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Effect of climate change on the population of butterfly families - species richness, abundance and species composition across the different seasons of the year in Kalaburagi, Karnataka, India

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ABSTRACT

Butterflies are very sensitive insects for climate change, environmental pollution. Butterflies are model for most of the studies which focus on the effect of climate change on the species richness, change in abundance, species distribution, population size; it is also because of butterflies are umbrella species,. The conservation programme of butterflies will surely help to conserve other species from plants to microscopic organisms. In this study an attempt was made to evaluate the change in butterfly population dynamics through different seasons of the year. According to the observation made during research period it is clear that species richness was the highest from August to November (Monsoon and Early Monsoon) followed by Winter. The lowest were in Hot Summer and Summer that is from February to May. This study is an example for the impact of climate change on the diversity of butterflies from semi-arid geographical region of India; revealed the impact of climate on the species composition, species richness and abundance of butterflies. Such studies are very much important to show that the effects of climate change whether it is natural or human induced change the species composition of species directly and indirectly effecting the ecosystem balance.

***Keywords*:** Climate Change, Butterflies, Abundance, Species composition, Papilionidae, Hesperiidae, Pieridae, Lycaenidae, Nymphalidae

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1. INTRODUCTION

Sharma (2007) defines ecological factors as, "any external force, substance or condition, which surrounds and affects the life of an organism in any way, becomes a 'factor' of its environment. These factors have been called as, 'environmental factors' or 'ecological factors". Further explains how these factors affect the population of an organism or the single species as, "an important aspect of the effects of environment on the life of an organism is the interaction of ecological factors. Under natural conditions, the life or organism is affected by the sum of all ecological factors – the environment – and not by any individual factor. Though efforts are made to focus on various components of environment separately, the environment in fact is not even the sum of all its components put together but it is the product of interactions between all the components".

Daubenmire (1959) classified the factors into seven coordinate headings as – soil, water, temperature, light, atmosphere, fire, and biotic factors. Many ecologists category all the factors under four main heading including sub-ecological factors, namely: 1. Climatic or Aerial factors, including Light, Temperature of air (Atmospheric temperature), Rainfall (precipitation), Humidity of air, and Atmosphere (gases and wind); 2. Topographic or physiographic factors, which include altitude, direction of mountain chains and valleys; 3. Edaphic factors dealing with the structure, formation, physical and chemical details of the soil. The fourth one covers biotic factors; it includes interaction of a selected organism or population or community within them or with the other animals in its habitat. Climate of any region is chiefly determined by such meteorological influences. These factors, concerned mainly with the aerial environment of organisms include light, temperature of air, humidity of air, precipitation (rain fall) and gaseous components of atmosphere (Sharma, 2007).

One of the most interesting and controversial topics in the applied ecology today is that of climate change and global warming. Climate change can influence the ecologies of insects in many ways, and it is of great significance to consider how actual and potential changes in the world's weather patterns have affected, and will affect, insects. Climatic variables such as temperature, wind, and rain can have enormous consequences for the ecology of insects. Many aspects of host exploitation, growth, reproduction, and dispersal are influenced fundamentally by these abiotic factors. However, it must be remembered that, in general they are fashion dependent. Instead, most climatic effects are density independent and, in isolation, cannot regulate insect populations around equilibrium densities. Abiotic factors can cause large fluctuations in insect abundance even if they do not regulate populations. Moreover, they can interact markedly with biotic factors such as competition and predation (Speight *et al*., 2008; Debapriya, 2017; Priti, 2018; Vitthalrao, 2019; Srinjana, 2016).

Variability of temperature is extremely important ecologically. Temperature rhythms, along with rhythms of light, moisture, and tides, largely control the seasonal and daily activities of plants and animals. Rainfall is determined largely by geography and the pattern of large air movements or weather systems. Rainfall generally tends to be unevenly distributed over the seasons in the tropics and subtropics, often with well-defined wet and dry seasons resulting. In the tropics, this seasonal rhythm of moisture regulates the seasonal activities of organisms, much as the seasonal rhythm of temperature and light regulated temperate zone organisms. The biotic situation is determined not by rainfall alone but by the balance between rainfall and potential evapotranspiration, by evaporation from the ecosystem. Humidity represents the amount of water vapor in the air. Absolute humidity is the actual amount of water in the air, since the amount of water vapor that air can hold varies with the temperature and pressure. Relative humidity represents the percentage of vapor actually present compared with saturation under existing temperature-pressure conditions. Because of the daily rhythm of humidity in nature, for example high at night and low during the day, as well as vertical and horizontal differences, humidity along with temperature and light regulate the activities of organisms and limit their distribution. Humidity is especially important in modifying the effects of temperature. Temperature and moisture are generally important in terrestrial environments and closely interacting that they are usually considered to be the most important part of climate. The interaction of temperature and moisture, as in the case of most factors, depends on the relative as well as the absolute values of each factor. Thus, temperature exerts a more sever limiting effect on organisms when there is either very much moisture or very little than when there are moderate conditions (Odum, 1913).

Weather parameters, particularly atmospheric humidity, are known to have a decisive effect on biodiversity. This is usually amply illustrated with the textbook comparison of faunal diversity of hot deserts on one hand, with tropical rainforest communities on the other. Butterflies, too, occur in greater variety and profusion in areas of heavy rainfall as compared with low rainfall areas (Peter, 2011). Within in the states of Western Ghats there is difference in the total butterfly species reported; 314, 316, 208 and 158 species reported from Kerala, Tamil Nadu, Goa and Gujarat, respectively (Gaonkar, 1996). Northeastern states are home to over a thousand species of butterflies, compared to plain of Uttar Pradesh with less than hundred, or Thar Desert with less than 50 species (Peile, 1973).

Seasonality is a common phenomenon in insect population. Butterflies are seasonal in their occurrence. They are common for only a few months and rare or absent in others (Kunte, 2000). Seasonal fluctuations are often influenced by environmental factors including temperatures, photoperiod, rainfall, humidity, variation in the availability of food resources, and vegetation cover such as herbs and shrubs (Hussain *et al*., 2010; Anu, 2006; Anu *et al*., 2009; Shanthi *et al*., 2009; and Tiple and Khurad, 2009). Studies in India have established a relationship between butterfly species richness, density and diversity with respect to seasonality (Panchali *et al*., 2014). Many butterfly species are strictly seasonal and they are common for only a few months and rare or absent in others (Kuntem 1997, 2000). Such a seasonal trend could be attributed to synchrony with phenology of their food plants (Spitzer, 1983). Butterflies are sensitive to the changes in the habitat and climate, which influence their distribution and abundance (Winter – Blyth, 1957).

Temperature and rainfall are the two vital abiotic factors which effect the butterfly species richness, abundance immediately (Kunte, 2000-2001; Padhye *et al*., 2006; Tiple and Khurad, 2009). Butterfly species richness and their abundance increases with increase in temperature and decreases with increase in the temperature (Hussain *et al*., 2011). Increase in relative humidity in rainy season and increased temperature in Summer influences the increase and decrease in the specie richness and abundance of butterflies in rainy and Summer seasons were reported by Hussain *et al*. (2011) and Mathew and Anto (2007). Fire also directly effects the butterfly population and species composition of a habitat (Kunte, 1997). Soil is another abiotic factor that influences the faunal composition of a habitat; the distribution of plants will affect the butterfly species richness, composition and abundance, hence soil is indirectly responsible for the stable butterfly community in a habitat.

The present work was intended to evaluate the variation in species richness and abundance of butterfly population with respect to temperature rain fall and relative humidity, in short to study the seasonal dynamics of butterfly population at Uploan Nature Park, Kalaburagi district, Karnataka.

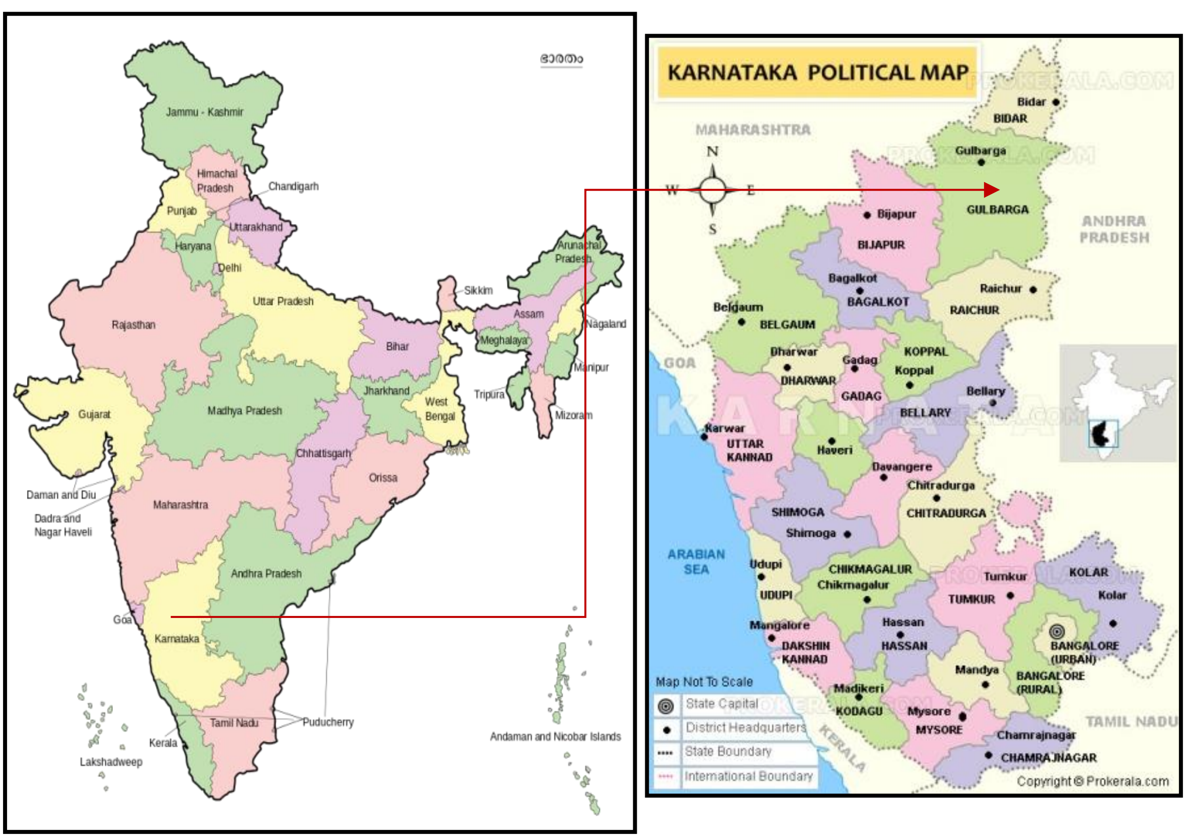
2. MATERIALS AND METHODS

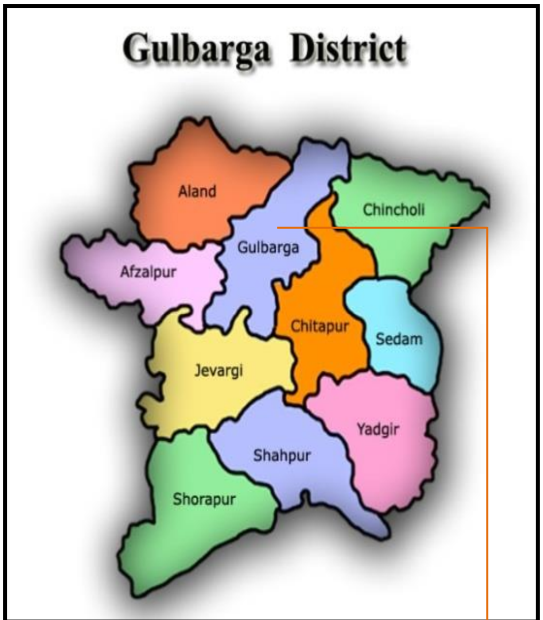
Study was conducted at Uplaon Nature Park, that lies on the geographical coordinates of 17°23’39.1826” N and 76°52’33.5019” E and at an altitude of 471 m above mean sea level situated about 13 km away from Kalaburagi Central bus stand, of survey number 16, with a geographical area 44.05 acre (18.88 Hectare.), comes under Kalaburagi District, Karnataka State, India.

During peak Summer, maximum temperature reaches 45 °C and December is the coldest month with minimum temperature of 10 to 15 °C, Average rain fall 1-839 mm (Reference – Kalaburagi District Profile Government of Karnataka: the knowledge hub Asia). Uplaon Nature Park Global Positioning System (GPS) was used to record the geographical coordination.

Study area

Figure 1. Research station - Uplaon Nature Park, Kalaburagi district Karnataka, India.





Seasonal variation in butterfly species composition and their abundance

To evaluate the effect of Temperature, Rain fall, atmospheric humidity (Relative Humidity - RH) on butterfly community, species composition, abundance, species richness, the study was conducted between June 2015 to December 2017 (Two years seven months).

Depending on the climatic conditions of the study site the year was divided into six seasons:

Summer – February and March
Hot Summer – April and May
Early Monsoon – June and July
Monsoon – August and September
Post Monsoon – October and November
Winter – December and January.

In all the six seasons butterflies were monitored between 8 am to 12.30 pm, seasonal variation of butterfly species and their abundance status in particular seasons were observed and recorded for the study. To evaluate the effect of Temperature, Rain falls, atmospheric humidity (Relative Humidity - RH) on butterfly community, species composition, abundance, species richness during the research period, data were collected from, Meteorological Department, Meteorological Centre, Central observatory, Palace Road Bangalore, Karnataka, Ministry of Earth Sciences Government of India.

In general India is drought prone country with nearly 1/6th of its geographical area affecting about 12% of its population (Jayasree and Venkatesh, 2015). Karnataka ranks second next only to Rajasthan in India, in terms of total geographical area prone to drought (Jayasree and Venkatesh, 2015 and Nagaraja *et al*., 2011). In Karnataka, 18 districts are droughts prone. Bagalkot, Bidar, Bijapur, Kalaburagi, Koppal, Raichur and Yadgir are the most drought prone districts of North Karnataka (Jayasree and Venkatesh, 2015). On an average the region receives about 650 mm of rainfall in about 50 days.

Monsoon rainfall contribution is almost 75-80% which generally breaks by mid-June and lasts till end of October (Jayasree and Venkatesh, 2015). December is the coldest month, March and May are hot and dry, mean monthly temperatures hover around 32 °C (Rupali 2015). The value of any region lies in between 5-12, that region considered under semi-arid class. The calculation of AI for 18 districts of Karnataka comes under the range between 5-12.

Drought intensity of Kalaburagi was calculated by Jayasree and Venkatesh (2015) the value is 0.7 and varying between 1.9 and 1.24 among stations with duration 2.58 years with the longest duration 4.0 years (Jayasree and Venkatesh, 2015).

3. RESULTS AND DISCUSSION

Convenience of study and interpretation of data: the year was divided into six seasons – 1. Summer – February and March, 2. Hot Summer – April and May, 3. Early Monsoon – June and July, 4. Monsoon – August and September, 5. Post Monsoon – October and November, 6. Winter – December and January. Temperature, rain fall and relative humidity of the research station were collected from, Meteorological Department, Meteorological Centre, Central observatory, Palace Road Bangalore, Karnataka, Ministry of Earth Sciences Government of India.

The mean values of - maximum temperature, total rainfall and relative humidity from 2015 June to 2017 December (two years and seven months), are given in the **Table 1**:

- Maximum temperature was 41.72 °C in Hot Summer (April, May) and minimum temperature was recorded 17.53 °C in Post Monsoon (December, January). The highest mean relative humidity was 84.67% recorded in Monsoon, and minimum was 48.26% in Hot Summer. Total highest rainfall was in Post Monsoon and Monsoon generally and the lowest in Hot Summer. Species richness recorded in all the six families, are given in the **Table 2**.
- In all the families highest species richness was in Post Monsoon (October and November) followed by Monsoon (August and September) and the lowest were recorded in Hot Summer (April and May).
- Total abundance and relative abundance of all the five families for six seasons are given in **Table 3**. The lowest species abundance was 78 in hot Summer with a relative abundance 1.93%, followed by Summer, 227 relative abundance and 5.63% of relative abundance. The highest abundance and relative abundance were recorded in Post Monsoon (with 1476 abundance and 36.58% relative abundance) followed by monsoon and Winter.

- Average Population size during Summer, hot Summer, early monsoon, monsoon, Post Monsoon and Winter were 9.8, 6.4, 12.6, 13.2, 15.6 and 15.4, respectively. The highest population size was in Post Monsoon and the lowest in Hot Summer.
- Species diversity indices for Papilionidae, Hesperiidae, Pieridae, Nymphalidae and Lycaenidae are given in **Tables 4**, **5**, **6**, **7**, and **8**, respectively.
- According to the observation during research period it is clear that species richness was the highest during Monsoon and early monsoon that is from August to November followed by Winter; the lowest were in Hot Summer and Summer that is from February to May.
- This decrease in species richness, abundance and relative abundance in Summer and hot Summer is because of increased temperature, decreased relative humidity, scarcity of water, dry land, dry vegetation.
- 27-29 °C and 60-80% relative humidity are the optimum for butterfly growth and activity (Mathew and Anto, 2007).

Family – Papilionidae

A total of six species were recorded in this family. The lowest species (5) and abundance (11) were recorded in hot Summer. Remaining all the seasons, there is no change in the species richness but there was major difference in the individuals recorded in the seasons. The highest abundance was recorded in Post Monsoon that is 199 followed by Winter (88). Species richness, abundance, relative abundance, average population size, and Simpson diversity index of the family Papilionidae are given in the Table 4.

Abundance, relative abundance and average population size shows peaks in Post Monsoon followed by monsoon and Winter and the lowest peak was in hot Summer followed by Summer and early Summer. This result indicates that October and November were the two favorable months followed by August, September, December and January. April and May were the two hottest periods; the values decreased in these two months, and they were low comparatively to Post Monsoon. All the six recorded species were observed in all the seasons except for Common Mormon. Common Mormon has not been observed in hot Summer. The distribution of all the six species in different seasons of the year given in **Table 9**. For the family Papilionidae Post Monsoon and Monsoon was the most suitable period for the activity and in contrast hot Summer hider the activity of Papilionids.

Family – Hesperiidae

Total of seven species were recorded in this family. Total abundance was 280. In this family the highest abundance was recorded in Post Monsoon that is 97 individuals were counted with relative abundance 34.64% and the least were in hot Summer with 9 individuals and 3.21% of relative abundance. The second largest values for abundance and relative abundance were in monsoon and Winter; further decreased values were recorded in Summer. This indicates that Post Monsoon is the conducive season for Hesperiidae community and hot Summer is the unfavorable for the community.

Table 5 provides complete result for all the seasons for Hesperiidae family. The species distribution reveals that except for Common Banded Awl, all the six species were recorded in all the seasons, Common Banded awl not recorded in hot Summer. The species distribution of Hesperiidae in different seasons of the year is given in **Table 10**.

Family – Pieridae

Species richness, abundance, relative abundance, average population size and Simpson index are presented in Table 6. The distribution of all the 21 species recorded are given in **Table 11**. The result of the Pieridae was also same as in Papilionidae and Hesperiidae. The abundance of 338 and 233 were recorded in Post Monsoon and monsoon, respectively. 12, 66, 132 and 233 individuals were recorded in hot Summer, Summer, early monsoon, and Winter, respectively. Post Monsoon was the optimum season for the activities for this family butterfly and hot Summer and Summer were the not favorable seasons. Common Emigrant, Mottled Emigrant, Common Gras Yellow, Pioneer, and Common Gull were recorded in all the seasons while one spot Grass Yellow, Three Spot Grass Yellow were documented in Post Monsoon and Winter only. Within the family of butterflies different species shows difference in the temperature tolerant capacity (Kunte, 1997).

Family – Lycaenidae

Overall, 25 species were recorded during the research period. All the six seasons, Post Monsoon was the best season for Lycaenidae, followed by Winter and monsoon. The least abundance was recorded in hot Summer, Summer. 412, 250, 209, 115, 60, and 14 individuals were recorded in Post Monsoon, Winter, monsoon, early monsoon, Summer, and hot Summer, respectively. The average population sizes in Summer, hot Summer, early monsoon, monsoon, Post Monsoon and Winter were 6.6, 2.4, 8.25, 14.56, 17.79, and 10.63, respectively. Post Monsoon was the best season for Lycaenids and hot Summer was the most unfavorable season. Cornelian, Common Line blue, Dark Cerulean, Pea Blue, Zebra Blue, Gram Blue, Small Grass Jewl, Grass Jewel were observed in all the seasons and relatively less were recorded in hot Summer and Summer. Indian Sunbeam, Scarce Shot Silverline and Common Shot Silverline appeared only from Post Monsoon to Winter, no individuals of these three species were observed in Summer, hot Summer, early monsoon, and monsoon.

Family – Nymphalidae

Total of 24 species were recorded in family Nymphalidae. 430 individuals were recorded in Post Monsoon with the relative abundance 34.43%, 287 abundance and 22.98% relative abundance in Winter, 283 abundance and 12.66% relative abundance in monsoon. The least were recorded in hot Summer followed by Summer and early monsoon with 32, 50 and 167 abundance and 2.56, 4 and 13.37% of relative abundance, respectively. Average population sizes in Summer, hot Summer, early monsoon, monsoon, Post Monsoon and Winter were 6.6, 2.4, 8.25, 14.56, 17.79, and 10.63, respectively. Post Monsoon is the best season for Nuymphalids followed by Winter and monsoon.

Hot Summer is not favorable for the butterfly activity for Nymphalid butterflies. Species distribution of Nymphalids is depicted in **Table 13**. Plain Tiger, Common tiger, Common Crow, Common Evening Brown, Common Three ring, Joker, Lemon Pansy and Tawny Coster were observed and recorded in all the seasons while Blue tiger, Dark Blue Tiger, King Crow, Double

Banded Crow, Common Fourring, Common Leopard, Angled Caster, Common Caster had not been observed in Summer and hot Summer. Summer recorded species are less counted comparatively to these recorded in monsoon Post Monsoon.

4. CONCLUSIONS

From the study it can be concluded that Post Monsoon is the best season for all the butterfly families and hot Summer is the unfavorable season for all the families. Specifically Post Monsoon is the suitable season, gradually there is an increase in the abundance from early monsoon and reaches its peak at Post Monsoon; after this gradual decrease was observed from Winter to Summer, and a sudden decrease was recorded in hot Summer for all the families of butterflies. This was because of the high temperature in hot Summer and optimum temperature and relative humidity and rain fall in Post Monsoon. The similar results were observed by Raghavendra *et al*. (2011), recorded 49 species of butterflies in Winter, 26 in Summer, 44 in Monsoon at their research area Bhadra Wildlife Sanctuary, Karnataka.

The least number of species were recorded in Summer. Butterflies require a certain minimum level of atmospheric humidity to survive. If this falls below a certain level for a sufficient length of time, the species can be exterminated from an area, despite of the continued presence of their larval host plants. Many butterfly species appear to require a certain minimum amount of atmospheric humidity throughout the year in order to survive in an area (Peter, 2011). Hussain *et al*. (2011) studied the seasonal variation in the butterfly species richness and abundance in DAE Parkus, Kalpakkam, Tamil Nadu, India.

They classified a year into four periods: June to September - Southwest monsoon (SWM); October to December- North West monsoon (NEM); January to February – Winter; March to May- Hot Summer. Average temperature was SWM, NEM, Winter and Summer were recorded as 30.6 °C, 28.4 °C, 27.7 °C and 31 °C and the mean rainfall for the all four seasons were 224 mm, 744.5 mm, 18.5 mm, and 35 mm, respectively. The least species richness was in Summer (16) species and the highest in NEM, that is in October, November and December months. 95 individuals were recorded in Summer, 204 in SWM (June, July, August and September), 248 in Winter, and 287 in NEM (October, November and December months). The least species richness and abundance of butterflies in hot Summer is mainly because of very hot temperature, scarcity of water, poor nectar and dry vegetation was the reason.

According to Hussain *et al*. (2011) the increased species richness and abundance during NEM was because of sufficient rain fall, mean 744.5 mm, and conducive temperature 28 °C. Nymphalidae was dominant family in all the seasons of the year followed by Pieridae, Lycaenidae and Papilionidae. Plain tiger and Tawny Coster were reported in all the seasons. including hot Summer. The abundance of Pieridae was in NEM and Lycaenidae in Winter. And they concluded that September to February is conducive for butterfly in their study because of the high humidity and optimum temperature. 27-29 °C and 80-85% relative humidity were suitable climatic conditions for the butterfly Population in their research station finally they opened. Didham and Springate (2003) documented maximum number of insect diversity and abundance from October to December.

According with Kunte (2005), Tiple and Khurad (2009), Hill *et al*. (2003); Padhye *et al*. (2006); Didham and Springate (2003), the peak season of butterflies (Species richness, abundance) is October to December. Kunte (2005) also reported peak butterfly activity from

October to January/February in his study at Nilgiri and Anamalai Hills, South Western hats, India. Panchali *et al*. (2014) recorded 158 species and 2480 individuals from June to September (Monsoon). Shannon Index, and evenness index were 4.968 and 0.981, respectively while in Summer Shannon index and evenness were 4.819 and 0.974, respectively. In autumn (October-November) and Winter (December – February) 4.714 and 4.282 were Shannon index, and 0.961 and 0.811 were the evenness of butterflies, respectively. Their study also reveals that Monsoon was the favorable season for butterflies. Atluri *et al*. (2011) also reported Monsoon is the best season for butterflies. Butterflies form peaks in the transition period between wet season and dry hot season (Emmel and Leck, 1970). Kunte (1997) focused the seasonality of butterflies in the four study sites, namely Sinhagad, Peacock bay, Pachgaon and Malwadi close to Pune, Maharashtra, India. The population of butterflies was low in Summer (April and May) and Spring (February and March) in all the four selected study sites. In Peacock bay and Pachgaon this was partly because of fires and in remaining two sites heat, scarcity of water, high temperature was the reason according to Kunte.

In contrast, Wynter Blyth (1956) reported March, April and October were the peak seasons for butterflies. But March to April there was the least butterfly activity and abundance was recorded from India. This indicates that optimum temperature and rainfall are necessary for the butterflies and they are sensitive to change in abiotic factors. The temperature, relative humidity and rainfall have the direct effect on species richness, abundance and species composition of the family of butterflies in the given habitat.

Fire can occur naturally or be initiated by human beings. It plays a very important role since it affects the vegetation directly (Kunte, 1997). During the research period, in March 2016 accidental fire was recorded due to short circuit (as said given by the one of the grander working in The Park), the fire affected area is shown, the plate number 1. Because of the combined effect of high temperature (39.4 °C) less relative humidity (19%) along with fire accident affected the butterfly population, Pea Blue, Plain Tiger, Zebra Blue, Common Emigrant, Common Yellow butterfly were even seen in the fire-afflicted area. Fire affected species composition and abundance but not species richness.

The same is also true in the Kunte (1997) investigation at Pachgaon and Peacock Bay (Pune, Maharashtra, India) in northern Western Ghats. Grass yellow population affected severely by man-initiated fire but there is no difference in species richness. Even more drastic than low atmospheric humidity levels is the effect of forest fires in Himalayan broadleaf forests (Peter, 2011). He visited the burnt forest for the first time in 2009, he recorded no butterflies species at all, he explained it as, in 2009; for the first time we notice broadleaf forest in the area burn; the effect was immediate and drastic. For the butterfly population was practically wiped out within the week (Peter, 2011). In one major fire in May, even the broadleaf forest burnt over most of the area, after which butterfly populations dropped almost to zero (Peter, 2011). Fire is a major factor that is almost a part of the normal "climate" in shaping the history of vegetation in most of the normal terrestrial environments of the world. Consequently, biotic communities adapt and compensate for this factor just as they do for temperature or water. As with most environmental factors, human beings have greatly modified its effect, increasing its influence in many cases and decreasing it in others.

In the present observation, 30-33 °C and 70-84% relative humidity was found optimum for butterflies. Optimum temperature, total rainfall and relative humidity are the important aspects for natural growth, abundance and reproductive fitness of butterflies. Seasonal timing and intensity are so critical to determining the consequence of burning. Human carelessness tends to increase "wildfire"; therefore, it is necessary to have a strong Parkaign for the fire protection in forests and recreation areas. The individual citizen should never start or cause fires anywhere in nature, but should recognize that the use of fire as a tool by trained persons is part of a good land management (Odum, 1913).

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Appendix

Table 1. Average temperature, total rain fall and relative humidity of Uploan Nature Park from June 2015- 2017

Year	Season	Months	Temperature (°C)		Monthly Total Rainfall (mm)	Mean Relative Humidity (%)
			Mean Maximum	Mean Minimum		
2015	Early Monsoon	June, July	35.6	24.35	43.7	76
	Monsoon	August, September	33.3	23.05	210.5	82
	Post Monsoon	October, November	34.35	22.05	13.2	75
	Winter	December, January	33.8	19.2	33.8	66
2016	Summer	February and March	38.1	22.7	4.45	49.5
	Hot Summer	April, May	41.85	27.3	21.95	53
	Early Monsoon	June, July	33.45	25.2	256.9	86
	Monsoon	August, September	31	22	203.9	87.5
	Post Monsoon	October, November	32.7	18.85	22.1	76.5
	Winter	December, January	32.65	17.1	0.1	70
2017	Summer	February and March	36.6	20.85	0.45	49.3
	Hot Summer	April, May	41.6	34.65	0.4	43.53
	Early Monsoon	June, July	33.85	23.3	5.45	80.1
	Monsoon	August, September	32.3	22.5	6.45	84.5
	Post Monsoon	October, November	32.95	20.35	2.1	76.7
	Winter	December, January	32.22	16.3	0	72.65

(Source of the data - All the data collected from, Meteorological Department, Meteorological Centre, Central observatory, Palace Road Bangalore, Karnataka, Ministry of Earth Sciences Government of India)

Table 2. Number of Species recorded in each family during different seasons of the year from June 2015 to 2017

S.N.	Family	Summer	Hot Summer	Early Monsoon	Monsoon	Post Monsoon	Winter
1	Papilionidae	6	5	6	6	6	6
2	Hesperiidae	7	6	7	7	7	7
3	Pieridae	10	5	16	16	19	19
4	Lycaenidae	17	7	18	20	25	24
5	Nymphalidae	9	9	16	17	21	21

Table 3. Abundance, Relative abundance and Average population size of butterflies in different seasons of the year from June 2015-2017

S.N.	Seasons of the Year	Total Abundance of all the families of butterflies	Relative abundance	Average Population size
1	Summer	227	5.63 %	9.8
2	Hot Summer	78	1.93 %	6.4
3	Early Monsoon	484	12 %	12.6
4	Monsoon	903	22.38 %	13.2
5	Post Monsoon	1476	36.58 %	15.6
6	Winter	867	21.49 %	15.4
7	Total	4035	100 %	

Table 4. Diversity indices of family Papilionidae during different seasons of the year from June 2015 to 2017

S.N.	Seasons of the year Papilionidae	Abundance	Species richness	Relative abundance in percentage	Average Population size	Diversity indices: Species richness indices: Margalef's index(D_{Mg})	Diversity indices: Species richness indices: Menhinick's index (D_{Mn})	Diversity indices: Simpson's index (D)	Diversity indices: Reciprocal of Simpson's index (1/D)	Diversity indices: Simpson's measure of evenness ($E_{1/D}$)	Diversity indices: Dominance Index: Berger – Parker index (d)	Gini Coefficient
1	Summer	24	6	5.18	4	1.57	1.22	0.17	5.87	0.97	0.29	0.26
2	Hot Sumer	11	5	2.38	2.2	1.66	1.50	0.14	6.87	1.37	0.27	0.18
3	Early Summer	45	6	9.72	7.5	1.31	0.89	0.19	5.05	0.84	0.33	0.29
4	Monsoon	96	6	20.73	16	1.09	0.61	0.18	5.32	0.88	0.28	0.23
5	Post Monsoon	199	6	42.98	33.17	0.94	0.42	0.18	5.29	0.88	0.29	0.20
6	Winter	88	6	19.01	14.67	1.11	0.63	0.16	5.96	0.99	0.23	0.13
	Total	463	6	100								

Table 5. Diversity indices of family Hesperiidae during different seasons of the year from June 2015 to 2017

S. N.	Seasons Family - Hesperiidae	Abundance	Species richness	Average Population size	Diversity indices						Gini Coefficient
					Species richness indices		Simpson's index (D)	Reciprocal of Simpson's index (1/D)	Simpson's measure of evenness ($E_{1/D}$)	Dominance Index	
					Margalef's index (D_{Mg})	Menhinick's index (D_{Mn})				Berger – Parker index (d)	
1	Summer	40	7	5.71	1.62	1.10	0.17	5.57	0.79	0.32	0.34
2	Hot Sumer	9	6	1.5	2.27	2	0.08	12	2	0.22	0.16
3	Early Monsoon	25	7	3.57	1.86	1.4	0.13	7.31	1.04	0.24	0.24
4	Monsoon	82	7	11.17	1.36	0.77	0.14	7.14	1.02	0.19	0.12
5	Post Monsoon	97	7	13.86	1.31	0.71	0.14	7.07	1.01	0.19	0.12
6	Winter	40	7	5.71	1.62	1.10	0.17	5.57	0.79	0.32	0.34

Table 6. Diversity indices of family Pieridae during different seasons of the year from June 2015 to 2017.

S. N.	Family - Pieridae	Total number of organisms	Total number of Species recorded	Average Population size	Diversity indices						Gini Coefficient
					Species richness indices		Simpson's index (D)	Reciprocal of Simpson's index (1/D)	Simpson's measure of evenness ($E_{1/D}$)	Dominance Index	
					Margalef's index(D_{Mg})	Menhinick's index (D_{Mn})				Berger – Parker index (d)	
1	Summer	66	10	6.6	2.14	1.23	0.12	7.95	0.79	0.19	0.35
2	Hot Summer	12	5	2.4	1.61	1.44	0.19	5.07	1.01	0.33	0.3
3	Early Monsoon	132	16	8.25	3.07	1.39	0.10	9.52	0.59	0.18	0.48
4	Monsoon	233	16	14.56	2.75	1.04	0.08	11.42	0.71	0.12	0.38
5	Post Monsoon	338	19	17.79	3.09	1.033	0.08	12.35	0.65	0.12	0.43
6	Winter	202	19	10.63	3.39	1.33	0.08	11.52	0.60	0.13	0.47

Table 7. Diversity indices of family Lycaenidae during different seasons of the year from June 2015 to 2017

S. N.	Family - Lycaenidae	Abundance	Species richness	Average Population size	Diversity indices						Gini Coefficient
					Species richness indices		Simpson's index (D)	Reciprocal of Simpson's index (1/D)	Simpson's measure of evenness ($E_{1/D}$)	Dominance Index	
					Margalef's index(D_{Mg})	Menhinick's index (D_{Mn})				Berger – Parker index (d)	
1	Summer	60	17	3.52	3.90	2.19	0.06	15.26	0.89	0.166	0.30
2	Hot Sumer	14	7	2	2.27	1.87	0.12	8.27	1.18	0.28	0.28
3	Early Monsoon	115	18	6.38	3.58	1.67	0.06	15.24	0.84	0.11	0.32
4	Monsoon	209	20	10.45	3.55	1.38	0.06	16.14	0.80	0.12	0.31
5	Post Monsoon	412	25	16.48	3.98	1.23	0.05	17.27	0.69	0.10	0.39
6	Winter	250	24	110.42	4.16	1.51	0.06	14.32	0.59	0.14	0.46

Table 8. Diversity indices of family Nymphalidae during different seasons of the year from June 2015 to 2017

S. N.	Family - Nymphalidae	Total number of organisms	Total number of Species recorded	Average Population size	Diversity indices						Gini Coefficient
					Species richness indices		Simpson's index (D)	Reciprocal of Simpson's index (1/D)	Simpson's measure of evenness ($E_{1/D}$)	Dominance Index	
					Margalef's index(D_{Mg})	Menhinick's index (D_{Mn})				Berger – Parker index (d)	
1	Summer	50	9	5.55	2.04	1.27	0.13	7.24	0.80	0.28	0.30
2	Hot Sumer	32	9	3.55	2.30	1.59	0.10	9.18	1.02	0.18	0.27
3	Early Monsoon	167	16	10.44	2.93	1.23	0.07	12.97	0.81	0.10	0.31
4	Monsoon	283	17	16.65	2.83	1.01	0.07	13.35	0.78	0.10	0.31
5	Post Monsoon	430	21	20.48	3.29	1.01	0.07	14.15	0.52	0.10	0.40
6	Winter	287	21	13.67	3.53	1.24	0.07	14.14	0.67	0.09	0.41

Table 9. Abundance of Papilionidae Species recorded in different seasons of the year from June 2015 to 2017

S.N.	Scientific Name	Common English Name	Summer	Hot Summer	Early Monsoon	Monsoon	Post Monsoon	Winter	Total
1	*Pachliopta aristolochiae* (Fabricius,1775)	Common Rose	5	2	15	27	58	11	118
2	*Pachliopta hector* (Linnaeus, 1758)	Crimson Rose	7	3	8	17	34	21	90
3	*Papilio demoleus* (Linnaeus, 1758)	Lime Butterfly	5	3	9	21	30	18	86
4	*Papilio polytes* (Linnaeus, 1758)	Common Mormon	3	0	7	6	13	11	40
5	*Graphium agamemnon* (Linnaeus, 1758)	Tailed Jay	1	1	3	13	34	13	65
6	*Graphium doson* (C.&R. Felder. 1864)	Common Jay	3	2	3	12	30	14	64
	Total		24	11	45	96	199	88	463

Table 10. Abundance of Hesperiidae Species recorded in different seasons of the year from June 2015 to 2017

S. N.	Scientific Name	Common English Name	Summer	Hot Summer	Early Monsoon	Monsoon	Post Monsoon	Winter	Total abundance
1	*Hasora badra* (Moore, 1858)	Common Awl	3	1	2	16	10	3	35
2	*Hasora chromus* (Cramer, 1780)	Common Banded Awl	3	0	2	14	11	1	31
3	*Pelopidas agna* (Moore, 1866)	Dark Branded Swift	2	2	5	8	14	6	37
4	*Pelopidas manthias* (Fabricius, 1798)	Small Branded Swift	4	1	3	10	17	8	43
5	*Pelopidas subochracea* (Moore, 1878)	Large Branded Swift	6	2	6	14	19	13	60
6	*Potanthus pseudomaesa* (Moore, 1881)	Indian Dart	6	2	5	10	15	5	43
7	*Potanthus trachala* (Mabille, 1881)	Broad Bi –dent Dart	3	1	2	10	11	4	31
	Total Abundance		27	9	25	82	97	40	280

Table 11. Abundance of Pieridae Species recorded in different seasons of the year from June 2015 to 2017

S.N.	Scientific Name	Common English Name	Summer	Hot Summer	Early Monsoon	Monsoon	Post Monsoon	Winter	Total
1	*Catopsilia Pomona* (Fabricius, 1775)	Common Emigrant	10	2	13	19	28	16	88
2	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	13	4	9	22	35	27	110
3	*Eurema andersoni* (Moore, 1886)	One-spot Grass Yellow	0	0	0	0	1	1	2
4	*Eurema blanda* (Boisduval, 1836)	Three-spot Grass Yellow	0	0	0	0	0	1	1
5	*Eurema brigitta* (Stoll, 1780)	Small Grass Yellow	10	0	10	13	10	7	50
6	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	11	4	13	16	26	17	87
7	*Eurema laeta* (Boisduval, 1836)	Spotless Grass Yellow	0	0	2	2	3	2	9
8	*Leptosia nina* (Fabricius, 1793)	Psyche	0	0	1	4	12	3	20
9	*Ixias Marianne* (Cramer, 1779)	White Orange Tip	0	0	6	14	25	15	60
10	*Ixias pyrene* (Linnaeus, 1764)	Yellow Orange Tip	0	0	2	7	22	17	48
11	*Colotis amata* (Cramer, 1775)	Small Salmon Arab	3	0	2	4	7	6	22
12	*Colotis aurora* (Cramer, 1780)	Plain Orange Tip	1	0	1	3	3	3	11
13	*Colotis danae* (Fabricius, 1775)	Crimson Tip	3	0	21	28	43	23	118
14	*Colotis etrida* (Boisduval, 1836)	Little Orange Tip	0	0	3	3	6	3	15
15	*Colotis fausta* (Olivier, 1804)	Large Salmon Arab	1	0	5	30	23	7	66
16	*Prioneris situ* (C.&R. Felder, 1865)	Painted Sawtooth	0	0	0	0	1	0	1
17	*Belenois aurota* (Fabricius, 1793)	Pioneer	7	1	24	28	31	28	119
18	*Cepora nerissa* (Fabricius, 1775)	Common Gull	7	0	18	28	41	21	115
19	*Delias eucharis* (Drury, 1773)	Common Jezabel	0	0	0	0	1	1	2
20	*Pareronia valeria* (Cramer, 1776)	Common Wanderer	0	1	0	0	0	0	1
21	*Hebomoia glaucippe* (Linnaeus, 1758)	Great Orange Tip	0	0	2	12	20	4	38
	Total		66	12	132	233	338	202	983

Table 12. Abundance of Lycaenidae Species recorded in different seasons of the year from June 2015 to 2017

S.N.	Scientific Name	Common English Name	Summer	Hot Summer	Early Monsoon	Monsoon	Post Monsoon	Winter	Total
1	*Curetis thetis* (Drury, 1773)	Indian Sunbeam	0	0	0	0	1	1	2
2	*Spindasis elima* (Moore, 1877)	Scarce Shot Silverline	0	0	0	0	2	1	3
3	*Spindasis ictis* (Hewitson, 1865)	Common Shot Silverline	0	0	0	0	2	1	3
4	*Spindasis vulcanus* (Fabricius, 1775)	Common Silverline	0	0	1	3	11	2	17
5	*Deudorix epijarbas* (Moore, 1857)	Cornelian	2	0	3	7	17	10	39
6	*Prosotas nora* (Felder, 1860)	Common Lineblue	3	3	3	16	17	11	53
7	*Jamides bochus* (Stoll, 1782)	Dark Cerulean	5	2	10	11	16	12	56
8	*Catochrysops panormus* (C.Felder, 1860)	Silver Foretmenot	10	0	11	14	18	25	78
9	*Catochrysops strabo strabo* (Fabricius, 1793)	Forgetmenot	7	0	12	17	34	24	94
10	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue	3	4	13	26	44	37	127
11	*Leptotes plinius* (Fabricius, 1793)	Zebra Blue	3	1	7	7	38	23	79
12	*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	3	0	2	11	26	5	47
13	*Tarucus extricates* (Butler, 1886)	Rounded Pierrot	3	0	3	13	24	6	49
14	Tarucus nara (Kollar, 1848)	Striped Pierrot	1	0	3	13	24	6	47
15	*Zizeeria karsandra* (Moore, 1865)	Dark Grass Blue	0	0	0	0	2	1	3
16	*Zizeeria otis* (Fabricius, 1787)	Lesser Grass Blue	0	0	0	1	4	3	8
17	*Everes lacturnus* (Godart, 1824)	Indian Cupid	0	0	0	0	2	0	2
18	*Azanus jesous* (Guerin – Meneville, 1849)	African Babul Blue	0	0	0	1	4	2	7
19	*Azanus ubaldus* (Stoll, 1782)	Bright Babul Blue	4	0	11	15	24	19	73
20	*Azanus Uranus* (Butler, 1886)	Dull Babul Blue	1	0	7	9	21	9	47
21	*Euchrysops cnejus* (Fabricius, 1798)	Gram Blue	5	1	6	17	27	8	64
22	*Freyeria putli* (Kollar, 1844)	Small Grass Jewel	3	1	7	6	18	8	43
23	*Freyeria trochylus* (Freyer, 1845)	Grass Jewel	2	2	8	6	16	13	47
24	*Luthrodes pandava* (Horsfield, 1829)	Plains Cupid	3	0	4	9	10	9	35

25	*Chilades parrhasius* (Fabricius, 17930	Small Cupid	2	0	4	7	10	14	37
	Total		60	14	115	209	412	250	1060

Table 13. Abundance of Nymphalidae Species recorded in different seasons of the year from June 2015 to 2017

S. N.	Scientific Name	Common English Name	Summer	Hot Summer	Early Monsoon	Monsoon	Post Monsoon	Winter	Total
1	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger	9	4	17	30	39	21	120
2	*Danaus genutia* (Cramer, 1779)	Common Tiger	4	6	17	19	44	19	109
3	*Tirumala limniace* (Cramer, 1775)	Blue Tiger	0	0	13	23	21	21	78
4	*Tirumala septwntrionis* (Butler, 1874)	Dark Blue Tiger	0	0	0	0	0	1	1
5	*Euploea core* (Cramer, 1780)	Common crow	5	2	15	20	22	12	76
6	*Euploea klugii* (Moore, 1858)	King Crow	0	0	0	0	3	1	4
7	*Euploea Sylvester* (Fabricius, 1793)	Double – branded Crow	0	0	1	1	0	0	2
8	*Charaxes solon* (Fabricius, 1793)	Black Rajah	0	1	0	0	0	0	1
9	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	14	5	11	18	24	22	94
10	*Ypthima asterope* (Klug, 1832)	Common Threering	4	0	15	30	34	16	99
11	*Ypthima huebneri* (Kirby, 1871)	Common Fourring	0	0	0	1	4	1	6
12	*Phalanta phalantha* (Drury, 1773)	Common Leopard	0	0	0	1	2	1	4
13	*Ariadne ariadne* (Linnaeus, 1763)	Angled Castor	0	0	0	0	2	0	2
14	*Ariadne merione* (Cramer, 1777)	Common Castor	0	0	0	0	1	1	2
15	*Byblia ilithyia* (Drury, 1773)	Joker	3	2	7	20	30	25	87
16	*Vanessa cardui* (Linnaeus, 1758)	Painted Lady	0	0	1	0	1	1	3
17	*Junonia almana* (Linnaeus, 1758)	Peacock Pansy	0	0	1	2	7	4	14
18	*Junonia atlites* (Linnaeus, 1763)	Grey Pansy	0	0	0	0	2	2	4
19	*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	0	0	2	14	32	24	72
20	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	5	3	17	25	37	28	115

21	*Junonia orithya* (Linnaeus, 1758)	Blue Pansy	0	6	11	18	26	19	80
22	*Hypolimnas bolina* (Linnaeus, 1758)	Great Eggfly	0	0	14	16	37	28	95
23	*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	2	0	15	26	32	22	97
24	*Acraea violae* (Fabricius, 1793)	Tawny Coster	4	3	10	19	30	18	84
	Total abundance		50	32	167	283	430	287	1249

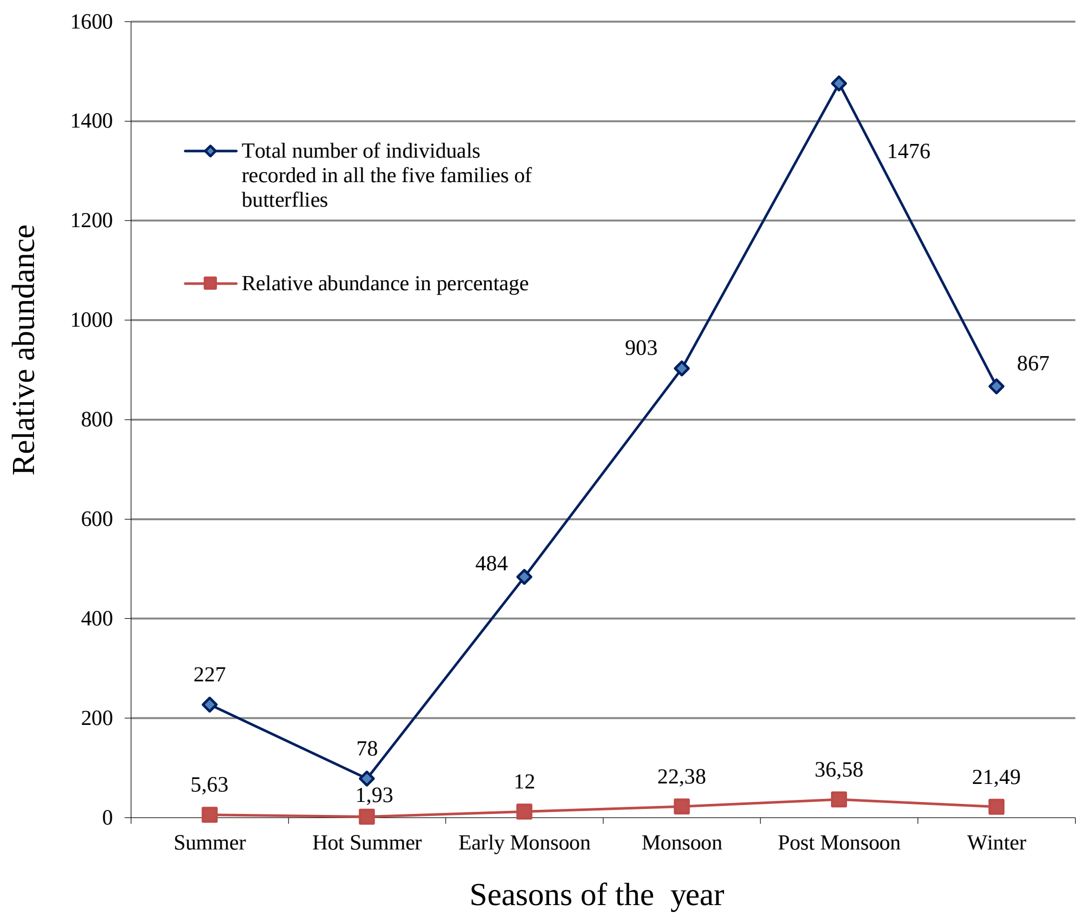

Figure 1. Relative abundance and total number of individuals recorded in the different seasons of the year (Average numbers from 2016 -2017)

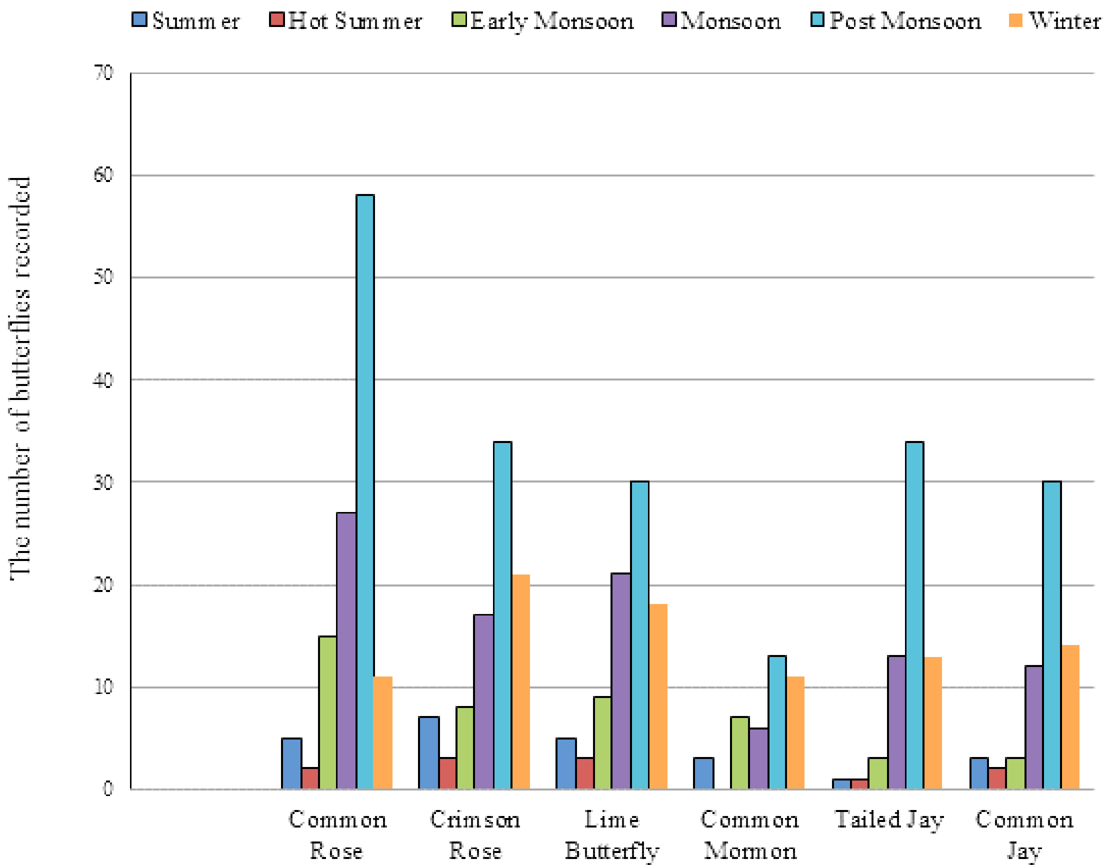

Figure 2. Seasonal distribution of family Papilionidae

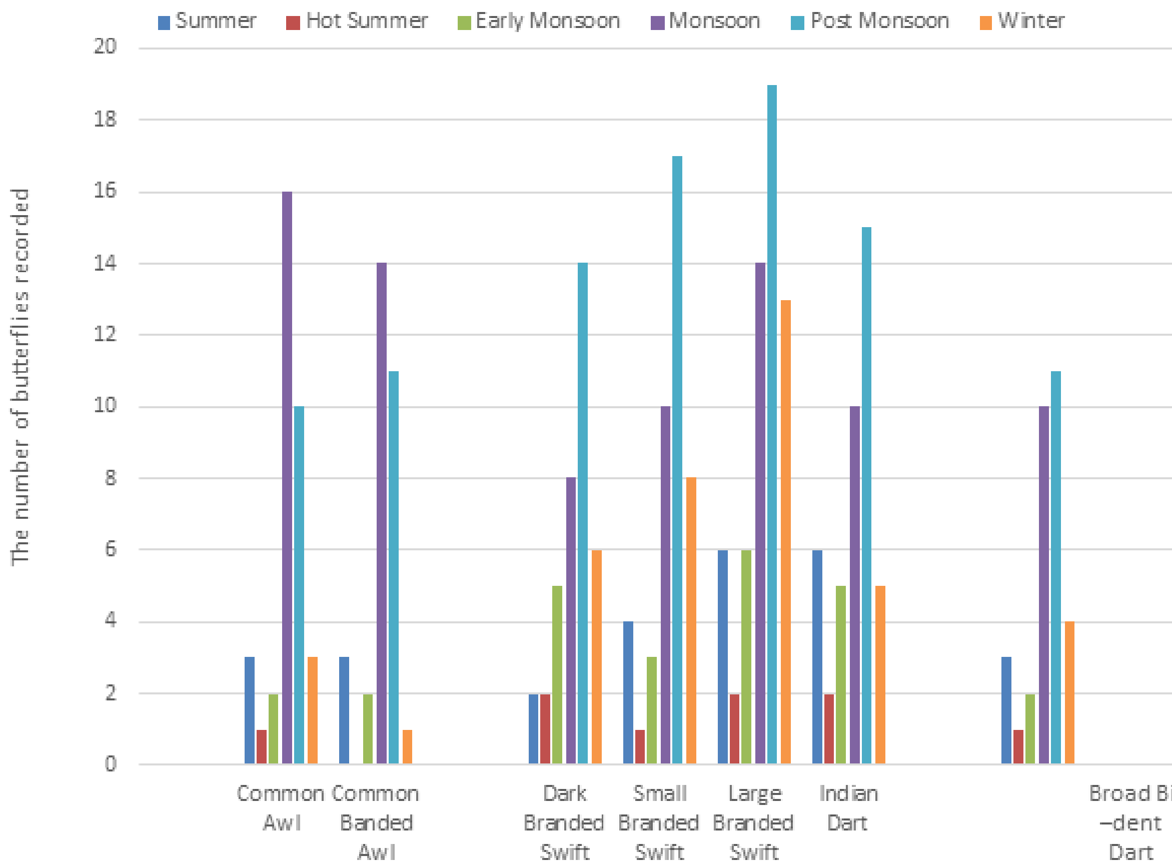

Figure 3. Seasonal abundance distribution of family Hesperiidae

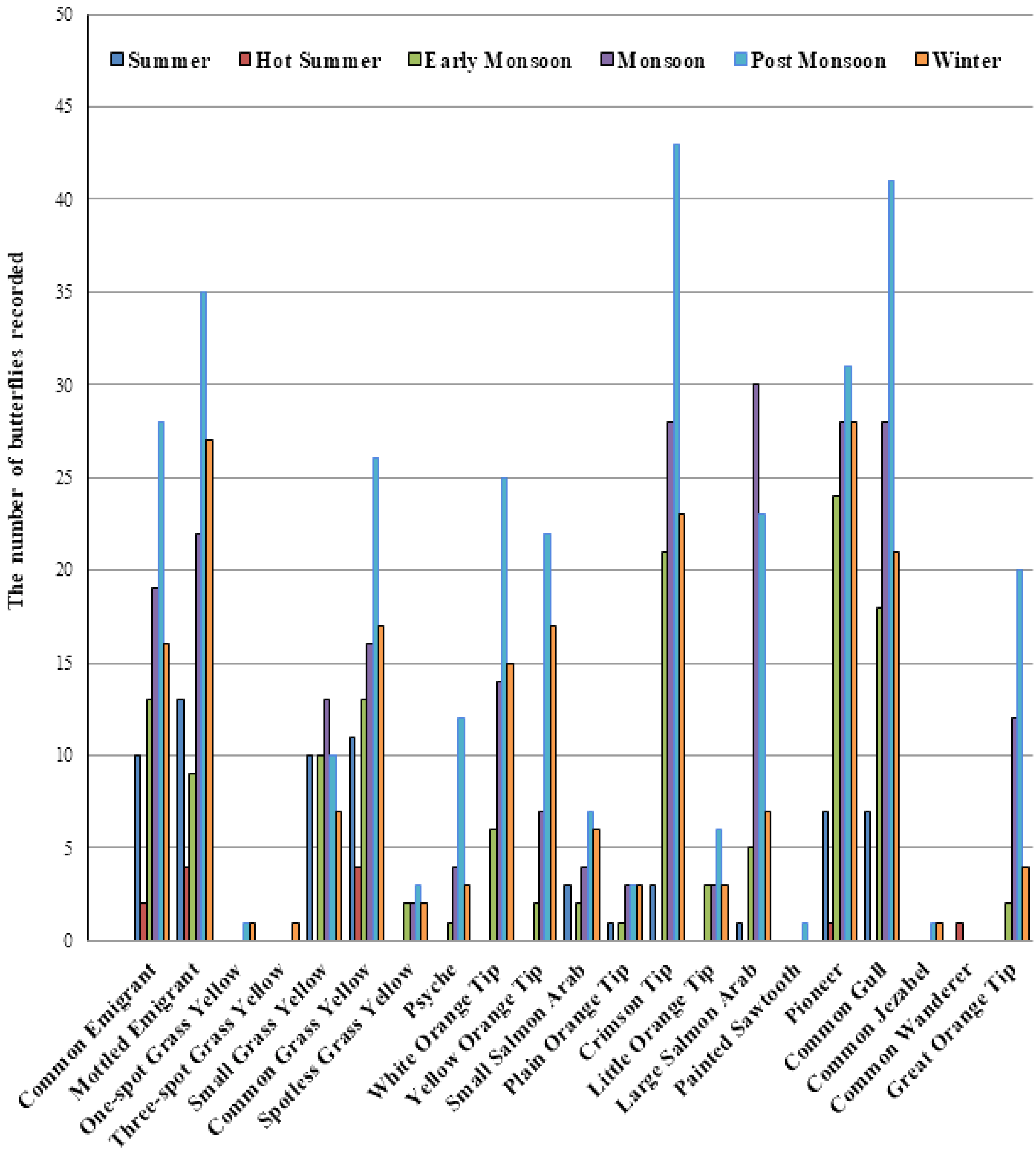

Figure 4. Seasonal abundance distribution of family Pieridae

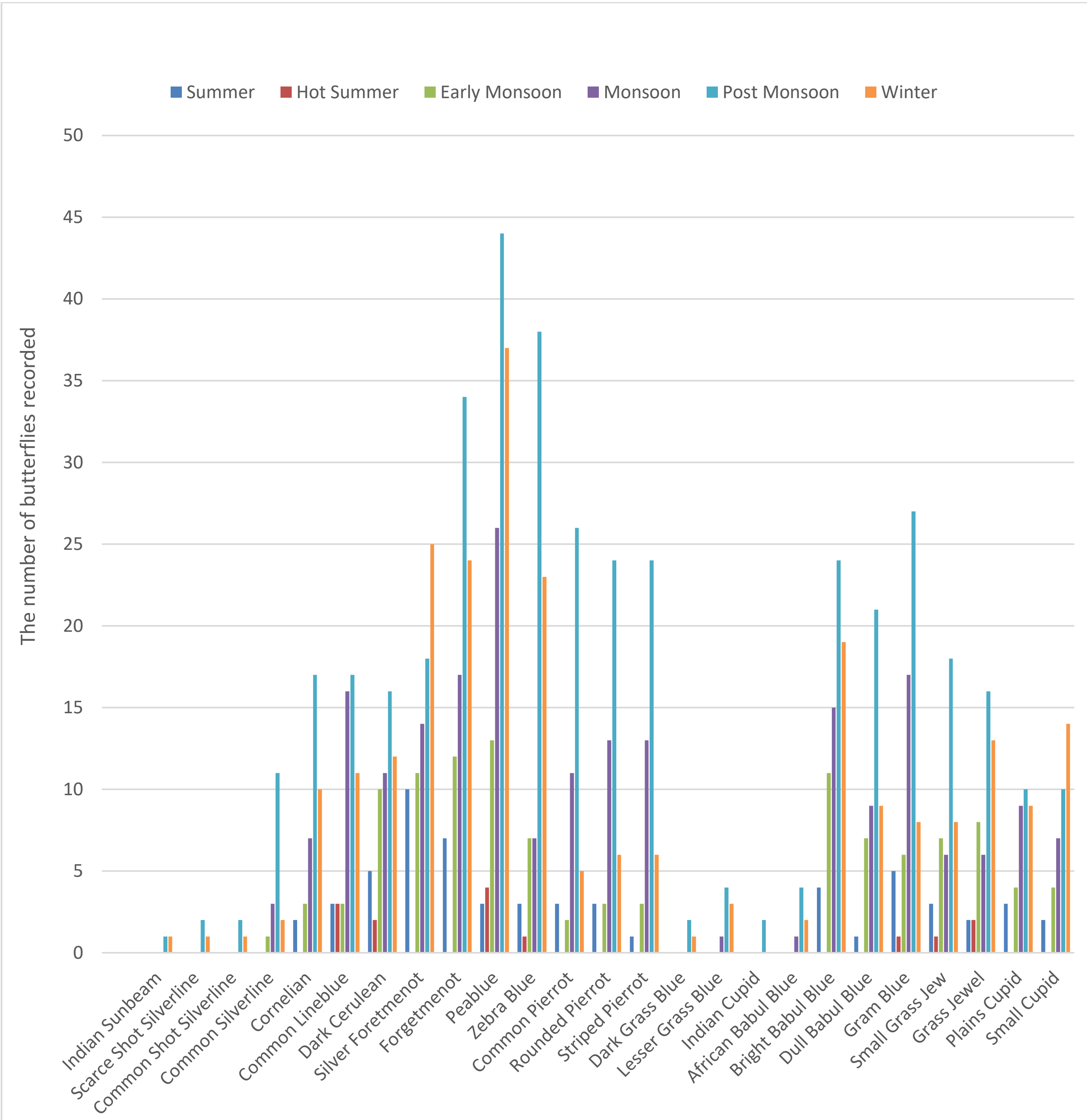

Figure 5. Seasonal abundance distribution of family Lycaenidae

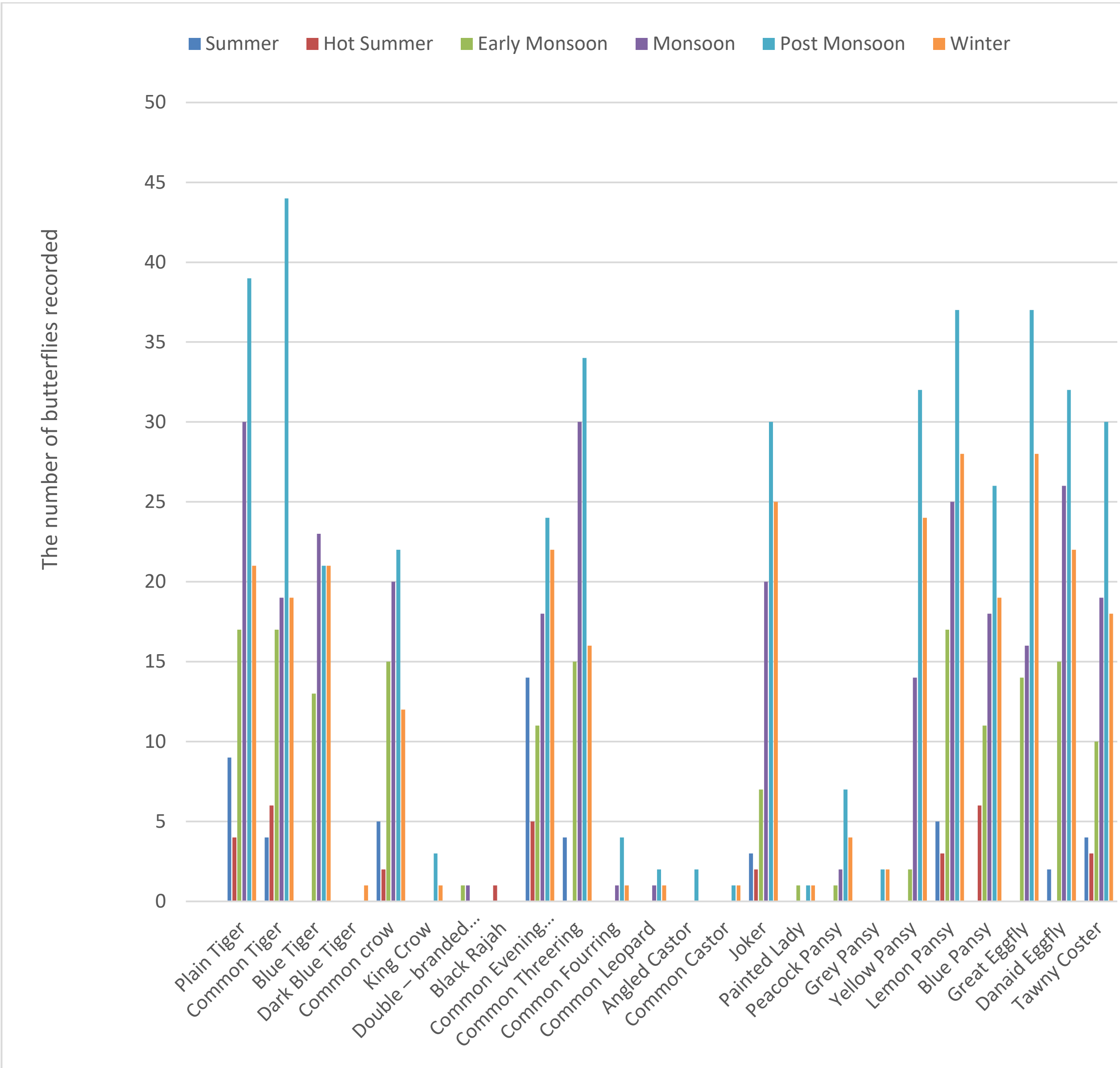

Figure 6. Seasonal abundance distribution of family Nymphalidae