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Butterflies and their correlation with the nectar host plants in the Pavagadh hill, Panchmahal district, Gujarat

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Abstract
The present study was carried out in Pavagadh Hill from January 2017 to December 2019 to provide information regarding butterfly species and their nectar host plant relationships. A total 20 butterfly species belonging to four families and 22 prominent nectar host plants were identified. It was found that visits of butterflies were more frequent to flowers to flowers with tubular corollas than to flowers with non-tubular corollas. The proboscis length of butterflies varied with species to species but there is a perfect match with the length of corolla for the foraging activity. The floral visits of butterflies contribute to pollination in plants. Hence there is mutualistic relationship is existing between butterflies and plant species. Moreover, the findings of this study definitely provide some basic knowledge for uplifting and maintaining butterfly parks or gardens.

Keywords: butterfly, nectar host plants, Pavagadh hill, co-evolution, correlation

Introduction

Butterflies are one of the most fascinating insects belonging to the order Lepidoptera. Members of this group are attracted by their peculiar colouration and beauty. Adults and larvae of butterflies depend on specific host plants for foliage, nectar and pollens. Butterflies play an important role in the ecosystem as pollinators because they pollinate variety of wild plants and crops (Tiple, *et al*, 2006) [15]. One of the important characteristics of butterflies is that they visit flowers to feed on nectar. The presence of butterfly species depends not only on the climatic condition but also on the presence or absence of larval host plants and appropriate nectar resources for the adult butterflies.

Butterflies are an important component of biodiversity and are ecologically important because of the role they play in the food chain of the forest ecosystem (Singh, 2012) [12]. Their larvae, caterpillars and adults form the food for various other organisms including birds and reptiles. Their presence is an important factor in determining the health of the ecosystem as they are good biological indicators of environmental variation and quality. Nectar is a highly enriched food resource consisting of carbohydrates, amino acids, lipids, antioxidants, alkaloids, proteins, vitamins, salts etc. (Dafni, 1992) [2]. But all these nutrients are not found in a single floral nectar source and hence flower visiting insects have to visit different flowers to acquire all the nutrients required. During adult stage butterflies essentially require considerable quantities of proteins, salts, vitamins etc. for longer life span and for producing large number of eggs (Kunte, 2000) [5].

The mouthparts of insect are adapted themselves to different modes of ingestion of food. The mouthpart of a butterfly is of siphoning and sucking type, which is best suited to draw nectar from the flowers. Butterflies possess a specialised structure used to feed nectar known as proboscis. It is coiled under the head at rest and it is extended when butterflies probe food. They feed on liquid diet during the adult stage by feeding on nectar which contains dissolved sugar, salts and other minerals from a variety of sources ranging from flowers, tree sap, rotting fruit, faeces and so on. When a butterfly finds a potential food source it unfurls its proboscis and uses the tip to feed on fluids.

In this study an attempt was made to examine proboscis length and its significance in carrying out activities of the butterflies in relation to their nectar plants. In order to study the corolla proboscis interrelationship, we have studied the coexistence of butterflies and different flowering plants. Co-evolution is the reciprocal evolutionary change that occurs between species when they interact each other through the process of natural selection. The mouthparts of insects are adapted themselves to different modes of ingestion of food. The mouthparts of a butterfly are of siphoning and sucking type, which is best suited to draw nectar from the flowers. They feed on liquid diet during the adult stage by feeding on nectar which contains dissolved sugar, salts and other minerals from a variety of sources ranging from flowers, tree sap, rotting fruit, faeces and so on. When a butterfly finds a potential food source it unfurls its proboscis and uses the tip to feed. Adult butterflies essentially require considerable quantities of proteins, salts, vitamins etc. for longer life span and for the production of large number of eggs (Kunte, 2000) [5].

Butterflies are attracted to pink, mauve, and purple flowers which mostly fly by day. The flowers are often large and scented, and the stamens are positioned such that pollen is deposited on the insects while they feed on the nectar (Ehrlich & Raven, 1964) [3]. Nectar is secreted for feeding the visiting insects. The position of Nectar glands is for an insect to touch both the stigmas and the anthers. They usually open during the day as butterflies are active during day time. It possesses a tubular corolla which allows the proboscis to enter and collect the nectar. Flowers are usually in clusters and it provides a landing platform for the butterflies. Plants that specialize in attracting butterfly pollinators often display brightly coloured flowers with long narrow spurs (Mukherjee *et al*., 2015) [6].

Butterflies need to be efficient foragers and recognize the flowers which reward. Flower signals such as colours and

scents assist them in this recognition process. Butterflies can taste the nectar and judge its content. The ability to associate colours with food rewards is highly developed in butterflies (Stefanescu & Traveset, 2009) [13]. In addition to floral colour, floral scent plays a central role (Honda *et al*., 1998) [4].

Material and Methods

Study Area

The study was carried out in Pavagadh Hill located in the Champaner-Pavagadh Archaeological Park. It is 53 km north east of Vadodara situated in Panchmahal district of Gujarat. Pavagadh hill has a height of 820 metres which is surrounded by dense forest having a large number of trees, shrubs, herbs, grasses and climbers etc. The wild vegetation of Pavagadh represent a dry deciduous forest vegetation which show flourished vegetation during rainy season because after monsoon there is a luxuriant growth of a variety of herbs and shrubs. This will last till early winter. With the onset of summer, the deciduous trees shed their leaves.

Sampling Protocol

The study was carried out in Pavagadh Hill from January 2017 to December 2019. The proboscis of different species of butterflies was examined in order to establish the co-evolutionary relationship among plants and butterflies. The length of corolla tube and length of proboscis of butterflies were examined. To measure the length of proboscis of butterflies they were captured with the help of insect net. Then they are removed from the net and proboscis length is measured after inserting a needle into the centre point of the coiled proboscis and straightening the proboscis out. The length of the proboscis is measured as the distance between the bases of the labial palps to the tip of the proboscis with the help of Dial Calliper.

Statistical Analysis

a. **Karl Pearson's Coefficient of Correlation:** It is also known as the Product Moment correlation of coefficient. It is used to measure the magnitude of the relationship between two variables. It measures the level of relation between linear related variables. The letter 'r' represents the coefficient of correlation.
b. **Regression Analysis:** It is a mathematical measure to show the average relationship between the two variables. It indicates the cause-and-effect relationship between the variables and establishes a functional relationship between them

$$Y = a + b X + \epsilon$$

Where: Y – Dependent variable
X – Independent (explanatory) variable
a – Intercept b – Slope ϵ – Residual (error)

In order to achieve the objectives, the above-mentioned materials and methods were implemented at different stages for the efficient conduct of the research work.

Results and Discussion

In this study an attempt was made to examine proboscis length and its significance in carrying out activities of the butterflies in relation to their nectar plants. In order to study the corolla proboscis interrelationship, we have examined the morphological features of butterflies and their preferred nectar host plants. Also, a correlation study was carried out between the corolla length of nectar host plants and the proboscis length of the frequently visiting butterflies. Out of the 20 butterflies observed most of the butterflies took the nectar of those flowers which has nearly the same length of corolla tube with respect to their proboscis length.

To study the morphology of butterflies, 5 species each from four families Papilionidae, Nymphalidae, Pieridae and Lycaenidae were selected (Table. 1). Butterflies were selected on the basis of their abundance in the study area. Those butterflies which were very common in the study area were only considered for performing morphometry. Butterflies depend on different types of plants for nectar. They mostly prefer herbs and shrubs for the nectar. A significant positive correlation ($r=0.824$; $R^2=0.679$) in the number of species was detected between the experimental groups (Graph 1). Taking the positive correlation into consideration, it can be concluded that if there is any variation in the corolla length, it will be reflected in the butterflies' proboscis length of butterflies too. Moreover, Table 3 shows the frequency of visit of selected butterflies on the nectar host plants. The data substantiates the correlation between nectar host plants and the butterflies and shows a regression fit of 67%. The remainder percentage can be entitled to the factors like colour, fragrance and morphology of the flower that are preferred by the butterflies.

Table 1: Butterfly Species examined with their Morphological Measurements

Sr. No.	Scientific Name	Proboscis Length (mm)	Body Length (mm)	Wingspan (mm)
	Papilionidae			
1.	*Graphium doson* C. & R. Felder, 1864	22.58 ± 0.601	27.2	79.9
2.	*Graphium agamemnon* Linnaeus, 1758	25.96 ± 0.114	28.28	85.6
3.	*Pachliopta aristolochiae* Fabricius, 1775	18.94 ± 0.906	21.9	85.0
4.	*Papilio polytes* Linnaeus, 1758	18.0 ± 0.158	22.8	95.1
5.	*Papilio demoleus* Linnaeus, 1758	23.4 ± 0.589	25.7	84.8
	Nymphalidae			
6.	*Danaus chrysippus* Linnaeus, 1758	12.94 ± 0.449	29.2	76.4
7.	*Hypolimnas misippus* Linnaeus, 1764	13.96 ± 0.114	22.4	83.5
8.	*Junonia lemonias* Linnaeus, 1758	12.04 ± 0.230	23.4	57.3
9.	*Danaus genutia* Cramer, 1779	12.14 ± 0.151	25.5	77.6
10.	*Tirumala limniace* Cramer, 1775	12.24 ± 0.270	28.2	95.6
	Pieridae			
11.	*Catopsilia pomona* Fabricius, 1775	15.92 ± 0.164	19.1	63.5

12.	*Catopsilia pyranthe* Linnaeus,1758	15.06 ± 0.089	20.4	60.1
13.	*Eurema brigitta* Stoll, 1780	13.02 ± 0.083	17.8	44.5
14.	*Eurema hecabe* Linnaeus, 1758	9.04 ± 0.114	16.2	45.46
15.	*Delias eucharis* Drury, 1773	15.98 ± 0.109	22.2	73.7
Lycaenidae				
16.	*Chilades lajus* Stoll, 1780	5.58 ± 0.238	8.7	28.1
17.	*Zizina otis* Fabricius, 1787	5.12 ± 0.192	6.7	19.1
18.	*Zizula hylax* Fabricius, 1775	6.6 ± 0.336	7.2	18.2
19.	*Freyeria trochylus* Freyer, 1845	4.72 ± 0.164	6.8	9.9
20.	*Zizeeria karsandra* Moore, 1865	5.3 ± 0.158	8.7	22.02

Table 2: Prominent Nectar Plant Species found in the Study Area

	Name of the Nectar Host Plant	Family	Flowering Season	Flower Colour	Corolla Shape	Type of Plant
1.	*Lantana camara*	Verbenaceae	throughout year	Yellow, Orange, Red & Pink	Tubular	Shrub
2.	*Nerium oleander*	Apocynaceae	throughout year	Pink	Tubular	Shrub
3.	*Jatropha pandurifolia*	Euphorbiaceae	Throughout Year	Red with yellow centre	Tubular	Shrub
4.	*Caesalpinia pulcherrima*	Fabaceae	throughout year	Red	Non- Tubular	Shrub
5.	*Tamarindus indica*	Caesalpiniaceae	May to Aug	Pale Yellow	Non- Tubular	Tree
6.	*Bougainvillea spectabilis*	Nyctaginaceae	throughout year	Pink	Tubular	Shrub
7.	*Murraya koenigii*	Rutaceae	Apr-May	White	Non- Tubular	Tree
8.	*Chromolaena odorata*	Asteraceae	Sept-Dec	White	Tubular	Shrub
9.	*Tridax procumbens*	Asteraceae	Throughout Year	Yellowish White	Tubular	Herb
10.	*Tectona grandis*	Verbenaceae	June-Sept	White	Non- Tubular	Tree
11.	*Tephrosia purpurea*	Fabaceae	Sept-Oct	Purple	Non- Tubular	Shrub
12.	*Allamanda cathartica*	Apocynaceae	Throughout year	Yellow	Tubular	Shrub
13.	*Cassia occidentalis*	Fabaceae	July-Dec	Yellow	Tubular	Shrub
14.	*Sida acuta*	Malvaceae	Aug-Dec	Yellow	Tubular	Herb
15.	*Catharanthus roseus*	Apocynaceae	Throughout year	Pink	Tubular	Shrub
16.	*Calotropis procera*	Apocynaceae	Aug-Dec	White with purple crown	Non- Tubular	Shrub
17.	*Tabernaemontana gamblei*	Apocynaceae	Throughout year	White	Tubular	Shrub
18	*Wedelia trilobata*	Asteraceae	Almost throughou the year	Yellow	Non- Tubular	Herb
19	*Emilia sonchifolia*	Asteraceae	Aug-Dec	Purple	Tubular	Herb
20	*Ixora coccinea*	Rubiaceae	Throughout year	Pink	Tubular	Shrub
21	*Sida rhombifolia*	Malvaceae	Aug-Dec	Yellow	Tubular	Herb
22	*Sida cordifolia*	Malvaceae	Aug-Dec	Yellow	Tubular	Herb

Table 3: Frequency of flowers visited by butterflies during the study period at Pavagadh Hill

Sr. No.	Name of the Nectar Host Plant	Corolla Length Mean±SD (mm)	Visited Butterflies	Frequency of Visits/Hour
1.	*Lantana camara*	9.96 ± 0.114	Common Jay	4
			Tailed Jay,	12
			Common Rose,	6
			Common Mormon	14
			Lime Swallowtail	6
			Common Emigrant	10
			Mottled Emigrant	10
			Common Jezebel	10
			Plain Tiger	16
			Danaid Eggfly	14
			Striped Tiger	14
			Blue Tiger	14
			Lemon Pansy	12
2.	*Chromolaena odorata*	10.06 ± 1.277	Common Emigrant	12
			Mottled Emigrant,	12
			Common GrassYellow	2
			Plain Tiger	14
			Danaid Eggfly	12
3.	*Tridax procumbens*	5.5 ± 0.070	Common Emigrant	6
			Mottled Emigrant	6
			Common Grass Yellow	12
			Small Grass Yellow,	10
			Lime Blue	16
			Tiny Grass Blue	16
4.	*Tephrosia purpurea*	03.06 ± 0.396	Grass Jewel	16
			Lesser Grass Blue	12
			Tiny Grass Blue	10
			Lime Blue	10
			Dark Grass Blue	10
5.	*Catharanthus roseus*	23.0 ± 1.083	Common Jay	6

			Lime Swallowtail	16
			Tailed Jay	8
			Common Rose	10
			Common Mormon	6
6.	*Sida acuta*	3.75 ± 0.250	Lemon Pansy	8
			Lime Blue	14
			Lesser Grass Blue	12
			Tiny Grass Blue	10
			Grass Jewel	16
			Dark Grass Blue	12
7.	*Wedelia trilobata*	2.5 ±0.207	Lemon Pansy	8
			Plain Tiger	6
			Danaid Eggfly	4
8.	*Emilia sonchifolia*	2.2 ±0.148	Lime Blue	12
			Lesser Grass Blue	12
			Tiny Grass Blue	12
			Grass Jewel	16
			Dark Grass Blue	14
9.	*Ixora coccinea*	25.5 ±1.204	Common Jay	16
			Tailed Jay	2
			Common Mormon	2
			Lime Swallowtail	12
			Common Rose	15
10.	*Sida rhombifolia*	5.28 ± 0.258	Lime Blue	18
			Lesser Grass Blue	16
			Tiny Grass Blue	14
			Grass Jewel	4
			Dark Grass Blue	12

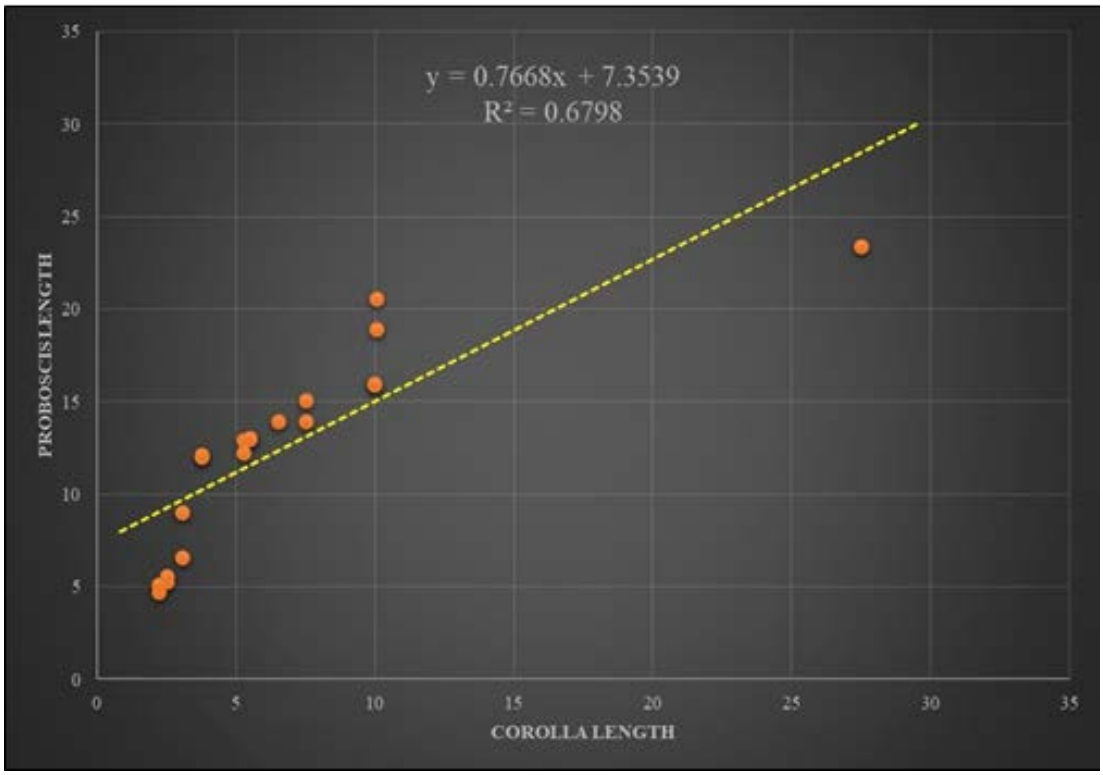

Fig 1: Co-evolutionary relationship among Butterflies and Plants. The values are in mm (Mean ± SD)

Discussion

Pavagadh hill is located in the Champaner-Pavagadh Archaeological Park which is a combination of forest, agricultural fields, hill, garden and concrete structures like monuments, temples, masjids, tombs, palaces and arches. This is an ideal site for studying the biodiversity as environmental conditions of the area and provide a conducive atmosphere for the growth of different types of flora and fauna.

This study was conducted to see the correlations between proboscis (mouth parts of butterfly) and nectar host plants (corolla). The foraging strategy depends on the structure of proboscis and when this strategy match with the corolla structure, there exist a correlation between butterflies and plants. They may visit many flowers of the nectar plants available in a locality but not necessarily forage on them. The results obtained, indicate that the butterfly proboscis had a significant role in co-evolution between the butterfly

species and the flowers of the nectar plants. A significant positive correlation (r=0.824; R^2=0.679) in the number of species was detected between the experimental groups (Graph 1). Taking the positive correlation into consideration, it can be concluded that if there is any variation in the corolla length, it will be reflected in the butterflies' proboscis length of butterflies too. Moreover, Table 3 shows the frequency of visit of selected butterflies on the nectar host plants. The data substantiates the correlation between nectar host plants and the butterflies and shows a regression fit of 67%. The remainder percentage can be entitled to the factors like colour, fragrance and morphology of the flower that are preferred by the butterflies.

Same kind of correlation was observed between butterflies and plants by **(**Sultana *et al*., 2018) [14] who studied the proboscis length of butterfly and their functional relation with the nectar plants and reported that there is a significant role of co-evolution between butterfly species and the flowers of host plants. Only those flowers are foraged which remain within the range of its strategy. Many other factors also involved like the colour of the flower, shape of corolla (tubular/non-tubular), nectar content, floral texture in developing the strategy of foraging. It was also observed from the study site that butterflies used to visit flowers with tubular corollas more frequently than those with non-tubular corollas. Butterflies also showed some colour preference towards nectar plants. The visits were more with flowers having red colour for example *Lantana camara* (Lantana), yellow colour *Sida acuta* (Common Wireweed) and *Tridax procumbens* (Coat buttons) pink-coloured flowers in *Catharanthus roseus* (Periwinkle) and white colour in *Chromolena ododrata* (Siam Weed). While conducting a study, to see diversity of butterflies in relation to nectar food plants from by (Nimbalkar *et al*., 2011**)** [7] reported that floral attributes influence nectar feeding behaviour of butterflies. Butterflies visit different plants in order to meet their nutritional requirement. Because all the nutrients are not found in a single floral nectar source and hence butterflies have to visit different kinds of flowers to acquire all the nutrients required (Rani & Raju, 2016) [9].

From the study, it is clear that there is a relationship existing between the butterflies and the nectar host plants utilized by them. The preferred nectar plants of these butterflies were either present throughout the year or these butterflies had a foraging habit of visiting different types of plants. So the availability of butterflies is directly associated with the presence of their larval or nectar host plants. Shrestha *et al*., 2020 [11] reported that species richness of butterflies was higher in places with shrubs compared to other places. The presence of larval host plants is an important factor which determines the abundance of butterflies. *Graphium agamemnon* Linnaeus, 1758 (Tailed Jay), which is one of the very common butterflies found at the study sites, has *Annona squamosa* (Sugar Apple) serving as the larval host plant. *Calotropis gigantea* (Giant Milkweed) serves as a host plant for *Danaus chrysippus* Linnaeus, 1758 (Plain Tiger) which is a very common butterfly present in all three habitats. The presence of *Murraya koenigii* (popularly known as Curry tree) is the host plant for *Papilio polytes* Linnaeus, 1758 (Common Mormon). *Nerium oleander* (Oleander) serves as a host plant for *Euploea core* Cramer, 1780 (Common Indian Crow). *Eurema hecabe* Linnaeus, 1758 (Common Grass Yellow) utilizes *Cassia tora* (Sickle pod) as the larval host plant. *Justicia betonica* (White Shrimp Plant) is the larval host plant of *Hypolimnas misippus* Linnaeus, 1764 (Danaid Eggfly). In the same way presence of nectar host plants also were an important factor for the abundance of butterflies. *Ixora coccinea* (Jungle Geranium), a pink-flowered shrub is a common nectar resource for the Papilionid butterflies. Its presence in the habitat made them very common in the habitat. The abundance of butterflies was due to the presence of nectar resources and even larval host plants increase during monsoon and post-monsoon seasons. While working in the Eastern Siwalik of Nepal, Bhusal & Khanal, 2008 reported that there is a significant correlation existing between species diversity and spring season. Spring season showed the abundance of diverse species which is positively affected by approaching warmer days, high relative humidity, and more rainfall. Diverse vegetation is aided by these abiotic factors, which are vital food sources for many butterfly species. The major flowering plants found in the study area are as follows. Trees like *Tectona grandis* (Teak tree) bear flowers during summer season (April-June) which attract butterflies like *Graphium agamemnon* Linnaeus, 1758 (Tailed Jay), *Catopsilia pyranthe* Linnaeus,1758 (Mottled Emigrant) and *Azadirachta indica* (Neem tree) bloom from March to May attracting butterflies like *Danaus chrysippus* Linnaeus, 1758 (Plain Tiger) and *Hypolimnas misippus* Linnaeus, 1764 (Danaid Eggfly). These plants become the nectar resources for the butterflies during summer season when other plants do not bloom. Shrubs like *Lantana camara* (Lantana), *Jatropha pandurifolia* (Peregrina), *Bougainvillea spectabilis* (Bougainvillea) and herb like *Tridax procumbens* (Coatbuttons) were some of the common nectar plants found in the study area which bear flowers throughout the year and attract butterfly species of different families.

Thus, the butterflies which preferred to forage on these flowers get food throughout the year. The complexity in the vegetation of Pavagadh hill make the site best suitable for the life of butterflies. While studying the habitat association of five habitats viz., Garden, Scrub jungle, Riparian woods, Sandy area and Casuarina plantation with diversity pattern of butterflies within the campus of DAE, IGCAR, Kalpakkam, Tamil Nadu was reported by Ramesh et.al. 2010 [8] reported that diversity and abundance of butterflies is directly associated with the availability of food plants because of the presence of different types of preferred nectar as well as larval host plants namely *Catharanthus roseus* (Periwinkle*), Tridax procumbens* (Coatbuttons), *Ixora coccinea* (Jungle geranium), *Tephrosia purpurea* (Wild Indigo) etc.

The natural habitat of Pavagadh is healthy and not disturbed. But the weather condition during summer season dries up the vegetation, especially the herbs to a large extent. Hence most of the nectar and larval host plants dry up during the summer season which could be the reason for the reduction of butterflies during this season. They mostly prefer herbs and shrubs for the nectar. (Sharma & Sharma, 2017) while working in the Gir Wildlife Sanctuary found that butterflies require all kinds of vegetation for the survival of different stages of their life cycle. They reported that the ideal habitat should be a mixture of grasslands, herbs, shrubs, and flowering trees because butterflies require mixed vegetation for survival of larval, pupal, and adult stage.

Conclusion

The forest area of Pavagadh Hill is a dry deciduous type and hence during summer the area became dried up and most of the vegetation also got dried up especially the herbs and shrubs. So, butterflies prefer to forage on plants which bear flowers throughout year. The unavailability or the decrease in the availability of nectar plants directly affected the diversity and abundance of butterflies. It was observed that during summer season the number of sights as well as the diversity went down. On the onset of monsoon, the plants start reappearing and flourish after that and bore flowers. Accordingly, there was an increase in the number of sightings as well as diversity of butterflies. One of the most important behavioural traits of adult butterflies is that they visit flowers to feed on nectar. The presence of any butterfly species depends not only on climatic condition and the availability of larval host plants but also on appropriate adult nectar sources or other food suitable flight and courtship. It is important to have all kinds of vegetation. All the stages namely egg, larvae, pupa and adults require a mixture of different kinds of plants. Presence of all such habitats and the favourable vegetation of different kinds of grasses, herbs, shrubs and trees make the study site unique.

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