CHAPTER 7.

STUDY OF BUTTERFLIES

INTRODUCTION

Butterflies, one of the most beautiful insects of the world, besides having aesthetic value have great ecological significance. Classified in order Lepidoptera, they form important exhibits in Zoos and Natural History Museums. Their immature stages or caterpillars are largely herbivorous and thus, the primary consumers in the ecosystem. However, caterpillars and adults are in turn fed upon by various higher groups of organisms such as birds, lizards and some mammals forming more than one link in the food web. They also play an important role as pollinators in an ecosystem (Mondal, 1998).

Though butterflies with moths are considered under the same group Lepidoptera, they differ in their habitats. Most butterflies being diurnal prefer the warmth of the sun for basking and feeding, whereas majority of moths are nocturnal, flying after sunset. However, there are exceptions to this rule. Presently, butterflies are classified into two super families, of which Hesperiodea includes all the skippers, while, Papilionoidea includes the rest, 'the true' butterflies. Hesperiodea consist of a single family Hesperiidae (skippers), whereas Papilionoidea has four families: Papilionidae (Swallowtails), Pieridae (Whites and Yellows), Nymphalidae (Brush-footed butterflies) and Lycaenidae (Blues). Taxonomists are yet to resolve and agree on classification of some groups into sub-families and tribes. Modern methods of molecular technology, like DNA sequencing and its application to systematic and taxonomic research is expected to help resolve question of certain relationships in the classification of these groups (Kehimkar, 2008).

There are about 18,000 species of butterflies in the world. India has 1,501 species of which 321 are skippers, 107 swallowtails, 109 whites and Yellow, 521 Brush footed butterflies and 443 Blues (Gaonkar, 1996; Kehimkar, 2008). However, Evans (1949) has recorded approximately 1439 species of butterflies from British India, Including Ceylon and Burma.

The butterflies have an adult life span from a week to nearly a year depending upon the species, many have long larval stages and several remain dormant in their pupal or egg stages to survive winters. They undergo complete metamorphosis and hence termed “holometabolous”. Butterflies may have one or more broods per year the number varying from temperate to tropical regions; showing a trend towards multivoltinism (Richards and Davies, 1993).

Polymorphism:

Many adult butterflies’ exhibit polymorphism-showing differences in appearance, a unique variation that occurs within a species. Such variations with two or more forms may be observed in the same area. *E.g.* the female common Mormon occurring in three forms, one mimics the Common Rose, the second mimics the Crimson Rose while the third resembles the male. Some butterfly species have environmentally induced alternative seasonal forms, showing seasonal polymorphism (Shapiro, 1976; Tiple and Khurad, 2009). Several environmental factors are believed to produce such seasonal forms (Roskam and Brakefield, 1999).

Butterflies also show interesting behavioural patterns that involve movements that cause rearrangements of parts of whole body creating different positions in relation to various activities (Yazdani and Agarwal, 1997) *i.e.* while seeking the partner (Scott, 1973; Davies, 1978; Tiple *et al.*, 2010) while perching, (Baker, 1972) and while defending the territory (Kemp and Wiklund, 2001). Behavioral patterns vary regionally in response to change in resource distributions. Butterflies being poikilothermic need to regulate their body temperature. They enjoy basking in the sunlight to increase the body temperature or withdraw underneath a leaf to lower the same. Most butterflies just spread their wings flat and align themselves for maximum exposure to sunlight (Dennis, 2010). Another interesting behavior is “mud puddling” usually shown by newly hatched males in response to sodium salt (Poulton, 1917). Mud puddling is a social activity where at times several hundred butterflies, especially males of one or more species gather on damp sand or mud banks.

Whatever may be the reason; the butterflies move or migrate from one place to another over a considerable distance when they are fun to watch. Change in day length, rainfall and temperature trigger various movements. Many butterflies typically move very short distances (Erhlich, 1961; Turner, 1971; Erhlich and Gilbert, 1973) while others are wide range species (Scott, 1973; Gilbert, 1969), several of them showing regular migratory movements (Williams, 1930; Johnson, 1969). Spectacular large scale migrations associated with the monsoon are seen in peninsular India (Williams, 1930; Johnson, 1969). The abiotic factors such as climate and weather affect butterfly populations irrespective of the density. In a habitat where resources are seasonal, variations between species in the timing of first and last appearances (phenology) and in number of generations during the 'growing season' (Voltinism) are noted (Lees, 1962). Initiation and breaking of diapauses is also under influence of various environmental factors (Lees, 1962). Climatic factors may also influence butterfly populations through effects on host quality (Singer, 1972). Depending on the type of habitat; eggs, young larvae and pupae may suffer heavy predation from invertebrates (Dempster, 1967) or birds (Baker, 1970).

Although we are a long way from being able to explain why local butterfly communities are structured on the basis of current knowledge, one can point to those niche dimensions that are most important in understanding their ecological segregation. With reference to ecological segregation of British butterflies, difference between butterfly richness has been reported with reference to i) larval food plant, ii) part of host used, iii) time of appearance (Phenology and voltinism), iv) habitat and, v) flowers visited by adults (adult resources) (Owen, 1959). This may stand true for Indian butterflies too. However, they form an important part of ecosystem and are increasingly being used in biodiversity studies and conservation prioritization programmes (Gadgil, 1996). Among insects, butterflies are one of the most suitable indirect measures of environmental variations as they are highly sensitive to local weather, climate, light levels and other parameters that affect the habitat (Ehrlich *et al*., 1972; Wood and Gillman, 1998).

Long-term monitoring of butterfly population can be central to the identification and conservation of threatened and endangered species as efficiency in study, techniques and statistical accuracy are required. These goals are often difficult to meet within the tight budgets typical of conservation projects (Murphy and Stuart, 1988). Conservation biology is a crisis science. It is vital that entomologists emphasize that some exceedingly economically valuable insect species may await discovery and hence saving as many biotopes and landscapes as possible is required. Hence, the present study documents butterfly density and diversity of one unexplored habitat in Toranmal area of Satpura range in North Maharashtra.

Butterflies are conspicuous components of open habitats and indicators of habitat quality. Patterns in distribution and abundance for many species are well known. Widespread species are often locally abundant and their abundance fluctuate more than geographically restricted species (Gaston, 1988). Short term changes in butterfly abundance result from variations in weather, whereas long term changes are due to modification of habitat quality and availability of food (Thomas, 1984).

MATERIAL AND METHODS

To study butterflies of Toranmal area, surveys were conducted once a month for two years from December 2006 to November 2008.

STUDY AREA:

Three biotopes selected for the study are within 10 km radius of Toranmal hill station having different biotopes as:

1. Transect-1 (T-1) Sitakhai Track:

It is located at 21˚53’ 28” N and 74˚ 28’ 05” E and 868 m AMSL on northern side of Toranmal. It runs parallel to the Sitakhai stream which is a perennial stream on the northwest side of transect surrounded by few agricultural plots. It has mix vegetation of herbs, shrubs and trees along the stream. The common weeds include *Plectranthus mollis*, *Tridax procumbens*, *Lantana camera* and *Abelmoschus manihot.*

2. Transect-2 (T-2) Kalapani Stream:

It is located at 21˚51’ 03” N and 74˚ 28’ 06” E and 822 m AMSL. This transect is located about (by road) 10 kms before Toranmal. It runs parallel to the Kalapani stream-a seasonal stream runing from June to January. It is surrounded by forested area with tall trees. *Tectona grandis* (Teak) is one of the dominant tree species of the area. At few places between the forested tract open areas are present with growth of shrubs and herbs. This area is used for cattle grazing. The major wild weeds in the area include *Achyranthes aspera, Cassia tora, Vernonia cinerea, Tridax procumbens, Andropogon spp, etc.*

3. Transect-3 (T-3) Lotus Lake Area:

Located at 21˚53’ 16” N and 74˚ 27’ 47” E and 900 m AMSL at northern side of Toranmal, it has a mixed vegetation comprising fruit plants, few ornamental shrubs, herbs and few trees. Shrubs like *Lantana camera*, *Tridax procumbens*, *Plectranthus* *mollis, Andropogon spp., Cassia obtusifolia* and trees like *Madhuca longifolia, Phyllanthus emblica, Terminalia arjuna, T. bellirica, Syzygium heyneanum, Mangifera indica, Bombax ceiba etc*. are the common plant species in the area.

Transects were surveyed using transect count method popularly known as 'Pollard Walk' (Pollard *et al*., 1975; Walpole and Sheldon, 1999). Observations were made on fixed transects of 500 m length and 5 m width on either side. Transect was walked between 7:00 h and 11:00 h at a constant pace. All the butterflies on the line as well as 5 m on either side were recorded with time and number of individuals seen for basking butterflies. Butterfly species were identified directly in the field or photographed. Some Lycaenids and hesperids difficult to be identified in flight were caught by hand net and identified upto species and released back in the same habitat. All the scientific names follow Varshney (1983) and Kunte (2000) while common English names are after Wynter-Blyth (1957) and Kehimkar (2008). Each transect was walked for 24 times over a period of 2 years accounting to total 72 transects in all three sites. Further, their density is calculated as number/hectare while species richness is considered as number of species encounted per transect per visit. The observed butterflies were grouped in five categories on the basis of number of sightings in the field. The status of butterflies is as (VC) very common (> 100 % sighting); (C) common (50 – 100 % sighting); (F) Frequent (25 – 50 % sighting); (R) Rare (10 – 25 % sighting); (VR) very rare (< 10 % sighting) (Tiple *et al*., 2006 and Tiple and Khurad, 2009). Flight period and seasonality of butterfly species were noted and the relative abundance of butterfly species in different habitats were analysed.

RESULTS

The data obtained during two year (December 2006 to November 2008) study period revealed that all five families of butterflies are represented at Toranmal.

Community composition of Butterfly fauna at Toranmal (Table 7.1 Fig. 1)

The butterfly fauna of Toranmal is rich. During the present study total 51 species (Annexture -VI) belonging to 38 genera were recorded. Qualitatively and quantitatively the families recorded in the decreasing order are: Nymphalidae the most dominant family with 25 species belonging to 17 genera and averaging 49 % species richness of total species, followed by family Lycaenidae (10 species, 9 genera and 21.6 %), Pieridae (9 species, 7 genera and 17.6 %), Papilionidae (5 species, 3 genera and 9.8 %) and Hesperiidae (2 species, 2 genera and 4 %).

Density and Species Richness of Total Butterfly with five families:

Seasonal changes in majority of parameters studied related to butterflies are highly significant at the level of 0.0001.

1. Transect-1 (T-1) Sitakhai Track:

The density of butterflies showed significant seasonal variations ($F_{3\ 20}$ 17.66) at Sitakhai Track. Maximum density of total butterflies was recorded in post monsoon (396 ± 28.92 /hectare) and minimum in the summer (51 ± 6.6 /hectare), while it was (214 ± 42.3 /hectare) and (301 ± 49 /hectare) in winter and monsoon respectively (Table 7.2a, Fig. 7.2a).

Family wise distribution of butterfly density revealed that the density of all the families were maximum in post-monsoon except Lycaenidae whose density was maximum in monsoon. Among the five families density of family Nymphalidae was maximum (199.7 ± 11.1 /hectare) in post monsoon followed by Pieridae (105.3 ± 10.11 /hectare), Papilionidae (42.67 ± 3.35 /hectare), Lycaenidae (32.83 ± 3.09 /hectare) and Hesperiidae (15.5 ± 1.2 /hectare). The density of Lycaenidae was highest in monsoon (45.83 ± 6.86 /hectare).

Minimum densities for all five families were recorded in summer. Among these, density of Nymphalidae was maximum (32.5 ± 4.07 /hectare) while that of Papilionidae and Hesperidae were zero with not a single species observed.

Total species richness of butterflies at Sitakhai tract showed same trend as that of density with significant seasonal variations ($F_{3\ 20}$ 22.88) (Table 7.3a, Fig. 7.3a). Maximum species richness was recorded in post-monsoon (31.33 ± 0.97) and minimum in the summer (7.66 ± 0.55), while it was (19.33 ± 3.46) and (24.67 ± 2.28) in winter and monsoon respectively.

Family wise distribution of butterfly also showed same trend with maximum species observed in post-monsoon except for Lycaenidae, where species richness was maximum in monsoon. Among the five families, species richness of family Nymphalidae was maximum (14.83 ± 0.30) followed by Pieridae (7.83 ± 0.16), Papilionidae (4.00 ± 0.0), Lycaenidae (3.16 ± 0.30) and Hesperiidae (1.33 ± 0.21). In monsoon Species richness of Lycaenidae was 4.5 ± 0.5. Minimum species richness for all five families was also recorded in summer. Among these, Nymphalidae was represented by maximum (5.0 ± 0.36) species while Papilionidae and Hesperiidae were not represented at all.

2. Transect-2 (T-2) Kalapni Stream:

Total Density of butterflies at Kalapani stream showed significant seasonal variations ($F_{3\ 20}$ 16.33) with maximum density recorded in post monsoon (345.63 ± 19.89 /hectare) and minimum in the summer (31 ± 4.68 /hectare), while it was (175 ± 45.4 /hectare) and (251 ± 45.26 /hectare) in winter and monsoon respectively (Table 7.2b, Fig. 7.2b). At Kalapani too family wise distribution of butterfly density revealed that Nymphalidae was dominant family among all the families and administered maximum density. It was maximum (173 ± 11.3) in post-monsoon, followed by Pieridae 92.50 ± 7.58/ hectares, and Papilionidae (34.33 ± 2.53/ hectare) as well as lycaenidae (33.3 ± 5.10/ hectare), followed by minimum (10.50 ± 1.89 /hectare) of Hesperridae. Same trend as noted for transect -1 was noted for transect-2 with minimum density for all five families in summer. Among them, maximum density was recorded for family Nymphalidae (25.3 ± 2.3 /hectare) and minimum nil for family Papilionidae and Hesperiidae.

Species richness of total butterflies at Kalapani stream showed significant seasonal variations ($F_{3\ 20}$ 19.21) with maximum species richness recorded in post monsoon (36.49 ± 1.60) and minimum in the summer (4.83 ± 0.72), while it was (21 ± 4.21) and (26.16 ± 3.87) in winter and monsoon respectively (Table 7.3b, Fig. 7.3b).

Family wise distribution of butterfly species richness at Kalapani stream also revealed that Nymphalidae was dominant family administering maximum species richness all throughout the year. Its maximum species richness occurred in post-monsoon 18.33 ± 0.55 while the family Hesperiidae occurred with minimum (1.0 ± 0.0) species richness. Minimum species richness was recorded in summer for all five families. Among these maximum 3.83 ± 0.30/hectare species were observed for Nymphalidae while minimum none for Papilionidae as well as Hesperidae.

3. Transect-3 (T-3) Lotus Lake Area:

Around Lotus Lake area also total Density of butterflies varied significantly across the season ($F_{3\ 20}$ 14.93). Maximum density of butterflies were recorded in post-monsoon

(381.8 ± 30.11/hectare) and minimum in summer (38.83 ± 4.02 /hectare) while it was 205.3 ± 52.22 /hectare and 257.2 ± 45.92 /hectare in winter and monsoon respectively (Table 7.2c, Fig. 7.2c). When family wise distribution of butterflies at Lotus Lake is considered, here also Family Nymphalidae was represented by maximum number of butterflies 208.8 ± 13.47 /hectare in post monsoon (Table 7.2c, fig. 7.2c). The density of butterflies belonging to Pieridae (80.67 ± 7.89 / hectare) and Papilioniodae (47 ± 4.83/ hectare) were highest in post-monsoon while Lycaenidae had highest density in monsoon (35.5 ± 5.89/ hectare) and Hesperiidae had almost same density (13.17 ± 2.22/ hectare and 13 ± 1.96/ hectare) in monsoon and post-monsoon. Minimum density of total butterflies 38.83 ± 4.02/ hectare was recorded in summer with Nymphalidae 26.33 ± 1.38 /hectare, Pieridae with 8.66 ± 1.18/ hectare and Lycaenidae with 3.83 ± 1.5/hectare while families Papilionidae and Hesperiidae were totally absent.

At Lotus Lake area also total species richness of butterflies varied significantly across the season ($F_{3\ 20}$ 23.48). Maximum species of butterflies were recorded in post monsoon (30.83 ± 0.09) and minimum (6.16 ± 0.9) in summer, with 19.0 ± 3.72 and 23.17 ± 2.35 in winter and monsoon respectively (Table 7.3c, Fig. 7.3c).When family wise species richness was considered same trend was observed as for T1 and T2 with maximum species of all families except Lycaenidae observed in post monsoon (Table 7.3c and Fig. 7.3c). During Post monsoon maximum 16.67 ± 0.55 species belongings to family Nymphalidae while minimum only one species belonging to Family Hesperiidae were observed. At Lotus Lake minimum species were observed during summer (Table 7.3c, Fig. 7.3c) with maximum 4.0 ± 0.36 species belonging to family Nymphalidae. No species belonging to families Papilionidae and Hesperiidae were observed during summer.

When average percentage density and species richness are considered (Table 7.1, Fig. 7.1, 7.4) 55.6 % total butterfly density with 49 % of species belonged to family Nymphalidae. Pieridae occupied next position with average 21.8 % density but 17.6 % species richness while Lycaenidae with 9.2 % average percentage density was represented by more species (21.6 %). Family Papilionidae was also represented by 9.2 % of average percentage density but its species richness was comparatively low *i.e.* only 9.8 %. Hesperiidae was represented as only 3.3 % average percentage density and 4 % species richness.

Though the Toranmal is forested land, variations were recorded in butterfly density, species richness and composition pattern in the three biotopes. However, density and species richness were similar. The maximum density of butterflies was recorded at Sitakhai Stream (T-1) followed by Lotus Lake Area (T-3) and Kalapani Stream (T-2), while the species richness were maximum at Kalapani Stream (T-2) followed by Sitakhai Stream (T-1) and Lotus Lake Area (T-3).

Of the 51 species were recorded, 18 were very common, 19 common, 2 frequent, 8 rare and 4 very rare species (Table 7.4).

When Pearson correlation (Table 7.5) was performed, density and species richness of butterflies were correlated with abiotic factors of Toranmal area like AT, humidity and rainfall, humidity showed positive significant correlation at the level 0.01 (2 tailed) with density and species richness at all three transect. Rainfall was also positively correlated at level of 0.01 and 0.05 with density and species richness at different transects while Atmospheric temperature did not showed any correlation.

Table 7.1 Average percentage density and species richness of total butterfly families of Toranmal area (T-1, T-2, T-3) during the year December 2006 to November 2008

	Papilionidae	Pieriidae	Nymphalidae	Lycaenidae	Hesperiidae
Density	9.23	21.8	55.6	9.2	3.3
Sp. richness	9.8	17.6	49	21.6	4

Table 7.2a Seasonal Variations in the density (no./hectare) of Total Butterflies compared to the families represented at Sitakhai streamT-1 during December 2006 to November 2008

Parameters	F value $F_{3\ 20}$	Winter	Summer	Monsoon	Post-monsoon
Tot. Butterfly	17.66	214 ± 42.3	51 ± 6.6	301 ± 49.6	396 ± 28.92
Papilionidae	9.605	17.50 ± 7.2	00 ± 00	28.50 ± 8.4	42.67 ± 3.35
Pieridae	11.76	53.67 ± 14.46	13.83 ± 1.78	61.17 ± 12.63	105.3 ± 10.11
Nymphalidae	23.63	131.8 ± 15.76	32.50 ± 2.66	154.8 ± 21.34	199.7 ± 11.17
Lycaenidae	20.67	7.83 ± 3.28	4.66 ± 1.99	45.83 ± 6.86	32.83 ± 3.09
Hesperiidae	17.34	3.16 ± 2.10	0.0 ± 0.0	10.67 ± 2.36	15.50 ± 1.20

Table 7.2b Seasonal Variations in the density (no./hectare) of Total Butterflies compared to the families represented at Kalapani streamT-2 during December 2006 to November 2008

Parameters	F value $F_{3\ 20}$	Winter	Summer	Monsoon	Post-monsoon
Tot. Butterfly	16.33	175 ± 45.8	31.0 ± 4.68	251 ± 45.26	345.63 ± 19.89
Papilionidae	12.88	15.33 ± 6.34	00 ± 00	16 ± 3.81	34.33 ± 2.53
Pieridae	16.09	33.67 ± 13.48	5.16 ± 2.04	50.5 ± 9.38	92.50 ± 7.58
Nymphalidae	16.01	113 ± 19.9	25.3 ± 2.3	132.2 ± 21.2	175 ± 11.3
Lycaenidae	12.48	8.66 ± 3.63	0.50 ± 0.34	39.50 ± 8.63	33.3 ± 5.10
Hesperiidae	9.57	3.83 ± 2.45	0.0 ± 0.0	12.83 ± 2.24	10.50 ± 1.89

Table 7.2c Seasonal Variations in the density (no./hectare) of Total Butterflies compared to the families represented at Lotus LakeT-3 during December 2006 to November 2008

Parameters	F value $F_{3\ 20}$	Winter	Summer	Monsoon	Post-monsoon
Tot. Butterfly	14.93	205.3 ± 52.22	38.83 ± 4.02	257.2 ± 45.92	381.8 ± 30.11
Papilionidae	10.41	20.67 ± 8.91	00 ± 00	23.83 ± 6.30	47 ± 4.83
Pieridae.	12.48	38 ± 11.56	8.66 ± 1.18	41.50 ± 8.99	80.67 ± 7.89
Nymphalidae	17.02	133 ± 25.38	26.33 ± 1.38	143.2 ± 22.52	208.8 ± 13.47
Lycaenidae	17.26	9.47 ± 3.71	3.83 ± 1.50	35.5 ± 5.89	32.33 ± 1.96
Hesperiidae.	11.19	4.16 ± 2.66	0.0 ± 0.0	13.17 ± 2.22	13.0 ± 1.96

Table: 7.3a Seasonal Variations in the species richness (No. of species) of total Butterflies compared to the families represented at Sitakhai Stream T-1 during December 2006 to November 2008

Parameters	F value $F_{3\ 20}$	Winter	Summer	Monsoon	Post-monsoon
Tot. Butterfly	22.88	19.33 ± 3.46	7.66 ± 0.55	24.67 ± 2.28	31.33 ± 0.97
Papilionidae	12.33	1.66 ± 0.76	00 ± 00	2.33 ± 0.55	4.00 ± 0.0
Pieridae	13.48	5.0 ± 0.96	2.33 ± 0.21	4.83 ± 0.70	7.83 ± 0.16
Nymphalidae	38.36	11.17 ± 1.07	5.0 ± 0.36	12.0 ± 0.63	14.83 ± 0.30
Lycaenidae	29.64	1.16 ± 0.30	0.33 ± 0.21	4.50 ± 0.50	3.16 ± 0.30
Hesperiidae	8.44	0.50 ± 0.34	0.0 ± 0.0	1.0 ± 0.0	1.33 ± 0.21

Table: 7.3b Seasonal Variations in the species richness (No. of species) of total Butterflies compared to the families represented at Kalapani Stream T-2 during December 2006 to November 2008

Parameters	F value $F_{3\ 20}$	Winter	Summer	Monsoon	Post-monsoon
Tot. Butterfly	19.21	21.0 ± 4.21	4.83 ± 0.72	26.16 ± 3.87	36.49 ± 1.60
Papilionidae	12.13	2.33 ± 0.91	00 ± 00	3.33 ± 0.55	4.50 ± 0.22
Pieridae	13.08	3.66 ± 1.38	0.66 ± 0.21	4.50 ± 0.95	8.33 ± 0.42
Nymphalidae	42.28	13.33 ± 1.17	3.83 ± 0.30	12.33 ± 1.28	18.33 ± 0.55
Lycaenidae	11.86	1.33 ± 0.55	0.33 ± 0.21	5.0 ± 1.09	4.33 ± 0.42
Hesperiidae	22.50	0.33 ± 0.21	0.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0

Table: 7.3c Seasonal Variations in the species richness (No. of species) of total Butterflies compared to the families represented at Lotus Lake T-3 during December 2006 to November 2008

Parameters	F value $F_{3\ 20}$	Winter	Summer	Monsoon	Post-monsoon
Tot. Butterfly	23.48	19.0 ± 3.72	6.16 ± 0.9	23.17 ± 2.35	30.83 ± 0.09
Papilionidae	12.93	2.33 ± 0.91	00 ± 00	3.33 ± 0.55	4.66 ± 0.21
Pieridae.	11.13	3.0 ± 0.63	1.50 ± 0.22	2.66 ± 0.55	5.0 ± 0.0
Nymphalidae	28.95	12.0 ± 1.61	4.0 ± 0.36	12.67 ± 0.91	16.67 ± 0.55
Lycaenidae	16.68	1.0 ± 0.36	0.66 ± 0.42	3.50 ± 0.34	3.33 ± 0.33
Hesperiidae	22.50	0.33 ± 0.21	0.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0

Table 7.4 Distribution of butterflies species according to their status at Toramal area.

Status	VC	C	F	R	VR	Total
Number	18	19	2	8	4	51

Table 7.5 Pearson correlation of density and species richness of total butterflies with abiotic factors of Toranmal area (T-1, T-2, T-3) during the year December 2006 to November 2008

	Total Density of Butterflies			Total Species richness of Butterflies		
	T-1	T-2	T-3	T-1	T-2	T-3
Atm. Temp.	-.209	-.212	-.260	-.236	-.171	-.279
Humidity	.639**	.630**	.578**	.576**	.570**	.543**
Rainfall	.529**	.512*	.453*	.465	.472*	.431*

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Fig. 7.1 Average percentage species richness of total butterfly families of Toranmal area (T-1, T-2, T-3) during December 2006 to November 2008

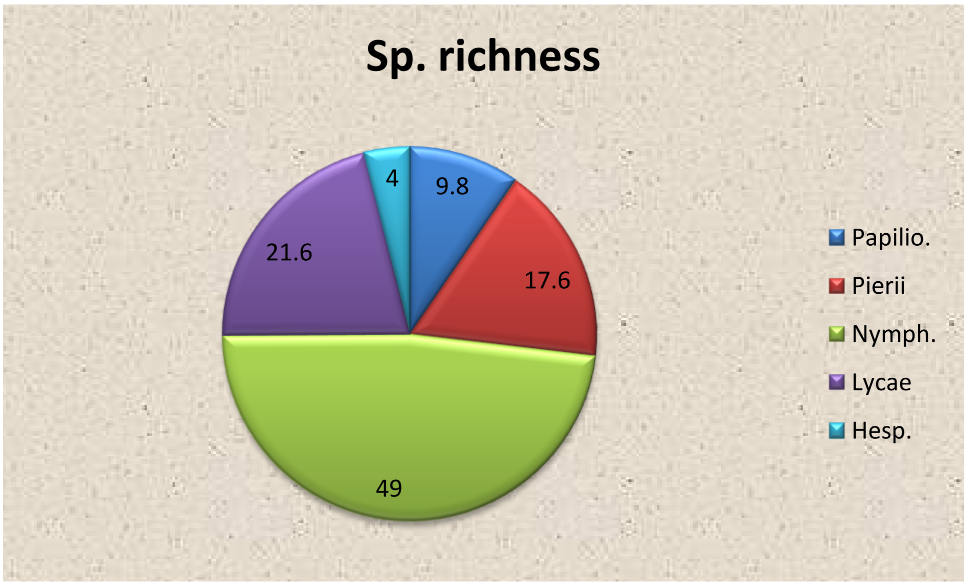


Fig. 7.2a Seasonal Variations in the density (no/hectare) of total Butterflies compared to the families represented at Sitakhai Stream T-1 during December 2006 to November 2008

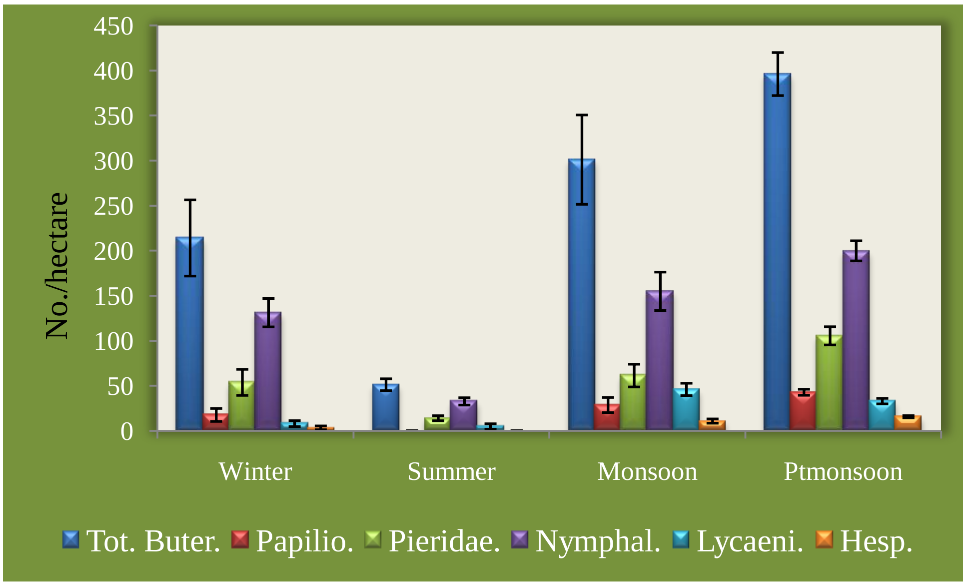


Fig. 7.2b Seasonal Variations in the density (no/hectare) of total Butterflies compared to the families represented at Kalapani Stream T-2 during December 2006 to November 2008

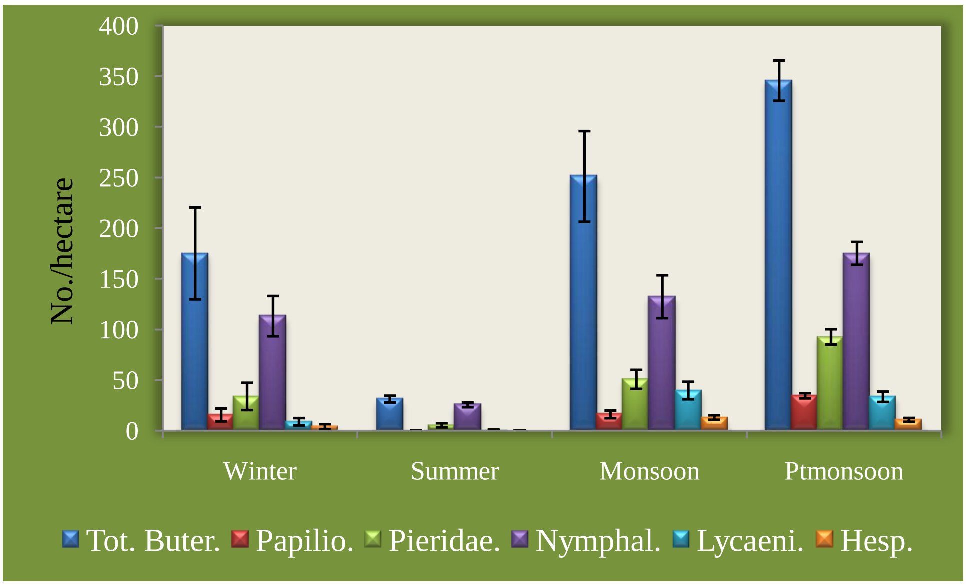


Fig. 7.2c Seasonal Variations in the density (no/hectare) of total Butterflies compared to the families represented at Lotus Lake T-3 during December 2006 to November 2008

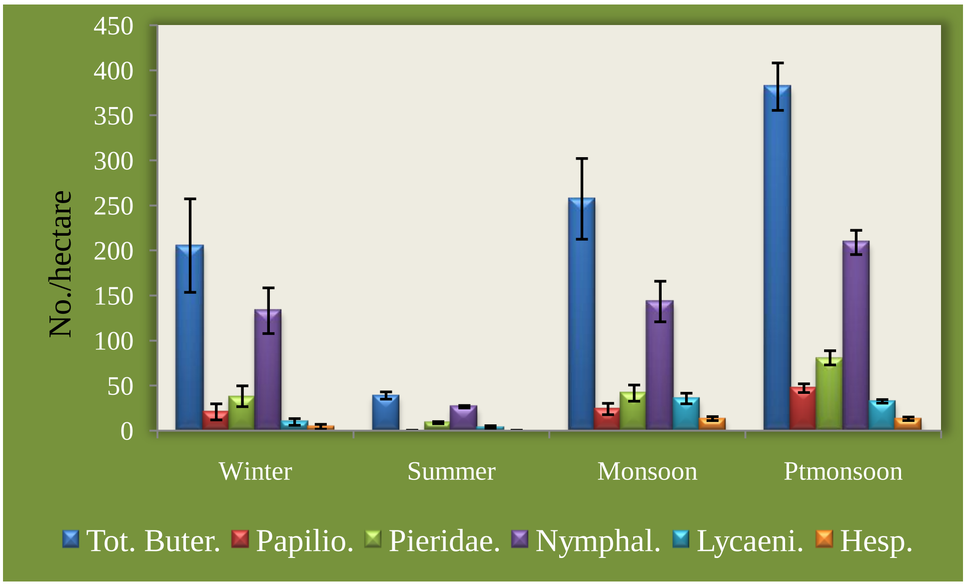


Fig. 7.3a Seasonal Variations in the species richness (No. of species) of total Butterflies compared to the families represented at Sitakhai Stream T-1 during December 2006 to November 2008

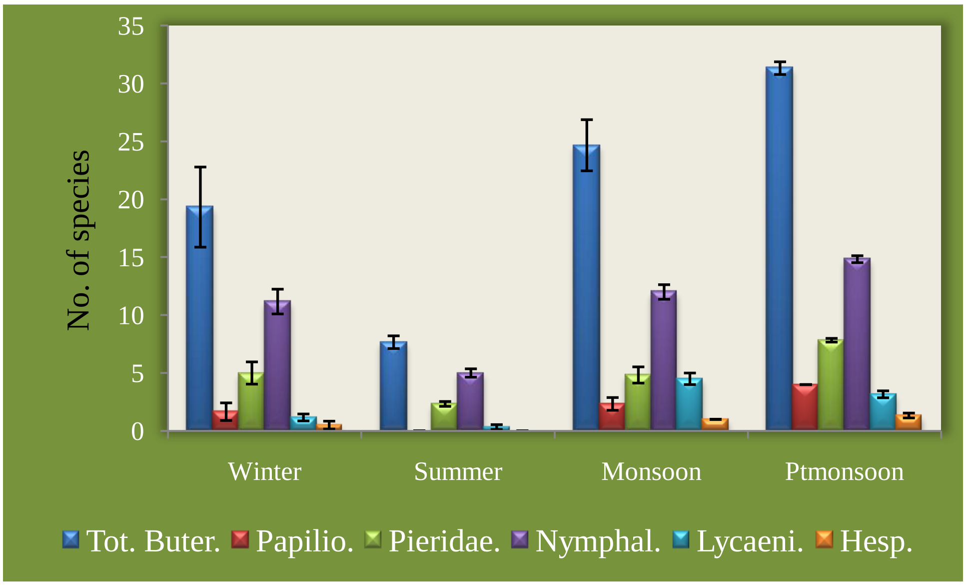


Fig. 7.3b Seasonal Variations in the species richness (No. of species) of total Butterflies compared to the families represented at Kalapani Stream T-2 during December 2006 to November 2008

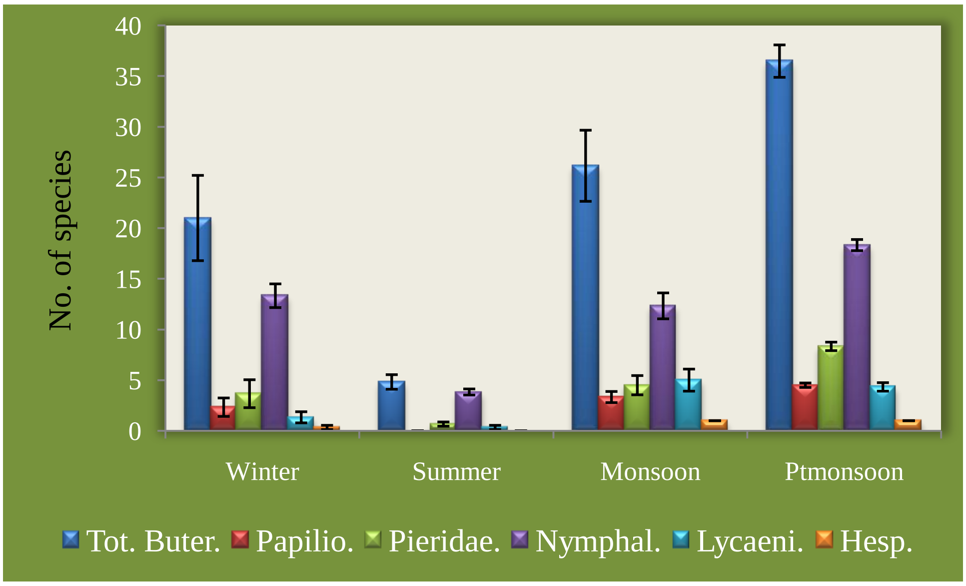


Fig. 7.3c Seasonal Variations in species richness (No. of species) of total Butterflies compared to the families represented at Lotus Lake T-3 during December 2006 to November 2008

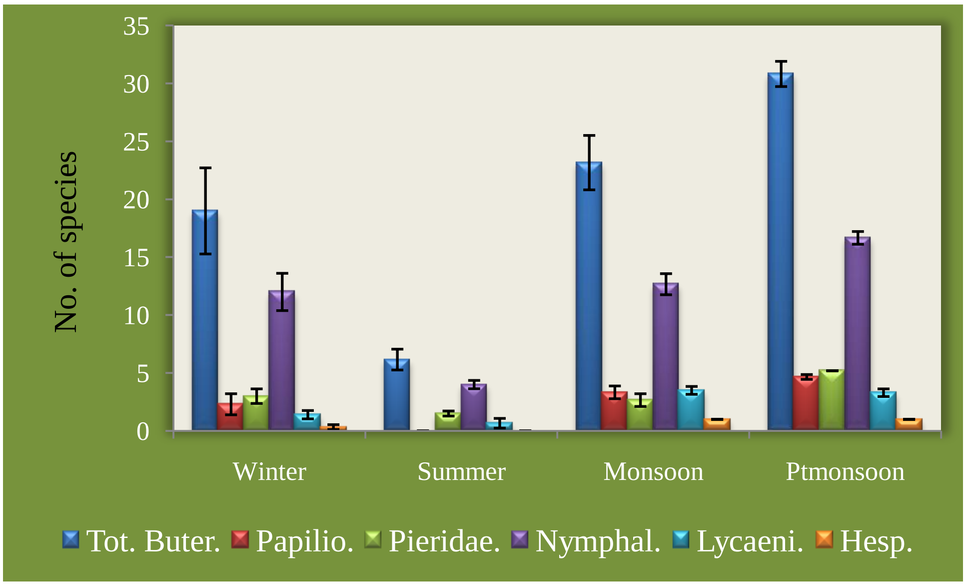
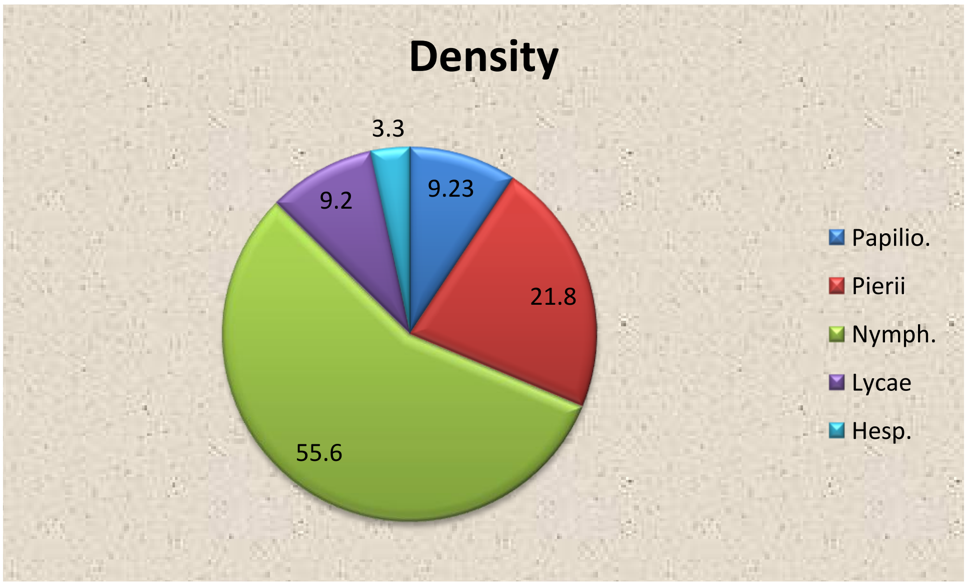


Fig. 7.4 Average percentage density of total butterfly families of Toranmal area (T-1, T-2, T-3) during December 2006 to November 2008



DISCUSSION

Toranmal Plateau is located at the tri-junction of peninsular India, Western Ghats and semiarid zone of India, where the post monsoon seems to be the most favourable season for butterflies when temperature is moderate and rains have stopped. This is reflected as maximum density as well as diversity (species richness) of butterflies density noted in this season around Toranmal area (Table 7.2a, 7.2b, 7.2c). However, two seasonal peaks for butterfly abundance, one in late monsoon and second in summer reported in other studies (Wynter-Blyth, 1957; Padhye *et al*., 2006,) were not observed at Toranmal area as lowest density and diversity of butterflies occurred in summer. Kunte (2001); Tiple *et al*. (2007); Tiple and Khurad (2009) and Hussain *et al*. (2011) have also reported single peak in butterfly abundance in the similar climatic conditions of India. In the present study butterfly density started increasing from the beginning of monsoon till the early winter and declined from winter up to the end of summer at all the three biotopes (transects). Similar results were reported from Satpura mountain range (Chandrakar *et al*., 2007; Wadatkar and Kasambe, 2009) and from Melghat Tiger Reserve (Tiple, 2011; Tiple and Khurad, 2009; Sharma and Radhakrishnan, 2004).

Seasonality is a common phenomenon in insect populations (Wolda, 1989). Seasonal fluctuations are usually influenced by environmental factors including seasonal appearance of food resources and vegetation cover such as herbs and shrubs (Kubo *et al*., 2008; Anu *et al*., 2009; Shanti *et al*., 2009; Tiple and Khurad, 2009). Hence, they are very sensitive to changes in microclimate and habitat (Kremen, 1992). Many species are strictly seasonal (Kunte, 1997). The seasonality of butterfly abundance is influenced by various factors like i) resources ii) mates iii) predators, pathogens and aggressors and iv) weather (Andrewartha and Birch, 1973). The environmental factors like temperature, rainfall and humidity serve to limit the existence of insects in their habitat or the place in which they live.

Temperature acts on insects in two ways i) by acting directly on survival, and development and ii) indirectly through availability of food, humidity, rainfall, wind, atmospheric pressure, *etc*. All the insects are poikilothermic, without any precise mechanism for regulating body temperature. Therefore, change in their body temperature follows more or less is associated with the surrounding temperature making them less active in winter as well as summer and active in moderate temperature of post-monsoon when food is also abundunt.

Significant seasonal variations were noted in all the three biotopes (transects) surveyed. Seasonality of butterfly abundance in the present study was also influenced by humidity and rainfall (Table 7.4) which corroborates consistency with earlier work showing that these parameters have a strong influence on the distribution and abundance of butterflies (Turner *et al*., 1987; Pollard, 1988; Roy *et al*., 2001; Constanti *et al*., 2004; Padhye, 2006, Tiple and Khurad, 2009, Barua *et al*., 2010). At higher altitude temperature probably does not elicit much effect hence; atmospheric temperature did not show any correlation with the total density of butterflies.

In tropical region with distinct wet and dry seasons, many insect species attain maximum adult abundance during wet season (Didham and Springate, 2003; Tiple and Khurad, 2009; Hussain *et al*., 2011). The maximum density of butterflies recorded in the post-monsoon and minimum in the summer may be attributed to the wet and dry seasons respectively. In India, rainfall is one of the major climatic factors that govern diversity and abundance of butterfly fauna. Indian subcontinent receives the major 70 percent of rains during southwest monsoon (June to September). Toranmal falling in subtropical region also receives sufficient rains during this period that prevails with conductive temperatures. This season is vital to both butterflies as well as larval host plants (food resources). This monsoon rains govern the distribution of butterfly communities in major part of India (Kunte, 2005; Padhye *et al*., 2006; Hill *et al*., 2003a). Indian summer is dry and hot, with severe drought like conditions that limit growth of most plant species. This is expected to have predictably adverse effects on herbivorous insects and more particularly on butterflies, when the desiccation of both the host plants and the nectar sources occurs (Ehrlich *et al*., 1980; Murphy *et al*., 1983). Thus, it is not surprising that butterfly assemblages in Indian climatic conditions during this period (summer) show low density and diversity (Kunte, 2005; Tiple and Khurad, 2009).

A constant supply of moisture is needed for metabolic reactions as well as for the dissolution and transport of salts. The water content in insects varies from less than 50 % to more than 90 % of total body weight (Wigglesworth, 1972). Variations occur between different species as well as between different stages in the life-cycle of the same species. Soft bodied stages of insects such as caterpillars tend to have comparatively large amount of water in their soft tissues and active stages commonly have higher water content than dormant stages. Like temperature preferendum (as discussed by Yazdani and Agrawal, 1997) insects also exhibit the phenomenon of humidity preferendum, (Roth and Willis, 1951). They have a tendency to congregate within a narrow range of humidity called preferred humidity. In the present study, the humidity range was higher to moderate in monsoon and post-monsoon when maximum density and diversity of butterflies were recorded. Despite varied observations recorded on the effect of environmental moisture, this factor by itself is 'non-critical' but in combination with temperature and varied wind speeds, the environmental moisture becomes an important factor. The temperature and humidity are inseparable ecologically. Air movements may prove beneficial if humidity is high. Such conditions of moderate temperature and humidity were recorded in the post-monsoon at Toranmal which may attribute to suitable environment for higher density and diversity of butterflies.

At Toranmal, rainfall and humidity were strongly correlated with butterfly density (Table 7.4). As discussed in previous chapter the probable explanation lies in the energy in the ecosystem. The 'More individuals hypothesis' (also called as the 'energy-richness hypothesis') proposed by Srivastava and Lawton (1998) postulates that more productive areas have more individuals. Further, Wright (1983) puts forward the hypothesis that at the base of the global food web, plant richness is limited 'primarily by solar energy and water availability' (*i.e.* water-energy dynamics), the main driving component being the primary productivity. At Toranmal area this is mainly governed by the southwest monsoon. Monsoon determines not only the density and distribution of plants but also other fauna dependent on them. Hence, the distribution of larval and nectar host plants have a distinct impact on the status of herbivorous butterfly (Culin, 1997; Solman, 2004). The abundant growth of plant in monsoon, after summer decline; favours the developmental stages of butterfly as well as adult leading to increase in their density from moderate in monsoon to peak in post-monsoon. Toranmal receives negligible rain from North East monsoon in winter, when most of the vegetation starts drying. Factors such as scarcity of water, poor nectar and dry vegetation result in low butterfly abundance and lower survival ability of most species leading to their lowest density in summer. Since, butterflies are phytophagus insects through larval and adult stages; butterfly distribution sensitively reflects changes in vegetation (Erhlich *et al*., 1972). Butterflies like any other insects are very vulnerable to changes in their environment because of their specialized life cycle. Any minor to major abiotic stress may lead to substantial decline to complete dwindling of a particular species and thus change in diversity of the area, a character used as an indicator of environmental degradation (Pollard, 1988; Sway, 1990).

The family wise distribution of density follows almost similar pattern to that of density of total butterflies as recorded at three biotopes. Population dynamics of butterfly species as reflected through relative abundance reveals their habitat character and status. These insects select their habitat in relation to their food and host plants.

SPECIES RICHNESS

Herbivore diversity is often correlated with plant diversity (Siemann *et al*., 1998) but whether this link is caused or simply co variation is driven by a common factor is not well established. However, the relative contributions of direct and indirect effects of climate on species richness are expected to depend on the geographic area and on the type of organisms (Hawkins *et al*., 2003). Turner *et al*., (1987) argued that sunshine and summer temperatures constrain butterfly richness in Great Britain because adult activity levels depend on ambient temperature and on basking in direct sunlight. In northern latitudes pure energy variables usually describe animal diversity better than other climatic factors suggesting that direct physiological effects, related to temperature, might dominate in cold climate. According to the hypothesis proposed by Currie *et al*. (2004) about species richness "patterns of species richness are typically strongly correlated with climatic variables that are related to productive or energy balance of an ecosystem"

The richness – climate correlation explained by Wright (1983) and Currie (1991) may explain seasonal difference in species richness of butterfly at the Toranmal area located in Northern Maharashtra, in subtropics of India, where maximum species richness was recorded in post-monsoon and minimum in summer with significant seasonal variations (Table 7.2a, b and c) Most importantly, generally observed increase in species richness with increased energy is manifested by an increased fraction of rare species. As their entire life directly depend on temperature and monsoon, butterflies prefer a suitable climatic condition and respond reasonably to even subtle changes in the climate. Mathew and Anto (2007) have reported that temperature ranges between 27 – 29 ˚C and humidity ranging between 60 – 80 % are most favourable for butterfly development. In the present study, the period of post-monsoon was found to be conducive for butterfly community, mainly due to the optimum temperature and high humidity. The rainfall and humidity were significantly positively correlated with total species richness of butterflies (Table 7.4). Earlier studies (Padhye *et al*., 2006; Tiple and Khurad, 2009 ; Hussain *et al*., 2011) have also suggested that temperature and precipitation are the two vital factors which influence butterflies richness. Butterfly species were fewer in number in higher temperatures of summer at Toranmal. Higher atmospheric temperature negatively affects butterfly life cycle and physiological activities (Roy *et al*., 2001). It is the southwest monsoon which causes the immense growth of vegetation in this region of North Maharashtra. This vegetation growth is adequate to support the various life stages of butterfly and act as driving factor to increase abundance of species at Toranmal. Variation in rainfall patterns is one of the most important factor affecting the seasonality of tropical insects (Hill *et al*., 2003b; Wolda, 1989).

Family wise distribution/Status

Diversity and Habitat

Of the 51 species of butterflies recorded in Toranmal area six species were recorded only from Kalapani Stream (T-2). They are *Colotis fausta*, *Athyma perius, Tirumala septentrionis, Castalius rosimon*, *Spindasis valcanus* and *Arohopata amantes.* These species were mainly rare or very rare except *Castalius rosimon*. Though this species is fond of sunshine and open country, it is reported in forested regions up to 1400 m. in South Indian hills (Kehimkar, 2008). At Toranmal it was found only at forested tract of Kalapani. This forested area has diverse vegetation as well as less anthropogenic pressure and grazing. The forested area having mix vegetation of large trees, shrubs and herbs provide better opportunity for varied butterfly species in terms of larval food, nectar plant resource and mate location sites to avoid competition. Similar observations were reported by Tiple and Khurad (2009) for wild area with fewer disturbances, where the anthropogenic pressures and grazing pressures were low.

At Sitakhai Stream (T-1) three species *Ypthima asterope, Cynthia cardui* and *Udaspes folus* were observed which were not recorded in other two biotopes. Of these *Ypthima asterope* was common whereas other two were rare and very rare respectively.

Ypthima asterope is a species of drier low land habitats near open agricultural areas as well as mixed deciduous forest (Kehimkar, 2008) typical of Sitakhai Tract. The other two species *Cynthia cardui* is a species of open grounds at higher altitudes whereas *Udaspes folus* prefers deciduous and semi evergreen forests and flies in shade dappled with sunlight among bushes, under trees, close to ground or along forest streams (Kehimkar, 2008) the microhabitat available around Sitakhai. At this area moderate human activity with grazing pressure and vegetation composition having more herbs and shrubs, and few trees, is present. At the third biotope (T-3) only one species *Ariadne ariadne* was recorded that had sole representation to this area. This species prefers open areas. The lotus Lake area has comparatively more human impact and grazing pressure and the vegetation present includes grasses, shrubs and few trees.

Of the 18 very common species, *Catopsilia pomona, Eurema hecabe, Tirumala limniceae*, *Danaus chrysippus* and *Euploea core* were regularly observed throughout the year at all the three biotopes with flight period of 1-12 (Annexture – VI). According to Kehimkar (2008) *Catopsila pomona* is a common species of garden and city areas. *Eurema spp*. (Grass yellows) had high population observed in all biotopes throughout the year (Kunte, 1997) showing dry and wet season forms due to their polyphagus nature. According to Larsen (1987) this may be one of their evolutionary advantages which make them among commonest butterflies in the world. *Tirumala Limniceae* is also a common species seen in gardens as well as forested tracts upto 2000 m. in Himalay while, *Danus chrysippus* prefers open country but found in forests too and upto 2500 m. in the hills whereas *Euploea cone* occurs in forest to open country.

The seasonal patterns of species richness are influenced by variations in the flight period of different butterflies (Tiple *et al*., 2007). The flight period (Annexure VI) of only 10 species, 5 species mentioned earlier with *Melanitis leda, Junonia lemonias, Cynthia cardui, Psuedozizeeria maha*, *Arhopala amantes* were found to be active in the summer and hence the species richness of butterfly was low in the summer at Toranmal. Some of these are common species *Melanitis leda and Junonia lemonias* with flight period from May to December. *Psuedozizeeria maha* also a common species has flight period from May to July while *Cynthia cardui a* common species of summer and *Ahropala amantes* a very rare species of Toranmal area have flight period from May to July and only May respectively. In summer the non-availability of nectar and larval host plants in the biotope may result in change in the flight period. The importance of resource types (consumer and utility) is indicated in a number of studies in temperate contexts (Dennis *et al*., 2003). Porter *et al.* (1992) reported shifts in nectar flower use with emergence period broods. In the present study, the flight period of maximum species overlapped in the monsoon and post-monsoon which increases the species richness in these seasons.

In the present study, of 51 species of butterflies, maximum were very common and common (72.5 %), (4 %) were frequent, and (23.5 %) rare and very rare (Table 7.4). The very rare species recorded were *Colotis fausta, Tirumala septentrionis, Arhopala amantes and Udaspes folus*. Four species of butterflies recorded in the study come under the protection category of the Indian Wild Life (Protection) Act 1972. These are *Pachliopta hector*, *Hypolimnas misippus, Castalius rosimon* under schedule I and *Hypolimnas misippus* under schedule II. The species recorded which came also comes under schedule IV of the wild life (protection) Act was *Euploea core* as per list given by Gupta and Mondal, (2005).

Family wise density and species richness of butterflies.

In the present study of Toranmal area, of the 5 butterfly families observed Nymphalidae was richest in terms of density as well as species richness. It was found to be dominant family in varied environmental conditions followed by Pieridae (Sreekumar and Balakrishanan, 2001; Raut and Pandharkar, 2010; Hussian *et al*., 2011). The dominance of Nymphalidae is attributed to the polyphagous habit which helps them survive on varied food plants (Sreekumar and Balakrishanan, 2001). The second family in density and species richness was Pieridae. Pierids are sun lovers seen basking in sun with wings partially open and majority of them are seen in open country (Kehimkar, 2008). In the study of Ahir and Parikh (2006) in the Gir protected area, pierids were observed to be the most common family in the dense forest vegetation. The present study in the Toranmal forest, which is forest but with gaps where sunlight can penetrate easily density of Pieridae was good. Lycaenidae is the family representing blues that are known to adapt to varied climate and feed on variety of larval food plants (Kunte, 2001) but their species richness was comparatively low in study area. Although low in species richness, the moderate density of lycaenidae can be attributed to regular presence of some of the species that were very common in the area. Papilionidae had lower species richness compared to other family because they are known to prefer tall trees providing moderate sunlight (Mathews and Anto, 2007). This type of habitat is not present at Toranmal area where major vegetation is composed of shrubs and herbs. At Kalapani, forest is dominated by *Tectona grandis,* which is not favoured by papilionids, known to depend on food plants belonging to Aristolochiaceae, and Rutaceae. Family Hesperiidae was represented by only 2 species hence low density and diversity. Their general flight period is early morning hours at dawn and dusk (Kehimkar, 2008) where as present study was conducted during day time and hence low density and diversity. Family Hesperiidae may be studied in details in future.

In conclusion it can be said that varied subhabitats of Tornamal area at higher elevation in semi arid zone of North Maharashtar supports good diversity of Butterflies which need to be conserved by protecting the vegetation and water resources of the area.