the selected area. It depends on both species richness and evenness. This index measures the probability that any two individuals drawn randomly from an infinitely large community will belong to same species. The Simpson's Index (Simpson, 1949) was calculated as-

$$D = \Sigma ni \, (ni-1) / N \, (N-1)$$

Where, N = total number of individuals, ni = number of individuals of ith species
The value of 'D' ranges from 0 to 1. Higher value of 'D' represents lower diversity
D= 0 represents infinite diversity, D=1 represents no diversity

Margalef's Index (R)
This index is also an alpha diversity index and used as a simple measure of species richness (Magurran, 1988).

$$R = (S - 1) / In \, N$$

S = total number of species, N = total number of individuals in the sample
In = natural logarithm

Pielou's Evenness Index (e)
Pielou's index is an alpha diversity index that measures how evenly species are distributed in a community ((Pielou, 1969).

$$e = H / In \, S$$

H = Shannon – Wiener diversity index, S = total number of species in the sample

Relative dominance
The relative dominance of butterfly family was calculated by using dominance index.

$$\text{Relative dominance} = ni \times 100 / N$$

Where ni = number of butterflies in the 'i' th family, and N = the total number of butterflies in all the families collected in each habitat

Similarity and Dissimilarity measures (S)
It denotes the beta diversity of a community,

$$S = 2C/A+B$$

Where, A= number of species in site1, B= number of species in site2
C= number of species common in both site1 and site2

Jaccard's Index (J)
This is another parameter to study beta diversity**,**

$$J = S_c/S_a+S_b+S_c$$

Where, S_a and S_b are the number of species unique to samples a and b respectively, and S_c is the number of species common to the samples.

Results
(A)- Species composition and distribution of butterfly species among families
A total of 396 individuals of 19 species representing 15 genera, 5 families of superfamily Papilionoidea were recorded from both the sites during the study period. The higher number of species was reported from C.V garden (19 species) belonging to 5 families and 15 genera (Table 1a), whereas 11 species were reported from Abheda belonging to 3 families and 7 genera (Table 1b).
The least dominant family in term of species in C.V garden is Hesperiidae (5.2%) while in Abheda it is Lycaenidae (18.18%). In both C.V garden and Abheda, Nymphalidae is having the highest percentage of species constituting 36.8% and 54.54% of total abundance respectively.
Butterflies were categorized on the basis of their abundance in C.V garden and in Abheda as - VC- very common (> 20 sightings), C- common (3-20 sightings) and R- rare (1-2 sightings).
In C.V garden the most abundant species reported were *Eurema brigitta* and *Danaus chrysippus*. *Zizula hylax* is the most abundant species reported in Abheda.

Table 1a: Checklist of butterflies recorded from site-I (C.V garden).

Family	Common name	Scientific name	Status
Papilionidae (3)	Common jay	*Graphium doson*	C
	Common rose swallowtail	*Pachliopta aristolochiae*	R
	Common mormon swallowtail	*Papilio polytes*	C
Pieridae (4)	Mottled emigrant	*Catopsilia pyranthe*	C
	Brush bordered yellow	*Eurema brigitta*	VC
	Common grass yellow	*Eurema hecabe*	VC
	Striped albatross	*Appias libythea*	R
Lycaenidae (4)	Cassius blue	*Leptotes cassius*	C
	Dark grass blue	*Zizeeria karsandra*	R
	Striped pierrot	*Tarucus nara*	R
	Tiny grass blue	*Zizula hylax*	C
Nymphalidae (7)	Blue pansy	*Junonia orithya*	C
	Plain tiger butterfly	*Danaus chrysippus*	VC
	Lemon pansy	*Junonia lemonias*	C
	Tawny coster	*Acraea terpsicore*	C
	Common tiger butterfly	*Danaus genutia*	VC
	Grey pansy	*Junonia atlites*	C
	Danaid eggfly	*Hypolimnas misippus*	C
Hesperidae (1)	Formoson swift or Rice swift	*Borbo cinnara*	R

Table 1b: Checklist of butterflies recorded from site-II (Abheda).

Family	Common name	Scientific Name	Status
Pieridae (3)	Mottled emigrant	*Catopsilia pyranthe*	C
	Brush bordered yellow	*Eurema brigitta*	VC
	Common grass yellow	*Eurema hecabe*	C
Lycaenidae (2)	Cassius blue	*Leptotes cassius*	C
	Tiny grass blue	*Zizula hylax*	VC
Nymphalidae (6)	Blue pansy	*Junonia orithya*	R
	Plain tiger butterfly	*Danaus chrysippus*	VC
	Lemon pansy	*Junonia lemonias*	C
	Common tiger butterfly	*Danaus genutia*	VC
	Grey pansy	*Junonia atlites*	C

Table 1c: Comparison between site I and site II with respect to families, species and individuals.

Site	Number of families	Number of species	Number of individuals
S I	5	19	205
S II	3	11	191
Total			396

(B). Species diversity, richness and abundance

Alpha diversity

The study of alpha diversity of particular population is a combination of species richness and species evenness.

At site I, 5 families with 15 genera and 19 species were recorded. Family Nymphalidae constituted 37% of total butterfly population, family Pieridae and Lycaenidae constituted 21%, family Papilionidae constituted 16% and family Hesperiidae constituted 5% of the total butterfly population at site I. The C.V garden showed the highest Shannon-Weiner diversity index (2.288) and the highest Simpson diversity index (0.865).

At site II, 3 families with 7 genera and 11 species were recorded. Family Nymphalidae constituted 54.54% of total butterfly population, family Pieridae constituted 27.27% and family Lycaenidae constituted 18.18% of the total butterfly population at site II.

Shannon-Weiner diversity index of Abheda is 1.883 and the Simpson diversity index is 0.176.

Site I was found to be more abundant and diverse as compared to site II. Family Hesperiidae is least abundant at site I, whereas family Hesperiidae was not recorded from the site II.

Butterfly population in relation to time of day was more abundant in morning time (7.00 – 11.00 AM) over the evening time (4.00 – 6.00 PM). There is high significant difference in the abundance in relation to the time of day.

Abundance shows the proportion of the number of individual species to the total population. Relative abundance of site I was higher (9.2682) than the site II (5.7591%). Relative abundance of each species indicates the degree to which one species dominates the community.

The Pielou's index (e) of site I was (0.777) lower than the site2 (0.785). The higher value of Pielou's index at site II indicates that species are more evenly distributed at site II as compared to site I.

At site I Nymphalidae is the most dominant group, followed by Pieridae, Lycaenidae, Papilionidae. Family Hesperiidae is the least dominant group in the C.V garden.

At site II, Nymphalidae is the most dominant group like site I, followed by Lycaenidae. Family Pieridae represent the least dominant group of site II (Table 2).

Table 2: Comparison of butterfly diversity indices in site 1 & site 2.

Site	Margalef's Index (R)	Pielou's Index (e)	Simpson Index (D)	Shannon Index (H)
1	3.381	0.777	0.865	2.288
2	1.903	0.785	0.176	1.883

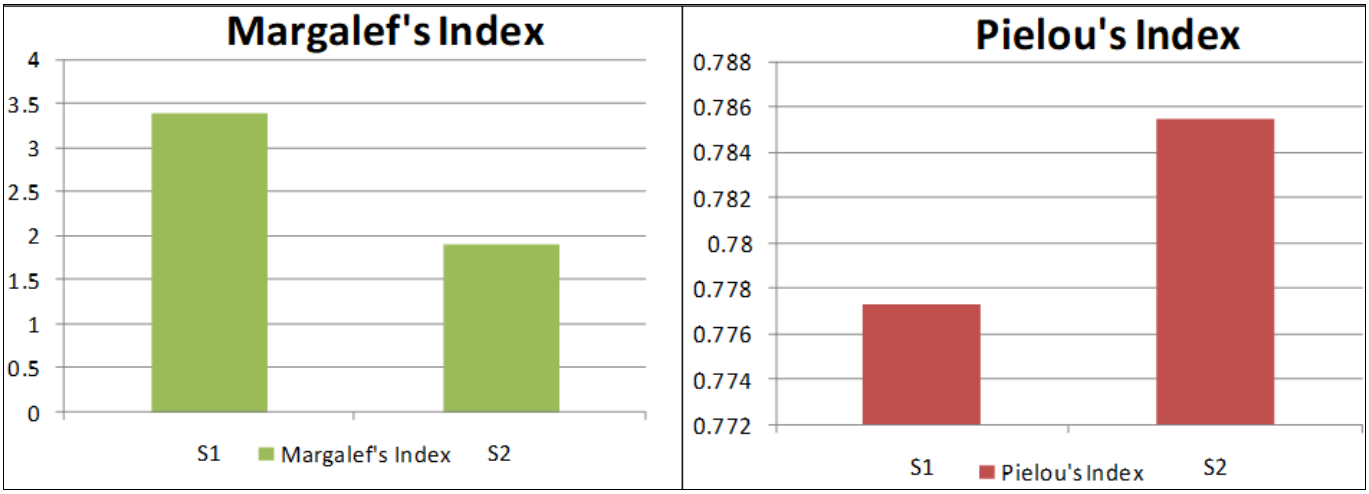

Fig 3a & 3b: Comparison of Margalef's index (species richness) and Pielou's index (species evenness) of site I & site II.

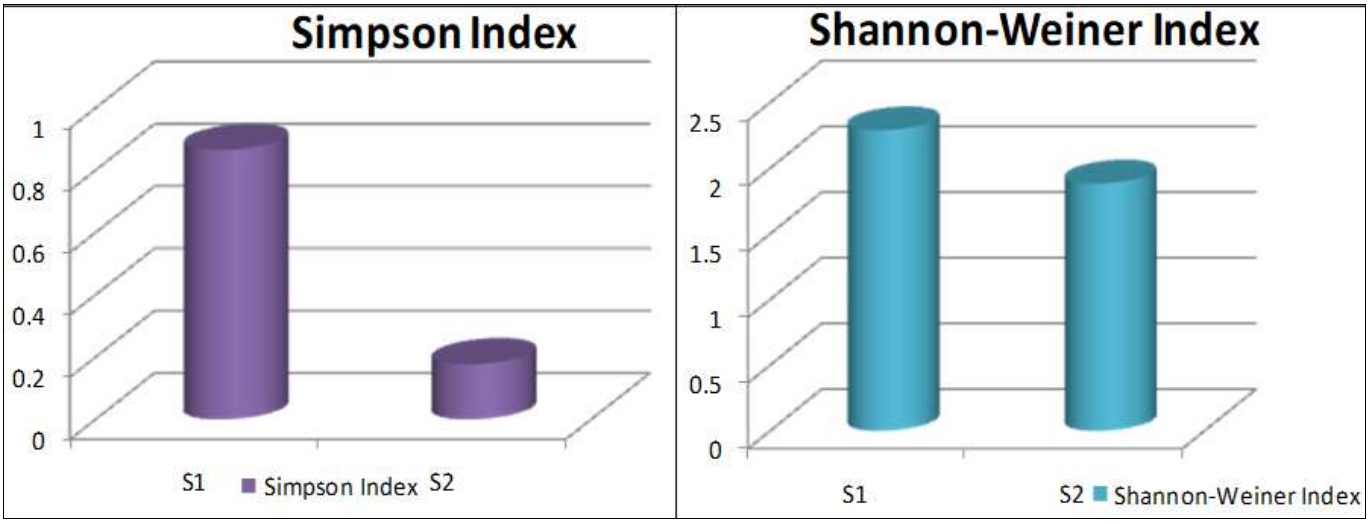

Fig 4a & 4b: Comparison of Simpson's index and Shannon-Weiner index of site I & site II.

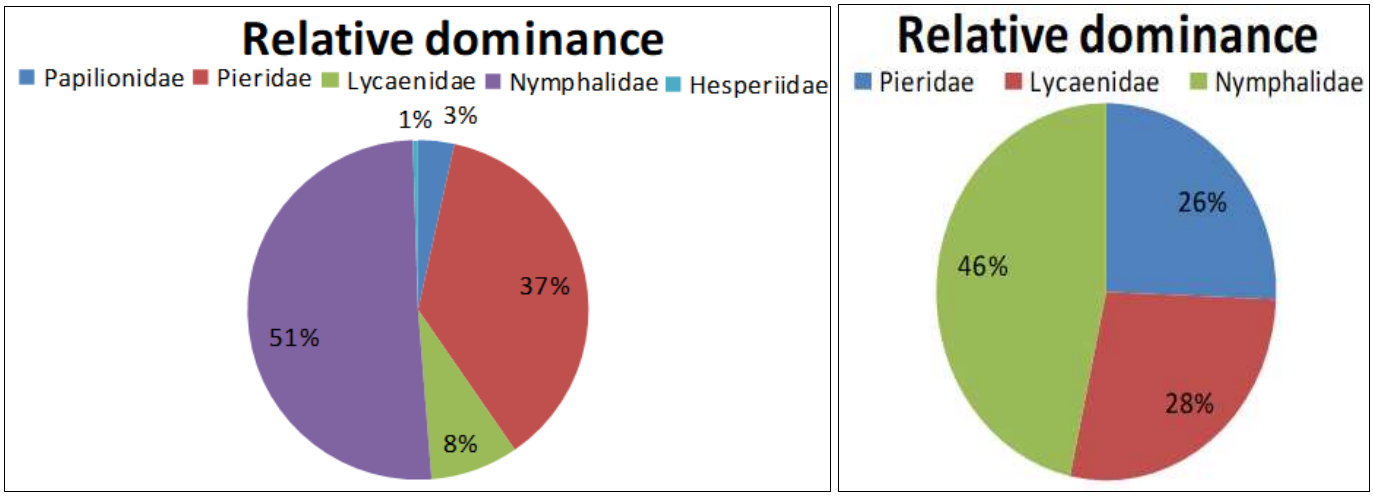

Fig 5a & 5b: Relative dominance of site I and site II.

Beta diversity: It is species diversity between two adjacent ecosystems and is measured by comparing the number of species unique to each ecosystem.

Beta diversity is calculated by similarity-dissimilarity index- The similarity index of S_I-$S_{II}$is 0.733 while the dissimilarity index is 0.267.

Jaccard's Index is another parameter of beta diversity- The Jaccard's index of s_1-s_2 is 0.578.

Gamma diversity

Gamma diversity describes the overall species diversity across communities within a larger geographical area.

In site I & site II, 396 individuals of butterflies were sampled belonging to 5 families & 19 species.

(C). Seasonal distribution and abundance of butterflies species among families

(1) Site-I

In terms of species composition at site I in Monsoon season family Nymphalidae showed highest species composition (53.8%) in comparison to other families. Family Lycaenidae showed lowest composition (7.6%), family Hesperiidae was totally absent from the site 1 in Monsoon season. Species composition of family Papilionidae was 15.3% and species composition of family Pieridae was found 23% in Monsoon season.

In Post-Monsoon season family Nymphalidae showed highest species composition (36.8%) followed by family Pieridae (21%) and Lycaenidae (21%) and the lowest species composition was showed by Hesperiidae (5.2%). Species composition of family Papilionidae in Post-Monsoon season was 15.7%.

In winter season family Nymphalidae and Pieridae showed the highest species composition (42.8%) followed by Lycaenidae (14.2%). While family Papilionidae and Hesperiidae were completely absent in winter season at Site I.

Family Nymphalidae (63.6%) showed highest species composition in summer season followed by Pieridae (27.2%) and Lycaenidae (9%) while family Papilionidae and Hesperiidae was completely absent in summer season at site I.

In terms of species composition family Nymphalidae showed highest composition 63.6% in summer season and least in Post-Monsoon season. Similarly family Papilionidae represented its highest composition in winter season and least in the Post-Monsoon season.

Family Pieridae showed highest composition (42.8%) in winter season and least composition in Post-Monsoon season.

Lycaenidae was highest (21%) in Post-Monsoon season, followed by winter season (14.2%), Monsoon season (7.6%) and least composition was in summer season (9%). Family Hesperiidae showed its presence only in Post-Monsoon season.

(2) Site-II

In terms of species composition at site II in Monsoon season family Nymphalidae showed highest composition (44.4%) in comparision to other families. Family Pieridae showed (33.3%) second highest species composition in Monsoon season followed by Lycaenidae (22.2%).

In Post-Monsoon season family Nymphalidae showed highest species composition (54.5%) followed by Pieridae (27.2%) and Lycaenidae (18.1%). In summer season Nymphalidae family showed highest species composition (50%) followed by Pieridae (37.5%) and Lycaenidae (12.5%).

In winter season, all the families (Pieridae, Lycaenidae and Nymphalidae) showed equal species composition (33.3%)

In terms of species composition, family Nymphalidae showed highest composition in Post-Monsoon season (54.4%) and least in winter season (33.3%).

Family Lycaenidae showed highest composition in winter season (33.3%) and least in summer season (12.5%). While Pieridae showed highest species composition in summer season (37.5%) and least in Post-Monsoon season (27.2%).

In terms of abundance all the families in both the sites were at their peak in Post-Monsoon season, followed by Monsoon, summer and winter season respectively (Table 3).

Table 3: Seasonal abundance of butterflies in site I & site II.

S. No.	Families	Abundant in season	
		Site-I	Site-II
1	Papilionidae	Post-Monsoon	-
2	Pieridae	Post-Monsoon	Post-Monsoon
3	Lycaenidae	Post-Monsoon	Post-Monsoon
4	Nymphalidae	Post-Monsoon	Post-Monsoon
5	Hesperiidae	Post-Monsoon	-

Table 4: Families showing highest abundance in all four seasons in site I & site II.

Site	Winter (Dec-March)	Summer (April-June)	Monsoon (July-Sept)	Post-Monsoon (Oct-Nov)
I	Pieridae	Nymphalidae	Nymphalidae	Nymphalidae
II	Nymphalidae	Nymphalidae	Nymphalidae	Nymphalidae

Discussion

The analysis of the results of present investigation showed that butterfly composition from both the habitats spread across 5 families, 15 genera and 19 species which is a indicator of rich biodiversity.

The biodiversity of butterflies at Abheda is low as compared to C.V garden due to less variation in vegetation. The proper maintenance of natural habitat of Abheda may be affected by anthropogenic activities.

In C.V garden the high diversity and richness of butterfly species was observed, which may be due to the availability of nector and host plants of butterflies. This result favors the statement of Sreekumar and Balakrishnan (2001a) [35] said that prevalence of butterfly species at a particular habitat depends on a wide range of factors, of which the availability of the food is the most important.

In general the highest diversity of butterfly species are found in those areas which provide the large number of host plants. Results of present study are supported by results of Krauss *et al.* 2003 [13] which says species number of all the butterflies increase significantly with increasing diversity of the surrounding landscape.

The higher Shannon-Weiner index (2.288) and the higher Simpson index (0.865) of site I indicates that site I is more diverse than site II regarding the species of butterflies.

The results of present study agree with the findings of Sayeswara (2018) [31] who recorded higher percentage of species of butterfly from Nymphalidae family (44.4%),

followed by Papilionidae (22.2%), Lycaenidae having (8.33%) and Hesperiidae family with least percentage of species of butterflies in the study area.

Both in C.V garden and Abheda the Nymphalidae showed the highest species richness and abundance. The dominance of Nymphalidae can be due to polyphagous habit that helped them to live in all habitats (Sreekumar and Balakrishnan, 2001b) [36] which comprised the largest family of butterflies.

In terms of abundance in Abheda the Lycaenidae family showed second highest abundance. The possible reason could be as the Lycaenidae family known to adopt various climates and feeding on a variety of larval food plants (Kunte, 2001) [17]. Rich diversity of butterflies especially the Nymphalidae and Lycaenidae indicates a varied assemblage of floral species.

The higher number of Pieridae and Lycaenidae is supported by studies of Bernard who reported that that these two families can be seen almost everywhere. In C.V garden the Pieridae showed the second highest abundance. Pieridae are sun lovers seen basking in sun with wings partially open (Kehimkar, 2008) [10]. The possible reason for the abundace of Pieridae family in C.V garden is the presence of supporting habitat.

In the present study family Hesperiidae was recorded minimally at site I and was absent from the site II. This result favors the statement of Ombugadu *et al*. (2021) [21]. The reason for the lowest species richness and abundance showed by Hesperiidae family may be their flight period (early morning hours at dawn and dusk, Kehimkar, 2008) [10].

At site II the possible reason for the non availability of Hesperiidae family could be absence of supporting habitat and the time of study (7 am to 11 am and evening 4 pm to 6 pm).

Site I was found to be more abundant and diverse due to low level of anthropogenic activities like construction and habitat loss. Higher abundance and diversity in the C.V garden is because this site provides wider food and shelter resources for the butterflies whereas lesser abundance and diversity at Abheda is due to the minimal availability of required vegetation. As the butterfly larval stages are plant specific, so a little disturbance to the abundance of required plants could have a negative impact on the population. Findings of present study is supported by Hill *et al*. 2003 [7] who reported great abundance of butterfly species in less disturbed habitats.

In C.V garden the highest species richness and abundance is showed in Post-Monsoon season especially in the month of September. This may be due to increase in new vegetation, flowering plants after rainy season.

The factors supporting the increase in vegetation are optimum temperature, light and rainfall indirectly supporting their abundance. The present result indicates that the abundance and richness of butterflies was changed with the abundance and richness of plant species (Mukherjee *et al.* 2019) [19].

From December onwards there is gradual decline in abundance of butterflies both in C.V garden and Abheda. This may be due to the least favorable weather which results in the loss of water, nectar and fresh vegetation.

Therefore, this variation of butterfly diversity in different seasons indicates that the abiotic factors such as rainfall, temperature and humidity played a vital role in influencing the distribution and abundance of butterflies. The results of present finding are supported by the study of Shubhalakshmi and Chaturvedi, 1999; Hill *et al*. 2003 [34, 7].

Conclusion: The analysis of results of present study clearly indicates that any change in the landscape directly affects the diversity and abundance of butterflies. Impact of land use change and habitat loss affects the biodiversity of butterflies. Many butterfly larval stages are plant specific, a little disturbance to the abundance of such plants could have a resultant negative effect on the population.

If the maintenance of gardens and landscaping are meticulously planned, the diversity of butterflies will definitely increase providing a rich area for butterfly conservation.

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