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Research article

ASSESSMENT OF TEMPORAL & SPATIAL VARIATION IN SPECIES RICHNESS AND DIVERSITY OF BUTTERFLY HOST PLANTS

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ABSTRACT: The study was conducted to identify and record the local butterfly host plant species thriving around the University Campus. Quadrat method of sampling was utilized in the study at 2 sites (an Undisturbed and a Disturbed), at three seasons Monsoon, winter, and summer. The parameters studied were frequency, density, abundance, IVI etc. On the basis of IVI values *Tridax procumbens* and *Cassia occidentalis* were the most dominant host plants throughout the year. Species diversity and species richness were calculated. It was observed that at undisturbed site species diversity was more than the other one. Highest species diversity was recorded in monsoon season. The observations support the value of native plants as important butterfly host plants. 21 host-plants species distributed in 13 families were recorded and maximum number of butterflies host plant were members of Asteraceae. We suggest that native species should be protected and their regeneration should be promoted. In our study area *Tridax procumbens* and *Sida acuta* were such species. Sustenance of these type of species will correspondingly help in conservation of butterflies as well as in maintaining the community composition and will be of importance in biodiversity conservation.
Key words: Butterfly host plants, Diversity index, IVI, Seasonal variation, Species richness index.

INTRODUCTION

Butterflies are highly sensitive to environmental change and are delicate creatures that act as good bio-indicators of the health of an ecosystem. They also are good pollinators (Rosenberg et al., 1986) [29]. The areas with undisturbed vegetation and high floral diversity support large butterfly communities, as many species are strictly seasonal and prefer only particular set of habitats [20]. Butterflies and their caterpillars are dependent on specific host plants for foliage, nectar and pollen as their food. Butterflies are often considered opportunistic foragers, which visit a wide variety of available flowers. Thus butterfly diversity reflects overall plant diversity, especially that of herbs and shrubs in the given area. Tiple et al. [35], studied factors influencing nectar plant resource visits by butterflies. The distributions of butterflies are exclusively dependent upon the availability of their food plants [11]. Butterflies are important natural resources as they help in pollination, a key process in natural propagation, important ecological indicators, as they are closely associated with plants both as adults and larvae and enhance the aesthetic value of the environments by their exquisite wing colours. There is an intimate association between butterflies and plants and their lives are exceptionally interlinked [11], which leads to different patterns in their distribution depending on the availability of their food plants. In fact, the positive correlation between plant and butterfly diversities has been reported or pointed out in many previous studies [9, 34,15,18,19,32,6]. However, there have been a few studies [14, 16, 36] in which the correlation is weak between butterfly diversity and vegetational community composition or species richness. In another study (Hawkins and Porter 2003) [13], it was pointed out that, although plant and butterfly diversities are positively correlated, plant diversity does not directly influence butterfly diversity but that both are probably responding to similar environmental factors. Plant communities are groups of plants sharing a common environment that interact with each other, animal populations, and the physical environment. As plant communities tend to co-occur on the landscape due to shared environmental requirements, they provide a valuable framework for organizing biological information creating mapable units for land management and conservation planning. Communities are often defined by dominant plant species and these plant associations provide useful habitat information for many animal species and provide an efficient starting point for biological surveys.

Knowledge about the host plants is crucial to the development of long term conservation strategy, principally for areas in which species of butterflies may be declining [11]. Host plant is one that supplies food resources and substrate for certain insects or other faunal species. Host plants are of two types such as primary host plants (Nectar/food plants) and secondary host plants (Larval host plants). Butterfly host plants are those plants, on which specific butterfly species lay eggs, and caterpillars will then hatch and use plant as their sole food [22]. The plants obtain the services of pollinators in carrying pollen from one flower to another [27].

Seasonal fluctuations of butterfly host plants are often influenced by environmental changes such as rainfall, temperature, photo periods, humidity, and periodic food supply [1, 8]. Phenology of host plants especially production of new leaves and flowers [5] is an important factor in population dynamics of herbivore insects. Host plant range [30] also determines their population fluctuations across the seasons. However, [2] noticed that in case of host-specific butterfly species, plant phenology and species richness predicts the fluctuation in density more strongly than the seasonal variation. Thus a pragmatic belief may be that species, with wide range of host plants, will exhibit low seasonality and vice versa [29]. However, at present study site there was no data available regarding any seasonality in relation to environmental factors and availability of host plants species. Hence, the present study was under taken to explore the seasonal variation and the population status of some butterfly host plant species, which included wild and cultivated plants. We focused on identified butterfly host plant species and seasonal variations in density, species richness and species diversity of host plants in relation to butterflies in each of the study site. Documentation of preference exhibited by butterflies towards wild and cultivated plants was also done.

MATERIALS AND METHODS

The present study was undertaken at two sites in University campus in Vadodara city; Gujarat (Western India). The Site-I was University Arboretum which was predominately having good vegetation & the Site-II was near residential area of University having open land and highest level of human disturbance. Both the sites lie at 22º19’13.34” north latitude and 73º10’45.85” east longitude at an altitude of 55m above sea level. The sites are at distance of 1 km from each other. The data taken from both the sites as mention on. At both the sites, some host plants are cultivated for its horticultural values, while many are observed to grow as wild. Quadrats study was done at both the Sites (I & II) from 09:30 to 12:30 hr, once in a week in every month and observation was also done during good weather periods (no heavy rain and strong wind). The study area was fully explored during August 2012 to May 2013. To study the seasonal patterns/diversity in butterfly host plants density and species richness, the entire year was divided into three seasons. The three seasons of the year are Monsoon from August to October, winter from November to February and summer from March to May.

Sampling Method

Quadrant method of sampling techniques was utilized for the vegetation study. Only herbaceous plants were selected for the quadrant analysis. Four random quadrants were selected by throwing 100x100 cm sq metal quadrants. All host plants species present were identified and recorded. The ecological parameters studied were frequency, density, abundance, etc. and on the basis of that the IVI was calculated. Total basal area in case of herbaceous vegetation, was measured on the ground level by using callipers. Calculations were done using formulae given by Curtis [7].

- Frequency (%) = Number of quadrats in which species occurred / Total number of quadrats studied x 100
- Density = Total number of individuals of a species in all quadrats / Total number of quadrats studied
- Importance Value Index (IVI) = Relative frequency (R_f) + Relative density (R_d) + Relative dominance (R_{do})
- Relative frequency = Number of occurrence of the species / Number Of occurrence of all the species x 100
- Relative density = Number of individual of the species / Number of individual of all species x 100
- Relative dominance = Total basal area of the species / Total basal area of all the species x 100

The diversity indices of host plant community were computed on the basis of density values of the plants on both the considered sites (I & II) during monsoon, winter, and summer seasons.

Margalef's species richness index was used to compare species richness across seasonal variation at two different sites. The index is calculated using the equation R= (S-1) / ln N, where S = total number of species; N = total number of individuals (Margalef, 1958) [25].

The α-diversity of host plants species across seasons and across sites was calculated using Shannon-Wiener Index (H') of diversity given by the equation. $H' = \sum pi\ (\log pi)$, where, pi = ni/N; ni = is the number of individuals of i^{th} species and N = ∑ ni (Magurran ,1988) [23]. The Shannon diversity index is also widely used for comparing diversity between various habitats [4].

Sorenson's Similarity Index [26] was used to measure the extent of host plant species compositional similarity/variation for each pair of both the sites. Similarity Index (*SI*) was calculated by using the formula given by Sorensen (Sorensen, T., 1948) [33]:

Similarity Index (SI) = $\frac{2C}{A+B}$; where, C= Number of species common in both the sites/ communities, A = Number of species present only at Site-I, B = Number of species present only at Site-II.

Dissimilarity Index (DI): Dissimilarity Index is the reverse sequence of similarity index. It was calculated by the formula: DI = 1 – SI; where, SI = Similarity Index

RESULTS AND DISCUSSION

The study was conducted to identify and select the local butterfly host plant species and for that a general survey was done at two different sites. The common wild and cultivated butterfly host plants and their season wise distributions observed are listed in Table 1. There are many areas in our University campus which have provided good locations for the field studies including identification of different species of butterfly host plants and understanding the influence of environmental factors for their abundance or decline. Two sites were selected for population study and at those sites the population parameters of different herbaceous species were recorded. The parameters studied were frequency, density, abundance, and IVI. The study was conducted at three seasons Monsoon, winter, and summer, the data are presented in Fig. 1-3.

During the present study at both the sites it was observed that Site-I was having high species diversity throughout the year, as compare to Site- II. Diverse type of vital butterfly host plants recorded were *Tridax procumbens, Sida acuta, Cassia occidentalis, Alternenthera pungens, Vernonia cinerea, Digera muricata, Sida cordifolia*. On the basis of IVI values *Tridax procumbens* and *Cassia occidentalis* were the most dominant host plants throughout the year. At Site-I *Tridax procumbens* was showing high IVI value throughout the year. From monsoon the host plants population started building and showed the first peak in late monsoon, followed by a second peak in winter. It was observed that *Tridax procumbens* (family Asteraceae) was showing high density in all seasons Fig. 1-3, at Site-I and it was observed to be the most utilize butterfly host plants in the study site. Whereas, compare to Site I there was not much population of butterfly host plants at Site-II, due to human intrusion, and cattle's. *Sida acuta* was showing maximum density till Oct month while *Cassia occidentalis* was having high density throughout the year. Although *Vernonia cinerea* was showing least density whole year at Site-II. Thus, *Cassia occidentalis* was showing maximum IVI value all over the season at Site-II Fig. 1-3. In general, most of the host plants have lower density at both the sites as discuss above. These lower values reflect that the availability of host plants in both sites is not enough to support the butterfly population. Members of many taxonomic families of plants are used by butterflies as nectar food plants, in our study we recorded: five members of family Asteraceae, two members of family Amaranthaceae, Fabaceae, and Malvaceae, while only one members of family Apocynaceae, Caesalpiniaceae, Euphorbiaceae, and Verbenaceae, functioning as host plants. Herbs start their life cycle in the beginning of the monsoon and complete it by the end of the post monsoon season. To compare the two communities Species richness index, Shannon-Weiner index and Similarity Index were calculated. The attributes of seasonal variation in diversity indices of the two study sites are depicted in Table 4&5. Similarity index along with the respective dissimilarity index was also calculated and indicated in Table 4. Similarity index was maximum during Monsoon and winter season (0.5) whereas, minimum during summer season (0.48). On the whole, the value always remained less than unity. Dissimilarity index is reverse sequence as compared to the similarity index Fig. 4. More or less uniform environmental conditions are revealed by higher value of similarity index, in contrast lower value indicates distinct heterogeneity. It is established that none of the communities of the study sites result into 1 or 0 which indicates that neither the community is completely overlap nor they are completely dissimilar but are very close to each.

In monsoon season the value of similarity index was maximum, due to high moisture content in soil, comparatively low temperature, bright light and higher organic content through humification which mostly bring about uniformity in the weather conditions. On the other hand, minimum value in summer season indicates higher heterogeneity in climatic conditions which results poor plant growth. Such seasonality is common among butterflies and has been attributed to availability of food plants, local migration and response to adverse conditions [20, 21].

Table 1: List of Wild and Cultivated Butterfly Host Plants recorded at study sites.

Sr.No.	Common name	Scientific name & Families	W/C	Habitat	Flowering season
	Amaranthaceae				
1	Khaki weed	*Alternenthera pungens* Kunth.	W	Herb	M,W,S
2	False Amaranth	*Digera muricata* L.	W	Herb	M
	Apocynaceae				
3	Karanda	*Carissa carandus* L.	C	Shrub	M,S
4	Madagascar periwinkle	*Vinca rosea* L.	C	Shrub	M,W,S
	Asteraceae				
5	Cinderella Weed	*Synedrella nodiflora* L.	W	Herb	M,W,S
6	Mexican Daisy	*Tridax procumbens* L.	W	Herb	M,W,S
7	Ash-coloured Fleabane	*Vernonia cinerea* L.	W	Herb	M,W,S
8	Whitetop Weed	*Parthenium hysterophorus* L.	C	Herb	M
9	French Marigold	*Tagetus patula* L.	C	Herb	M,S
	Caesalpinnaceae				
10	Coffee Senna	*Cassia occidentalis* L.	W	Herb	M,W,S
	Euphorbiaceae				
11	Asthma Weed	*Euphorbia hirta* L.	W	Herb	W,S
	Fabaceae				
12	Peacock Flower	*Caesalpinia pulcherrima* L.	W	Tree	M,W,S
13	Rattle Wort	*Crotolaria retusa* L.	W	Herb	W,S
	Malvaceae				
14	Morning Mallow	*Sida acuta* Burm.f.	W	Herb	M,W,S
15	Country Mallow	*Sida cordifolia* L.	W	Herb	W,S
	Oxalidaceae				
16	Mountain Oxalis	*Oxalis griffithii* L.	C	Shrub	M,S
	Papaveraceae				
17	Prickly Poppy	*Argemone mexicana* L.	C	Herb	M,W,S
	Plumbaginaceae				
18	Chitrak	*Plumbago zeylanica* L.	C	Herb	M,W,S
	Rubiaceae				
19	Jungle Geranium	*Ixora coccinea* L.	C	Shrub	M,W,S
	Rutaceae				
20	Citron	*Citrus medica* L.	C	Shrub	W
	Verbenaceae				
21	Pink Snakeweed	*Stachypterpheta mutabilis* (Jacq.) Vahl	C	Herb	M,W,S
	Cyperaceae				
22	Common Nut Sedge	*Cyperus rotundus* L.	W	Herb	M,W

M-monsoon, W-winter, S-summer *W-Wild; C-Cultivated

Table 2: List of butterflies harbouring on host plants in different seasons.

Host Plant Species	Butterflies		
Amaranthaceae	Monsoon	Winter	Summer
Alternenthera pungens Kunth.	Mottled immigrant	Lime blue	Common Grass yellow
	Gram blue	Plain tiger	Lime blue
	Common Grass yellow	Twany coster	Plain tiger
	Lime blue	Rounded pierrot	Twany coster
			Plain tiger
Digera muricata L.	Lesser grass blue		
	Yellow orange tip		
	Forget me not		
Apocynaceae			
Carissa carandus L.	Common grass yellow		Stripped tiger
	Plain tiger		Common Grass Yellow
	Twany coster		Lime blue
			Common immigrant
Vinca rosea L.	Common Grass yellow	Jezebel	Gram blue
	Common gull	Common immigrant	Plain tiger
		Gram blue	Tailed Jay
		Plain tiger	
		Tailed Jay	
Asteraceae			
Synedrella nodiflora L.	Jezebel	Forget me not	Great orange tip
	Mottled immigrant	Common gull	Lesser grass blue
	Plain tiger	Great orange tip	Gram blue
	Twany coster	Lesser grass blue	Common grass yellow
	Forget me not	Gram blue	Common gull
			Jezebel
Tridax procumbens L.	Common Grass yellow	Common Grass yellow	Lesser grass blue
	Twany coster	Common gull	Gram blue
	Plain tiger	Plain tiger	Forget me not
	Great orange tip	Great orange tip	Stripped tiger
	Choclate pansy	Yellow orange tip	Mottled immigrant
	Gram blue	Lemon pansy	Common gull
	Common leopard	Common crow	Plain tiger
		Tailed jay	Wanderer
		Common Rose	
		Gram blue	
Vernonia cinerea L.	Choclate pansy	Twany coster	Gram blue
	Common Grass yellow	Stripped tiger	Plain tiger
	Plain tiger		Twany coster
Parthenium hysterophorus L.	Common Grass yellow	Common crow	Common Grass yellow
	Gram blue	Gram blue	Gram blue
		Lemon pansy	Forget me not
		Lesser grass blue	
Tagetus patula L.	Common Grass yellow		Plain tiger
	Twany coster		Blue pansy
	Plain tiger		Lemon pansy
	Forget me not		Common Grass yellow
	Lemon pansy		Common rose
			Forget me not

Table-2 cont…….

Caesalpinnaceae			
Cassia occidentalis L.	Lime blue	Common Grass yellow	Stripped tiger
	Common Grass yellow	Twany coster	Gram blue
	Common gull	Plain tiger	Twany coster
	Plain tiger	Great orange tip	Tailed jay
	Forget me not	Stripped tiger	Mottled immigrant
		Rounded pierrot	Choclate pansy
		Lesser grass blue	
Euphorbiaceae			
Euphorbia hirta L.		Great orange tip	Plain tiger
		Twany coster	Twany coster
			Gram blue
Fabaceae			
Caesalpinia pulcherrima L.	Lime blue	Common Grass yellow	Plain tiger
	Common Grass yellow	Gram blue	Common Grass yellow
	Gram blue	Forget me not	Forget me not
Crotolaria retusa L.		Twany coster	Choclate pansy
		Stripped tiger	Tailed jay
		Tailed jay	Common Grass yellow
			Twany coster
Malvaceae			
Sida acuta Burm.f.	Great orange tip	Great orange tip	Tailed jay
	Common grass yellow	Lime blue	Twany coster
	Plain tiger	Gram blue	Lime blue
	Rounded pierrot	Stripped tiger	Forget me not
	Twany coster	Plain tiger	Lemon pansy
			Plain tiger
Sida cordifolia L.		Lesser grass blue	Common Grass yellow
		Lemon pansy	Plain tiger
		Common Grass yellow	Choclate pansy
		Common rose	
Oxalidaceae			
Oxalis griffithii L.	Yellow orange tip		Lemon pansy
	Lemon pansy		Plain tiger
	White black tip		Great orange tip
	Lemon pansy		
Papaveraceae			
Argemone mexicana L.	Common grass yellow	Lime blue	Yellow orange tip
	Plain tiger	Gram blue	Common grass yellow
	Rounded pierrot	Stripped tiger	
		Plain tiger	
Plumbaginaceae			
Plumbago zeylanica L.	Choclate pansy	Common grass yellow	Tailed jay
	Common Grass yellow	Tailed jay	Twany coster
	Plain tiger		Great orange tip
	Twany coster		
Rubiaceae			
Ixora coccinea L.	Tailed jay	Common grass yellow	Tailed jay
	Jezebel	Common tiger	Common immigrant
	Twany coster	Stripped tiger	Plain tiger
Rutaceae			
Citrus medica L.		Common grass yellow	
		Tailed jay	
		Jezebel	
		Plain tiger	
Verbenaceae			
Stachypterpheta mutabilis (Jacq.) Vahl.	Plain tiger	Tailed jay	Common tiger
	Common immigrant	Yellow orange tip	Mottled immigrant
	Common tiger	Common tiger	Tailed jay
	Mottled immigrant	Plain tiger	Choclate pansy
	Tailed jay		Common Grass yellow
Cyperaceae			
Cyperus rotundus L.	Common grass yellow	Gram blue	
	Yellow orange tip	Stripped tiger	
	Gram blue	Tailed jay	
	Stripped tiger		

Table 3. List of host plants preferred by butterfly species.

Host plants	No. of butterflies species
Tridax procumbens	19
Cassia occidentalis	14
Sida acuta	11
Synedrella nodiflora	10

Table 4. Similarity & Dissimilarity Index of Butterfly Host Plants in Different Seasons at 2 Sites.

Season	Similarity Index	Dissimilarity Index
Monsoon	**0.5**	**0.5**
Winter	0.5	0.5
Summer	0.2	0.8

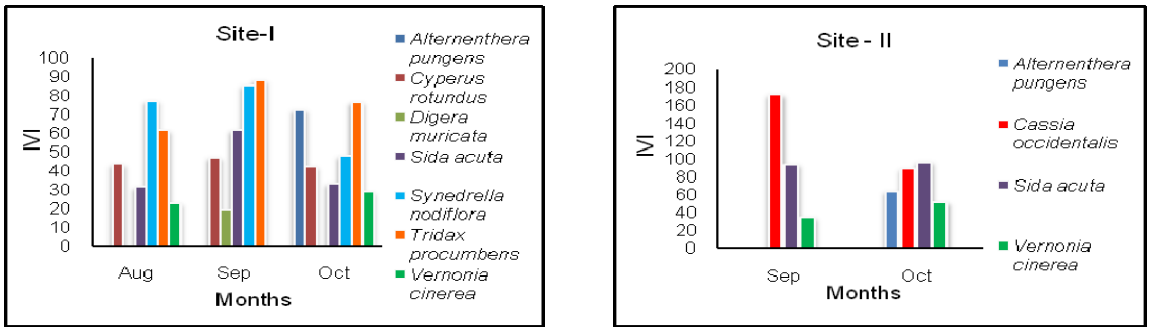

Fig. 1 Population Status of Butterfly host plants at Site I & II in Monsoon

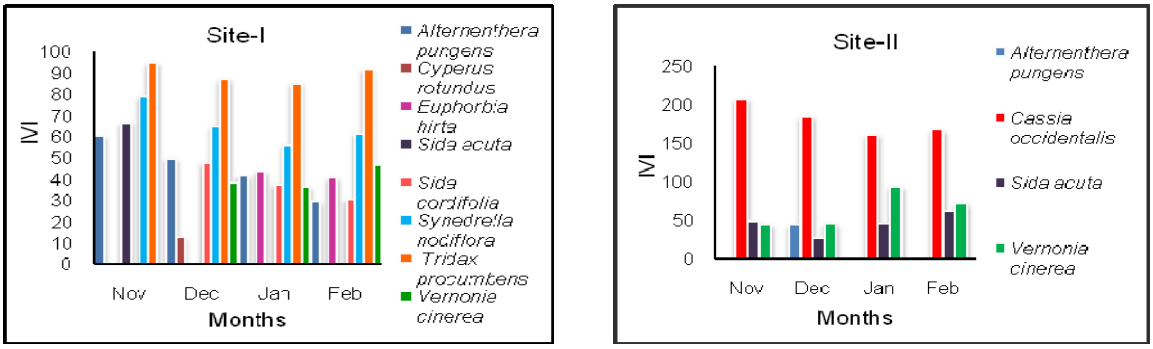

Fig. 2 Population Status of Butterfly host plants at Site I & II in winter

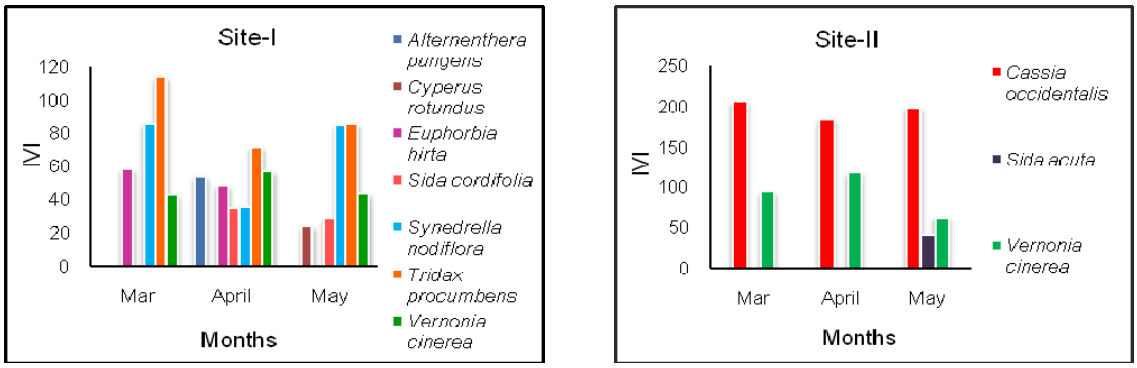

Fig. 3 Population Status of Butterfly host plants at Site I & II in summer

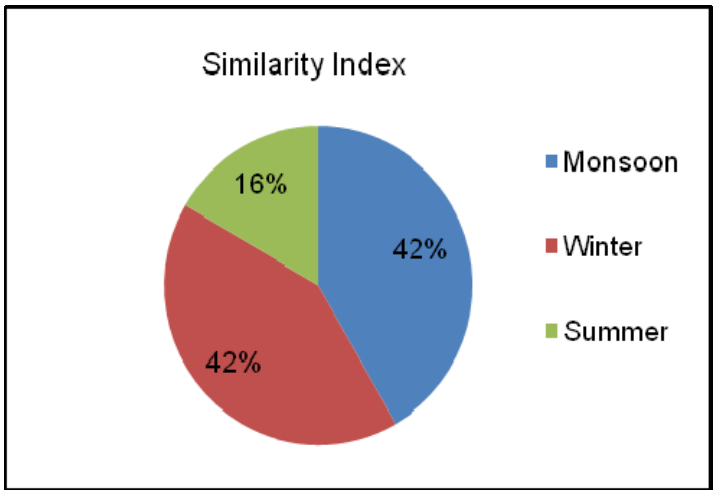

Fig. 4 Similarity Index showing minimum diversity in summer season

The seasonal distribution pattern shows two peaks of Species richness index during winter and summer (0.99 & 0.92) at Site-I Table 5. Thus, from this we may conclude that host plant species richness was more at Site-I Fig. 5. This indicates that the herbaceous host plant species is one of the most important factors determining the community structure. As, Kitahara et al. [17] propose that the maintenance and management of herbaceous plant species richness in a butterfly habitat, which underlies nectar plant species richness, is very important for the maintenance and conservation of butterfly species richness and diversity even in and around woodland landscapes of temperate regions. Shannon diversity index is a measure of diversity within a habitat since these indices incorporate both species richness and abundance into a single value. Species diversity affords stability to natural balance. α- Diversity index was also calculated and indicated in Table 6. Shannon - Weiner's index values was maximum during monsoon season at both the Sites-I and II, (i.e., 0.64 & 0.44), respectively. In contrast, the lowest value was during summer season, at Site II (0.32) compare to Site I (0.61) respectively. Hence, species richness and species diversity was more at Site-I compare to Site-II. The result of this survey reveals that species diversity is useful parameter for the comparison of communities under the influence of biotic disturbances or to know the state of succession and stability in the community. It is clear from diversity indices of host plant species that Site-I show maximum species diversity in comparison to Site-II Fig. 6.

Table 5. Seasonal Variation of Butterfly Host Plants Species Richness Index at 2 Different Sites.

Seasons	Species Richness Index	
	Site I	Site II
Monsoon	0.85	0.54
Winter	0.99	0.52
Summer	0.92	0.33

Table 6. Host plant diversity was evaluated using Shannon-Wiener Index (H') at 2 Different Sites.

Seasons	Shannon Weiner Index	
	Site I	Site II
Monsoon	0.64	0.44
Winter	0.62	0.36
Summer	0.61	0.32

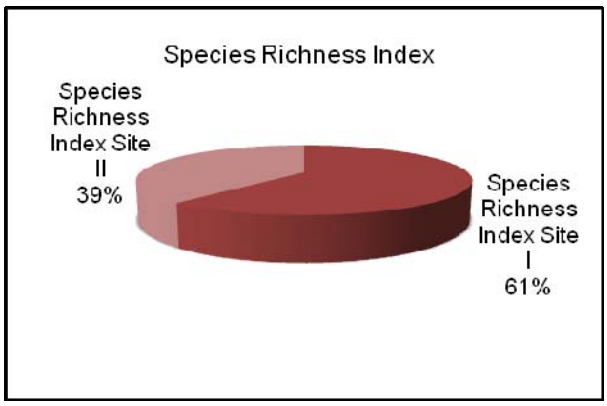

Fig. 5 Seasonal variation of host plants species richness at both sites

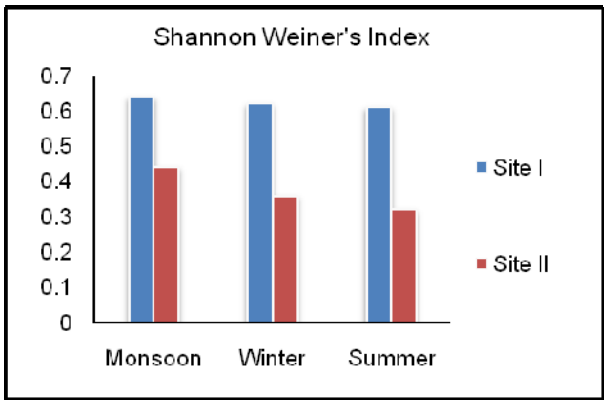

Fig. 6 Host plants diversity index maximum in monsoon season at both sites

The species diversity arose from the beginning of the monsoon, from the months August to October and reached a peak in the months from November to February. A decline in species diversity was observed form the months February and continued up to the end of May. Bhusal & Khanal [3] have reported that there is a significant correlation between species diversity and spring season, indicating the diversity of diverse species was positively affected by approaching warmer days, high relative humidity and more rainfall. These factors help to flourish diverse vegetations, which are vital food sources for many butterfly species. Gutierrez & Mendez [12] suggested that the abundance of butterflies is not affected by altitudes but it is more related to the availability of food plants. The herbs from the study area namely *Tridax procumbens* and *Sida acuta* are more preferred by butterflies, probably due to the fact that the flowering period of these herbs is throughout the year. The shrubs namely *Cassia occidentalis and Lantana camara* also have a flowering period throughout the year, so they are more used by butterflies as their food plants.

Monitoring and mapping biodiversity is the first step in systematic conservation planning [24]. In the study area, events like grazing pressure, influx of tourists, recreation, construction of roadways, use of pesticides and change in land use pattern, are mainly responsible for diversity loss of both butterflies and plants. Diversity of vegetation may perform a vital role in conserving local butterfly diversity along with the undisturbed ecological niches in that area. This suggests that some factor in addition to climatic change has affected butterfly species richness along this gradient. We suggest habitat alteration at low elevations, which has likely destroyed habitat directly (potentially affecting both larval hosts and adult nectar resources) and reduced connectivity among habitats. The importance of habitat alteration is borne out by significant, negative correlations between development and richness at low elevations (described above). Habitat conversion also affects mid elevation sites because it reduces the populations of species that colonize from lower elevations on an annual basis [37]. However, the Campus which was a good abode to many host plant species is now facing a decline in their density, diversity and richness due to many natural and anthropogenic factors. At study area seasonal variation of host plants preferred by number of different butterflies Table 2.

Each site was having variation in host plant populations. Four host plant species visited by the maximum number of butterfly species were identified Table 3. Throughout the year *Tridax procumbens* as it is nectar rich plant was visited by the maximum number (19) of butterfly species and was having more diversity.

The Arboretum area of the University is supporting for greater diversity and richness of butterfly host plants. We suggest that native species should be protected and their regeneration should be promoted. In our study area *Tridax procumbens* and *Sida acuta* were such species. Sustenance of these type of species will correspondingly help in conservation of butterflies as well as in maintaining the community composition and will be of importance in biodiversity conservation.

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