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Research article

SEASONAL PATTERNS IN BUTTERFLY DIVERSITY AND ABUNDANCE IN RELATION TO WEATHER PARAMETERS AT KAMBALAKONDA ECO-TOURISM PARK, VISHAKHAPATNAM.

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ABSTRACT: Kambalakonda eco-tourism park spread over an area of 80 hectares comprises Scrub Jungle type of vegetation with herbs, trees and shrubs with different flowering seasons. A total of 41 butterfly species belonging to 8 families were observed during the study period i.e. 2007-2008. Among these maximum butterfly sighting were witnessed in Pieridae followed by Nymphalidae, Papilionidae, Lycaenidae, Danaidae, Acaraeidae, Satyridae and Hesperiidae. Of the 41 butterfly species 23 were encountered all through the year. More than half of the total butterfly species were encountered in wet season (58%) i.e. during July- November because the frequent rains in this period promote luxuriant growth and flowering in this season that serves as food source for the butterflies. The regression analysis indicated that monthly average temperature, monthly average day length, monthly average relative humidity and monthly total rainfall could collectively influence the abundance of butterflies of different families to different extents.
Key words: Butterflies, Kambalakonda, Seasonality, Abundance, Weather parameters.

INTRODUCTION

In contrast to temperate regions tropical regions experience a fairly high temperature through out the year, and so many of the butterflies are found almost through out the year. Butterflies in tropical regions have been shown to be sensitive to environmental gradients [1], especially in those parts of tropics with well defined wet and dry seasons. [2,3,4]. This group of insects is ideal for studying the effect of climate change because, their life cycle, activity, distribution and abundance are influenced by temperature [5-10]. In four tropical habitats a highly seasonal trend in the occurrence of butterflies was considered to be governed by environmental factors [11]. The present study was aimed to examine the dynamics of butterfly species across seasons in relation to weather parameters in a special habitat Kambalakonda eco-tourism park at Vishakhapatnam.

MATERIALS AND METHODS

Study Area

Kambalakonda eco-tourism park spreading over an area of 80 hectares was carved out in Kambalakonda wild life sanctuary situated in the Eastern Ghats on the outskirts of Vishakhapatnam city. This park has a reservoir with the capacity to impound 200 lakh gallons of water providing good water source for the flora and fauna of the park.

Collection and identification of butterflies

Regular field trips were made at 10day intervals to record the composition, relative abundance and seasonality of the butterflies along a line transect measuring 2.3km which can be traversed in 1hr during 1000-1100h. The representative samples of butterflies were collected during field survey using the methods described by De Rhe–Philipe [12]. They were collected by stalking or by chasing the fast flying species or by gently sweeping low flying species. They were identified and released. As the butterflies normally appear in their largest numbers when there is plenty of green vegetation that serves as both foliar and floral hosts, the composition and abundance of plant species and their respective flowering periods were also noted along a line transect measuring 2.3km.

Analysis of data

Seasonal Index

The total number of butterflies sighted during each month for each butterfly species for the period of study (2007-2008) was calculated to compare the trends in the butterfly population.

Seasonal Index = Month-wise mean/Overall mean × 100

Where month-wise mean is mean number of each butterfly over one year period and overall mean is the mean of all month - wise means.

Multiple regression and simple correlation were calculated between number of butterfly sightings and four weather parameters (Monthly average temperature, monthly average relative humidity, monthly total rainfall and monthly average day length). Simple correlation was also calculated between number of butterfly sightings with number of plants and number of plants in flowering (MINITAB 2003).

RESULTS AND DISCUSSION

At the eco- tourism park the vegetation is of scrub jungle type and a total of 118 plant species distributed among 50 families were noted. Among these the herbaceous flora dominated (49) followed by trees (46) and shrubs (23). The herbaceous flora was distributed among 28 families, shrubs are distributed among 16 families and trees among 25 families. The family Fabaceae included more number of herb and tree species. All the shrubs and tree species are present through out the year while some of the herbs are strictly seasonal and some of them prevail through out the year.

Flowering season:

The herbaceous flora that showed flowering throughout the year include – *Evolvulus alsinoides, E.nummularis, Datura metal, Aristida* species, *Carissa carandus, Cassytha filiformis.* The only herb that shows flowering in wet season is: *Cissus quadrangularis.* Others flowered equally in both seasons such as *Barleria prionitis* (September - June), *Tylophora indica* (April - October), *Bridelia montana* (September - January) etc.

The shrub species *Calotropis gigantea* and *Lantana camara* flower throughout the year, and the others are seasonal in their flowering. The shrubs that show flowering in wet season are: *Gymnema sylvestre, Zizyphus oenoplia, Dodonaea viscosa, Manilkara hexandra.* The shrubs that show flowering in dry season are *Syzygium cumini* and *Chomelia asiatica*.

All the trees are seasonal in their flowering. *Leucaena leucocephala* is the only tree species that flowered throughout the year. The trees that show flowering in wet season are *Diospyros chloroxylon, Securinega virosa, Acacia nilotica, A. auriculiformis, A. chundra, A. leucophloea, Gardenia gummifera, Grewia rothii*. The trees that show flowering in dry season are *Polyalthia cerasoides, Maba neligerrensis, Pongamia pinnata, Memecylon edule, Azadirachta indica, Ixora arborea, Morinda pubescens, Chloroxylon swietenia*. Others like *Grewia tiliaefolia* (March - October) and *Erythroxylum monogynum* (December – August) flowered in both the seasons.

Of the 8 families of butterflies maximum butterfly sightings were witnessed in Pieridae (36.49%) followed by Nymphalidae (21.78%), Papilionidae (18.08%), Lycaenidae (9.27%), Danaidae (7.65%), Acaraeidae (4.93%), Satyridae (1.29%) and Hesperiidae (0.52%). But the number of butterfly species are maximum in Nymphalidae(11), followed by Pieridae & Papilionidae 8 each, Lycaenidae (7), Danaidae(3), Satyridae(2), Acraeidae and Hesperiidae(1) each. Among the 12 months of the year maximum number of butterflies were sighted in July (185) followed by November (166), September (149), October (146), August (137), December (121), March (120), April (114), January (111), June (106), February (104) and May (84).

The present study indicated that the number of plants in flowering and the maximum number of butterflies encountered were more during wet season (July – November). The least number of plants in flowering is in January - February. Correlation between total number of plants and total number of butterfly sightings during the study period showed significant positive correlation at 4.6% probability levels ($r = 0.584$, $P = 0.046$). The correlation between total number of flowering plants and the total number of butterfly sightings also showed a significant positive correlation at 4.7% probability levels ($r = 0.582$, $P = 0.047$). Of the 41 butterfly species 23 were encountered all through the year. Among these 9 butterflies appeared in relatively higher frequency in some part of the year. Thus *Euploea core core* appeared during September-December; *Junonia lemonias* July-September; *Acraea terpsicore* July-November; *Pachliiopta aristolochiae* August-November; *Anaphaeis aurota* January-March; *Catopsilia pyranthe* March-December; *Eurema hecabe simulata* July-November; *Phalanta phalantha phalantha* November; and *Leptosia nina nina* January-April.

The butterfly species *Danaus chrysippus chrysippus, Ariadne merione merione, Pachliopta hector, Catopsilia pomona, Neptis hylas, Castalius rosimon, Zizeeria karsandra, Graphium agamemnon menides, Papilio polymenstor, Colotis danae, C. eucharis eucharis* appeared in low numbers throughout the year with no distinguishable peak period.
The remaining 3 species appeared in low numbers but with relatively more numbers in some months: *Princeps demoleus* (July), *Junonia iphita* and *Papilio polytes polytes* (October).
Graphium doson and *Everes lacturnus syntala* appeared in major part of the year in low numbers but with relatively high numbers during September and July respectively.
Junonia orithya (Mar-April), *Hypolimnas misippus* (August-April), *Spindasis vulcanus vulcanus* (February-September), *Tirumala limniace leopardus* (July-January), *Melanitis leda ismene* (September-March), *Euthalia nais* (September-February), *Hypolimnas bolina* (July-December), *Rathinda amor* (March-September), *Pareronia valeria* (October-April), and *Borbo cinnara* (September-March) appeared more than six months in a year.
Lampides boeticus appeared from July-November but in very low numbers. *Elymnias caudata, Euthalia garuda, Junonia almana, Jamides celeno aelianus* and *Papilio crino* are rarely found.
Butterfly flight is severely limited by severe winter conditions that exist in temperate regions (Goodden)[18]. By contrast in tropics, climate is less seasonal, a fairly high temperature prevails throughout the year, and most of the flora and fauna generally remain luxuriant throughout the year, and most of the year (Ewusie)[13]. As is expected of a tropical situation, one or another of the 41 species of butterflies have been found to occur all through the year at kamabalakonda eco-tourism park, Visakhapatnam. However, seasonal variations in population size are evident even with those species 23 that occur throughout the year.

Seasonal distribution of butterflies:

The seasonal presence of insect species is synchronized with a seasonal presence of its food, if food availability varies seasonally (Wolda)[14]. Many studies showed the dependence of population density on the local habitat quality. Poyry *et al.*[15] indicated that the local habitat quality is of foremost importance in explaining variation in species richness and total density of butterflies. The impact of different environmental and floral variables on the butterfly fauna is discussed by Clausen *et al.*[16] and emphasized the importance of certain habitat types.
The kind of distribution of butterflies observed now coincided with the rainfall (Table 1) and this observation agrees with Wynter-Blyth[17] who observed that the distribution of butterflies at a locality mainly depends on the rainfall conditions of that region. Of the 41 butterfly species that occur at Visakhapatnam more than half of the total butterfly species are encountered in wet season (58%) because the frequent rains in this period promote luxuriant growth of vegetation. Further more, a number of plant species providing food source to adult butterflies are also available in peak bloom in this season. Thus the plant species such as *Cassia occidentalis, Tectona grandis, Zizyphus oenoplia, Blepharis maderaspatensis, Leucas aspera,* and *Stachytarpeta jamaicensis* providing nectar to adults are available in peak bloom in this season. However equally good number of plant species is in flowering during dry season and the plant species specially trees such as *Polyalthia cerasoides,* and *Syzygium cumini* provided nectar for the butterfly species and hence 42% of the total butterflies were encountered in this season. As rainfall conditions are complicated and differ from region to region in South India, butterfly distribution may similarly differ from region to region and from year to year. These observations agree well with what Goodden [18] have written about the temporal distribution of butterflies in the tropics. Owen [3] observed many species of butterflies in Sierra Leone of Africa to occur in all months of the year but each reaching a seasonal peak of abundance during a restricted period. Species richness was found to be highest in late monsoon and in early winter in northern Western Ghats of India and the majority of the butterfly species also showed abundance peaks in these seasons [11]. The seasonal population trends observed at KFRI [19] showed Papilionidae and Pieridae to occur continuously throughout the year. In Papilionidae there was a decline in population during November – December coinciding with the prevailing dry and windy conditions during this season. Satyridae, Hesperiidae and Nymphalidae showed up only during certain months. In the case of Danaidae there was very good population during May – November. Turner [6] suggested that climate factors might control butterfly diversity indirectly i.e. the climate regulates habitat diversity (plant species diversity) itself which acts as the intermediary cause. At Visakhapatnam one or the other plant species would be in flower all through the year, hence, the fluctuations in the relative abundance of the adult butterflies in wet and dry seasons may depend on the availability of both nectar and larval host plants.
The seasonal appearance of the blue mormon, *Papilio polymnestor* is of some interest. Wynter-Blyth [17] did not find *P. polymnestor* much on the plains nor in areas of low rainfall. It is commonest in evergreen forests such as found on the Western Ghats and in the Nilgiris between 2000 and 5000 feet. Mathew [19] also found *P. polymnestor* at KFRI, Kerala for most part of the year. In the present study it appeared though in small numbers throughout the year at Kambalakonda Eco-tourism Park where the vegetation is of scrub jungle type.

Though records are not available it is presumed that it may be a resident of the Eastern Ghats forest and Kambalakonda Eco-tourism Park is a part of Eastern Ghats and from there it might be migrating to the plains in small numbers. This butterfly was reported as a very scarce migrant in Bombay, but was not reported regularly year after year [20]. The other species such as *Euthalia garuda, Elymnias caudaa,* and *Jamides celeno* occurred in small numbers at Kambalakonda Eco-tourism Park. It is generally agreed that the most pronounced fluctuations in population size could be encountered with organisms which have limited breeding seasons, especially those with the short lifecycles and those with pronounced seasonal dispersal patterns Eg. Migrations [21]. At Visakhapatnam in addition to *Papilio polymnestor* some butterflies such as *Junonia almana, J. orithya, Rathinda amor, Euthalia nais, Lampides boeticus,* and *Papilio crino* also appeared in small numbers over short periods ranging from 2-5 months. In all probability, these might be the migrants. Butterfly migrations are on record in India [22], but the underlined causes are not fully understood [17]. Probably these organisms undertake migrations to escape the unfavourable climate in regions of their home or due to some urge to populate new regions and extend the range of species. While dealing with the diversity of butterflies of Australia which are typically a tropical or subtropical group the dominant groups Papilionidae, Pieridae, Nymphalidae and Lycaenidae are represented by several species.

At Kambalakonda Eco-tourism Park regression analysis indicated that all the four weather parameters i.e. monthly average temperature, monthly average day length, monthly average relative humidity and monthly total rainfall could collectively influence the abundance of the butterflies of different families to different extents. In Danaidae the population was present throughout the year. The seasonal index reached a peak in the months of October and December. The lowest values of seasonal index were encountered during February. The main representative of this family was *Euploea core* (Figures 1 & 2). The members of Danaidae showed negative correlation for monthly average day length with r value -0.108 (P= 0.738); and the remaining three parameters i.e., monthly average temperature with r 0.0094 (P=0.772); monthly average relative humidity with r value 0.243 (P=0.446); monthly total rainfall with r 0.359 (p=0252) showing positive correlation and the extent of influence is 42.7%. These values are between 0.9% - 42.7%. With respect to families Satyridae, Pieridae and Hesperiidae members showed negative correlation with all the four weather parameters. In Satyridae the seasonal index reached a peak in November and December. The lowest values of seasonal index were encountered during April - August. The main representative of this family was *Melanitis leda* (Figures 3 & 4). Thus in Satyridae the correlation coefficient (r) values being – 0.422 (P-0.172), – 0.412 (P-0.183), – 0.158 (P-0.624) and – 0.719 (0.008) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average daylength. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this family to the extent of 89.9%. These values are between 2.5% - 89.9%. In Pieridae the population was present throughout the year. The seasonal index reached a peak in July. The lowest values of seasonal index were encountered during May. The main representatives of this were *Anaphaeis aurota, Catopsilia pyranthe,* and *Eurema hecabe* (Figures 5 & 6).Thus in Pieridae the correlation coefficient (r) values being – 0.296 (P-0.351), – 0.422 (P-0.172), – 0.142 (P-0.660) and – 0.226 (P-0.479) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average daylength. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this family to the extent of 32.3%. These values are between 2% - 32.3%. Since the members of the family Hesperidae are not very conspicuous sampling was not adequate and the number of individuals sighted was low. The seasonal index reached a peak in March. The lowest values of seasonal index were encountered during April - August. The sole representative of this family was *Borbo cinnara* (Figures 7 & 8). Thus in Hesperidae the correlation coefficient (r) values being – 0.599 (P-0.040), – 0.492 (P-0.104), – 0.070 (P-0.828) and – 0.719 (P-0.008) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average daylength. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this family to the extent of 55%. These values are between 0.5% - 55%. In Nymphalidae the population was present throughout the year. The seasonal index reached a peak in July and November. The lowest values of seasonal index were encountered during May. The main representatives of this family were *Junonia iphita* and *J. lemonias* (Figures 9 & 10). Thus the Nymphalidae the correlation coefficient (r) values being – 0.065 (P-0.840), 0.090 (P-0.781), 0.157 (P-0.626) and – 0.079 (P-0.806) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average day length. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this Nymphalidae members showed a negative correlation with monthly average temperature and day length and positive correlation with monthly average relative humidity and total rainfall and to the extent of 5.9%; family to the extent of 5.9%.

These values are between 0.4% - 5.9%. In Acraeidae the population was present throughout the year. The seasonal index reached a peak in November. The lowest values of seasonal index were encountered during the two months February and June. The sole representative of this family was *Acraea terpsicore* (Figures 11 & 12). Thus the Acraeidae the correlation coefficient (r) values being 0.390 (P-0.210), 0.090 (P-0.782), – 0.076 (P-0.814) and 0.146 (P-0.652) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average day length. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this family to the extent of 46.9%. These values are between 0.6% - 46.9%. Acraeidae members showed negative correlation with monthly total rainfall and positive correlation with the remaining weather parameters and the extent of influence is 46.9%;

Lycaenidae and Papilionidae members showed positive correlation with all the weather parameters with an extent of influence of 47.6% and 70% respectively. In Lycaenidae the population was present throughout the year. The seasonal index reached a peak in July. The lowest values of seasonal index were encountered during November. The main representatives of this family were *Everes lacturnus*, and *Zizeeria karsandra* (Figures 13 & 14). In Lycaenidae the correlation coefficient (r) values being 0.120 (P-0.710), 0.511 (P-0.090), 0.235 (P-0.463) and 0.291 (P-0.359) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average day length. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this family to the extent of 47.6%. These values are between 1.4% - 47.6%. In Papilionidae the population was present throughout the year. The seasonal index reached a peak in September. The lowest values of seasonal index were encountered during January and February. The main representatives of this family were *Pachliopta aristolochiae*, *Papilio polytes* and *Princeps demoleus* (Figures 15 & 16). In Papilionidae the correlation coefficient (r) values being 0.462 (P-0.131), 0.440 (P-0.153), 0.603 (P-0.038) and 0.209 (P-0.515) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average day length. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies of this family to the extent of 70%. These values are between 4.4% - 70%. With respect to the overall population trend the seasonal index reached a peak in July. The lowest values of seasonal index were encountered during the month of May (Figures 17& 18). Correlation of weather parameters with the number of sightings of butterflies showed a positive correlation with monthly average temperature, monthly average relative humidity, and monthly total rainfall, and negatively correlated with monthly average day length, and are non-significant. The correlation coefficient (r) values 0.068 (P-0.833), 0.149 (P-0.644), 0.311 (P-0.326) and – 0.051 (P-0.876) respectively for monthly average temperature, monthly average relative humidity, monthly total rainfall, and monthly average day length. Regression analysis indicated that all the four weather parameters collectively could influence the distribution of butterflies to the extent of 17.2%. These values are between 0.3% - 17.2%.

Kerala Forest Research Institute research report on *in situ* propagation of butterflies in moist deciduous forest patch in the KFRI campus at Peechi (Mathew 2001 - Report no. 220) [19] showed an average temperature ranging between 25-26^0 C was the most favorable followed by 23-25^0 C and 27-29^0 C. Atmospheric humidity ranging between 80-100% was the most preferred range followed by 60-80%. With regard to daily rainfall 50 mm was the most favorable level followed by 50-100 mm rainfall. The families Nymphalidae and Danaidae showed a significant correlation to temperature. The former increased with increasing temperature while in the latter number of occurrences decreased at higher temperatures. Significant positive correlation to humidity was seen in the families Papilionidae and Danaidae where by number of occurrences increased at higher humidity levels. The families Papilionidae and Danaidae showed a positive significant correlation with rainfall.

With diminishing opportunities to protect large tracts of native habitat, efforts to preserve biodiversity in fragmented landscapes and to understand ecological processes in these systems are becoming increasingly important [23-26]. Recent studies recognized that human altered landscapes may present significant opportunities to conserve at least a portion of present biodiversity that might otherwise be lost under prevailing patterns of land use change [27, 28, 29]. Usually locations near natural forests are likely to result in the recolonization of more number of species compared to locations in urban areas. In the present study Kambalakonda eco- tourism park which is a part of Kambalakonda wild life sanctuary extending to an area of 7,139 ha. With the diversified habitat. *Papilio polymnestor*, the largest butterfly from Eastern Ghats with beautiful wing colour prefers to mate in the interior of the forest it is presumed that it may be a resident of Eastern Ghats and so appeared throughout the year at Kambalakonda Eco-tourism Park in the present study.

Special attention may be taken to rear this beautiful species as the conditions in this area suit its development. Since *Pachliopta hector* is endemic to South India and Sri Lanka it also needs special attention. Such management helps to preserve and increase the diversity and richness of these insects which in turn maintain the genetic diversity of plants that utilize these butterflies as pollinators.

Table: Mean Temperature, relative humidity, total rainfall and the length of photoperiod during study period at Visakhapatnam.

Month	Temperature (°C)		Relative Humidity (%)		Total rainfall (mm)	Daylength (hrs)
	Maximum	Minimum	0830	1730		
Jan	**28.55**	**19.10**	**61.50**	**71.50**	**000.4**	**11.12**
Feb	**28.76**	**21.62**	**75.08**	**72.39**	**113.5**	**11.48**
Mar	**30.75**	**23.85**	**73.50**	**72.00**	**038.0**	**12.15**
Apr	**31.67**	**26.03**	**72.31**	**78.01**	**001.5**	**13.12**
May	**33.65**	**27.57**	**71.91**	**75.67**	**013.7**	**13.38**
Jun	**31.72**	**26.70**	**75.90**	**79.83**	**197.8**	**13.10**
Jul	**31.33**	**26.49**	**78.46**	**79.50**	**127.5**	**13.04**
Aug	**31.28**	**26.08**	**78.82**	**80.08**	**093.4**	**13.22**
Sep	**30.87**	**25.6**	**81.21**	**83.05**	**258.9**	**12.33**
Oct	**31.78**	**25.04**	**74.54**	**73.99**	**191.2**	**12.24**
Nov	**30.75**	**23.2**	**68.00**	**68.50**	**014.8**	**11.32**
Dec	**29.24**	**21.69**	**72.27**	**72.11**	**000.0**	**11.05**

* Borrowed from IMD located at 100 m away from the study locality.

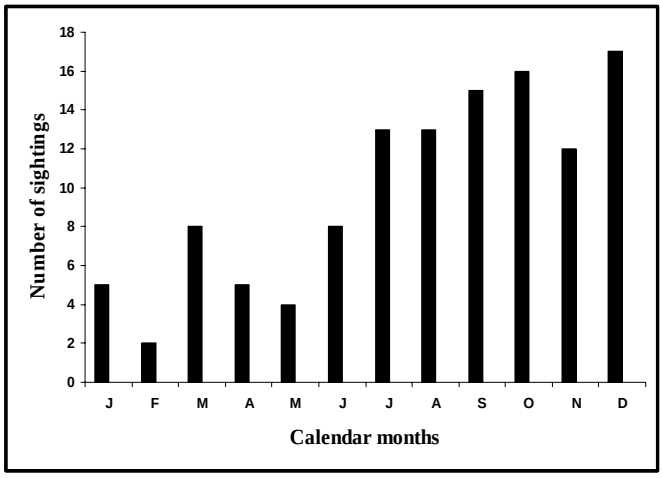

Figure 1

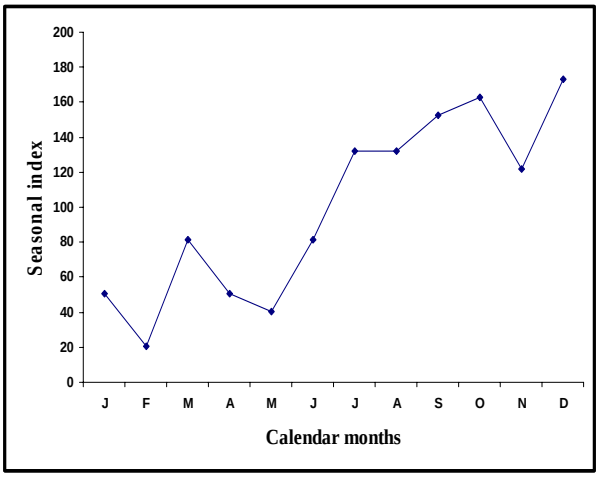

Figure 2

Figure 1 and 2. Population trends & Seasonal index of family Danaidae.

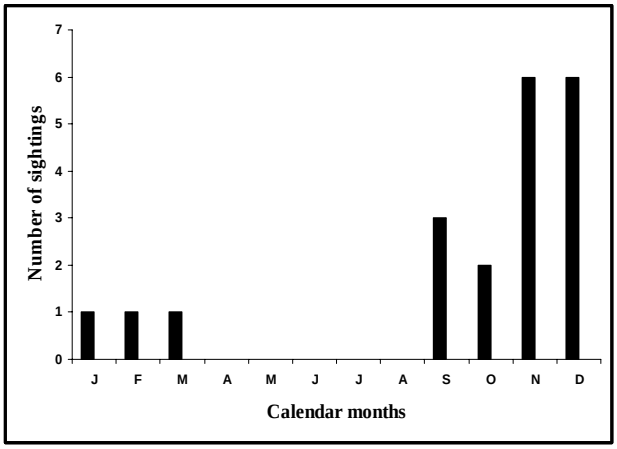

Figure 3

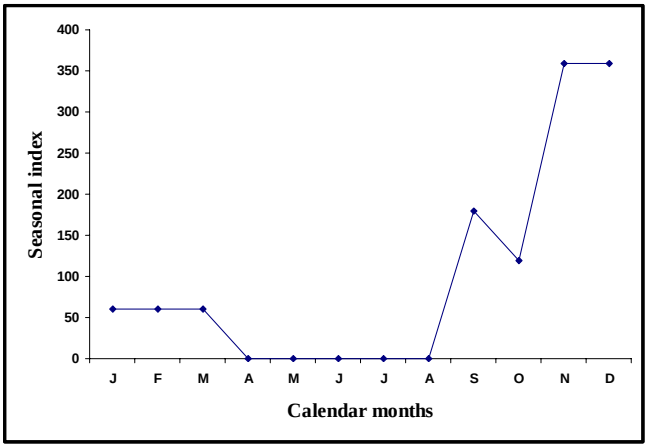

Figure 4

Figure 3 and 4. Population trends and Seasonal index of family Satyridae.

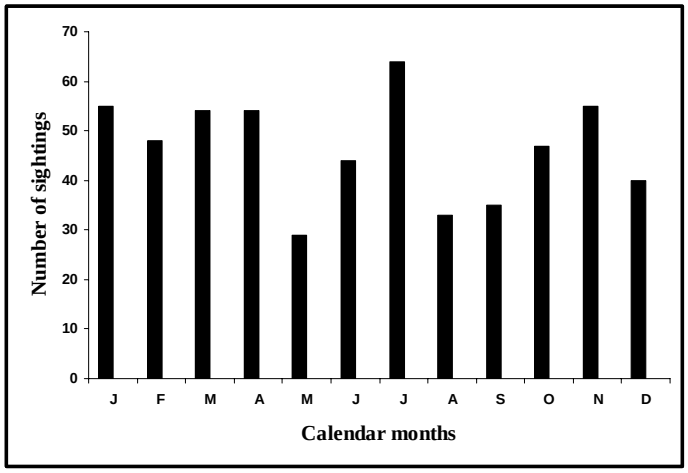

Figure 5

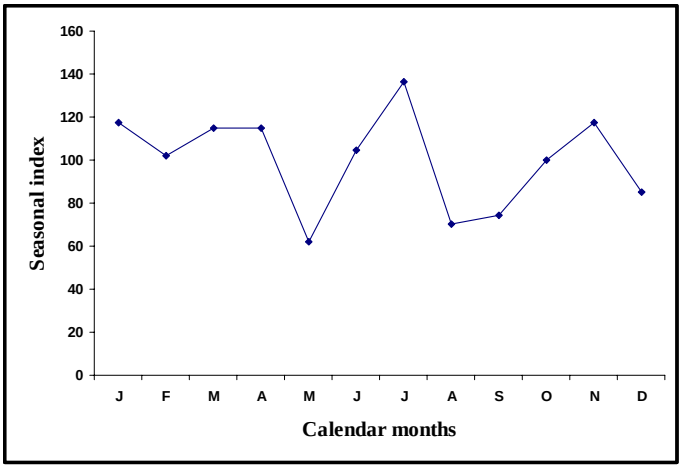

Figure 6

Figure 5 and 6. Population trends and Seasonal index of family Pieridae.

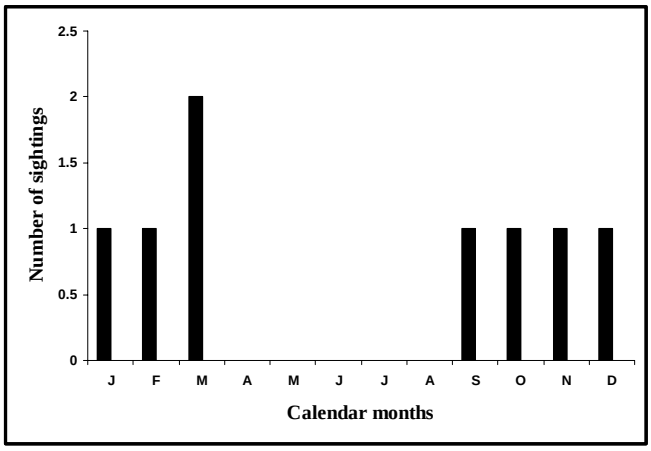

Figure 7

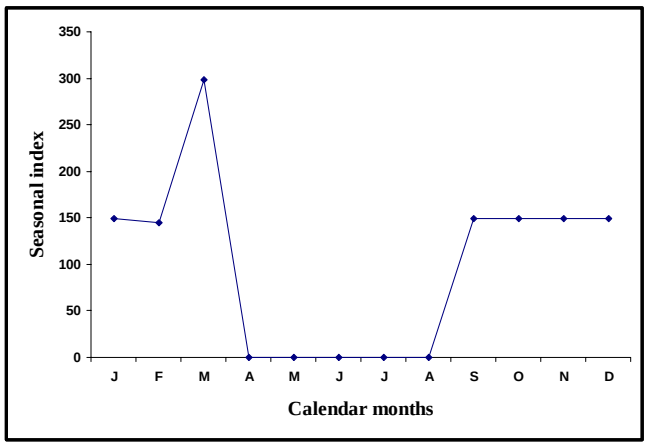

Figure 8

Figure 7 and 8. Population trends and Seasonal index of family Hesperiidae.

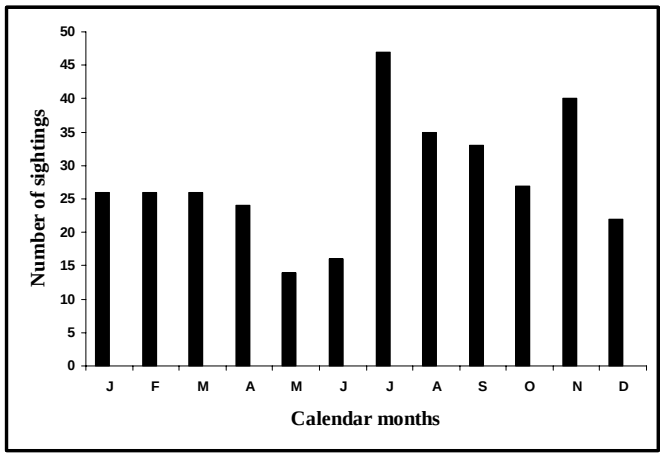

Figure 9

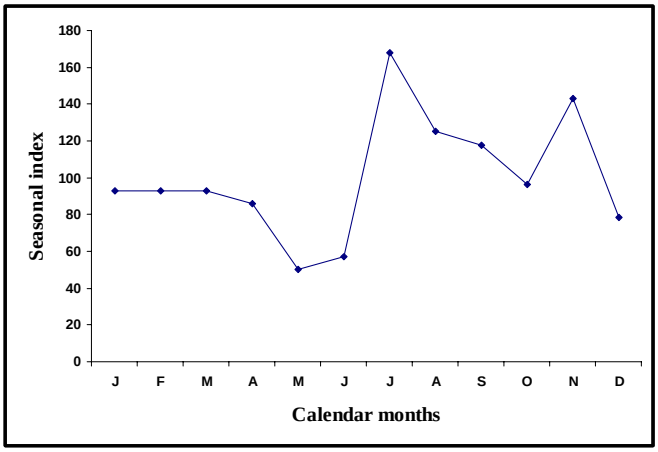

Figure 10

Figure 9 and 10. Population trends and Seasonal index of family Nymphalidae.

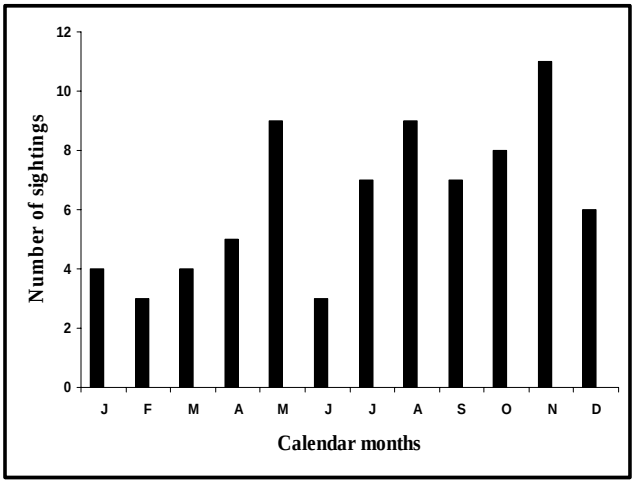

Figure 11

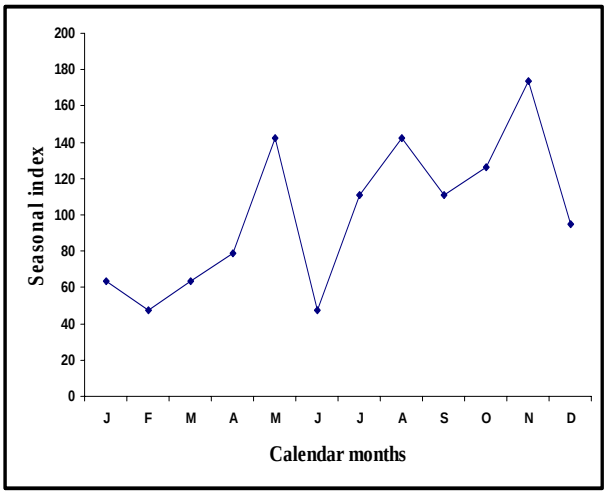

Figure 12

Figure 11and12. Population trends and Seasonal index of family Acraeidae.

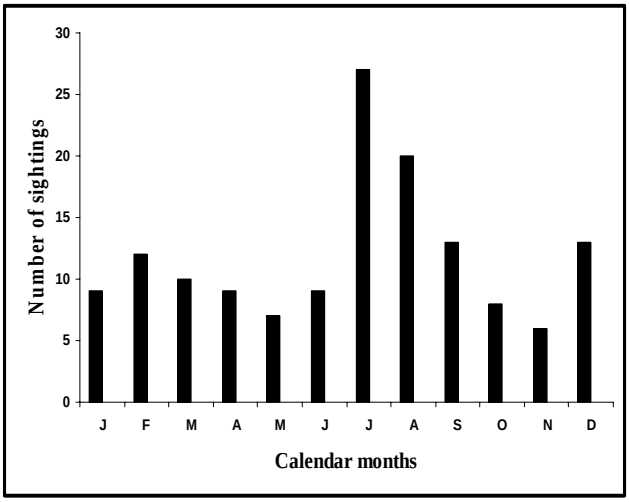

Figure 13

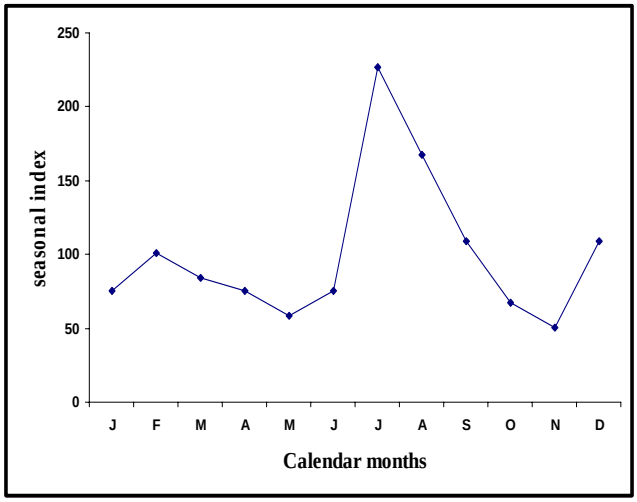

Figure 14

Figure 13 and 14. Population trends and Seasonal index of family Lycaeidae.

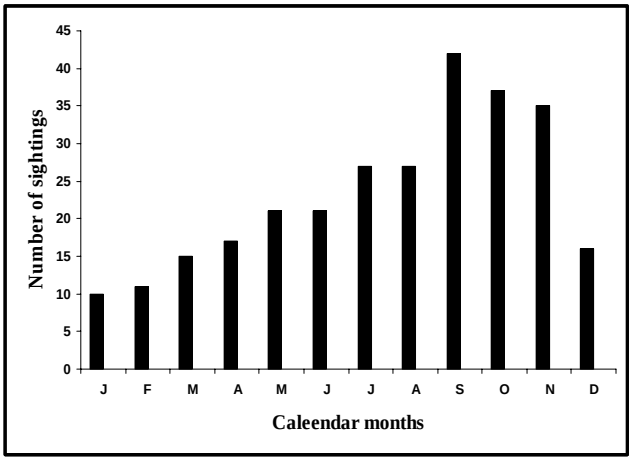

Figure 15

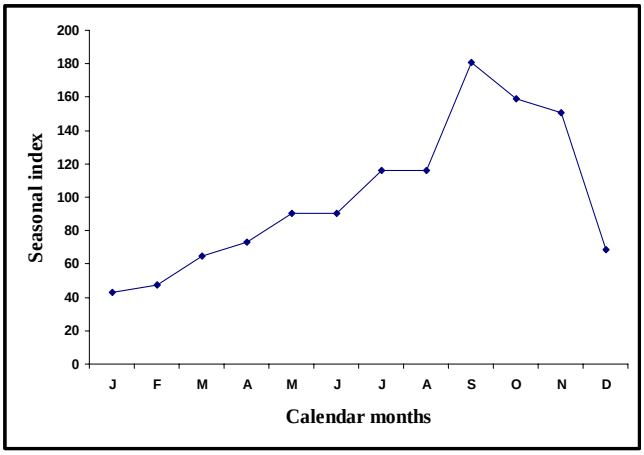

Figure 16

Figure 15 and 16. Population trends and Seasonal index of family Papilionida

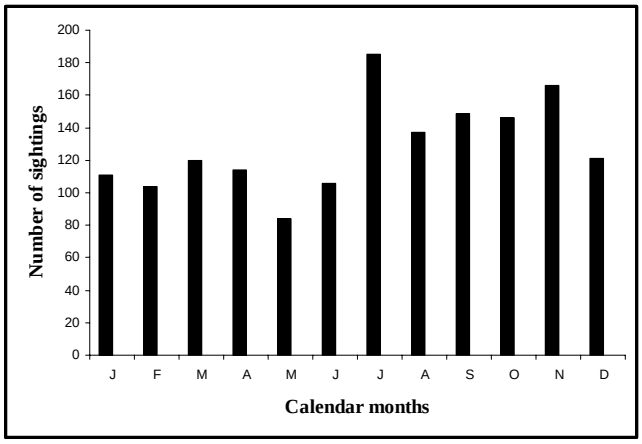

Figure 17

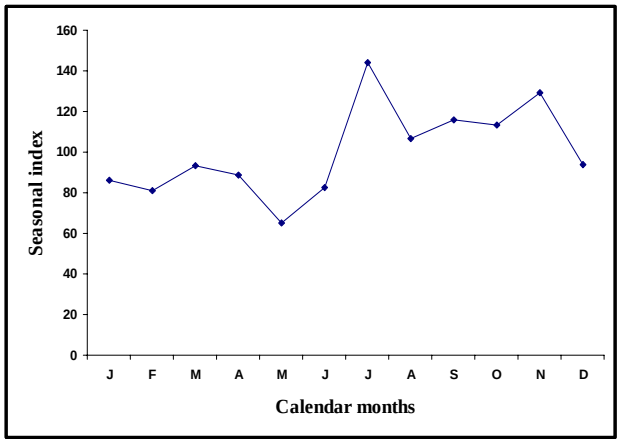

Figure 18

Figure 17 and 18. Overall population trends and Seasonal index of butterflies.

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