CHAPTER 8.

STUDY OF AVIFAUNA

INTRODUCTION

Ethical, social and economic relation between man and birds exist over ages. Many birds are beneficial as agents of pollination, germination and dispersal of seeds, as pests controlling agents that control insect and rodent pests, as scavengers that clear carcasses, still others offer flesh and eggs for the table while, there are several species that destroy crops in the agricultural field as well as fish ponds by devouring seeds and fishes respectively and spread diseases as well.

More than 9,600 species of birds occur all over the world. Out of these about 2100 species and their subspecies occur in Oriental region (Welty and Baptista, 1988) with about 1200 species recorded in various habitats of Indian subcontinent (Ali and Ripley, 1983). Several avifaunal species have silently vanished before science had even seen them well while over 1200 species across the world (12 percent of the world bird diversity) are currently under the threat of extinction (Rahmani, 2003).

Birds are part of all the habitats of the Indian Subcontinent. Native populations, in particular, are more or less visible all throughout the year while huge populations of migratory species arrive annually in winter. There is an explosion in bird population by the end of monsoon as many native species complete their breeding activities and the new generations join them in exploring the habitats. Simultaneous, the migratory populations start arriving increasing the load on various habitats. The comparatively warmer climatic conditions of India and its neighboring countries host millions of migratory birds. These habitats provide various kinds of food like plankton, molluscs, insects with their caterpillars, as well as seeds and fruits, effectively controlling their large numbers too.

Bird habitats particularly within the lake area seem to be strongly influenced by climatic changes and immediate human impact. When consequent environmental changes exceed the tolerance limit of species, habitat change also becomes an ultimate cause leading to long-term changes in bird distributions.

It is reasonable to expect that with the change in physical structure, environmental conditions change, influencing vegetation structure and plant community composition over the time. As water is a limiting resource for many plants in arid and semiarid regions, the annual change in the rainfall affects the growth and composition of birds which indirectly influence their distribution and abundance (Rotenberry and Wiens, 1980).

Many studies on bird-habitat relationship have been conducted for varied purposes and in many ways. There are several good reviews, conceptual papers and analytical treatises that deal with vertebrates in general (Morrison *et al.,* 1992), habitat selection by birds in particular (Hilden, 1965; James, 1971; Cody, 1985), and bird community structure with strong emphasis on bird habitat relationship (James, 1971; Wiens, 1989). These studies indicate importance of birds as simple, visible, easy to monitor indicators of health of an ecosystem. Wetlands, being ecologically important with high nutritional value and productivity, support good faunal diversity (Gibbs, 1993; Paracuellos, 2006) and thus wide varieties of birds also use wetland habitats either throughout their life or during certain part of their life (Weller, 1981). In addition, amidst the deforestation that continues at a pace around the world (Whitmore, 1997) forests are also equally important habitats for birds. In temperate forests, where most clearance occurred a century ago, species extinction (Pimm and Askins, 1995) has already been documented. In contrast, there are few confirmed extinctions in the continental tropics (Heywood and Stuart, 1992). Large numbers of tropical rainforest species are now listed as threatened because of the destruction of their habitats (Baillie and Groombridge, 1996). Thus, it may be only a matter of time before extinctions occur in this region.

Bird habitat models for conservation and management have traditionally focused on finer spatial scales, but increasingly it is being recognized that habitat use pattern is more sensitive compared to the spatial scale of observations (Morrison *et al*, 1998; Wiens *et al*., 1989). The Landscape structures specially affect intra and inter specific interactions and movement pattern of organisms (Dumming *et al.,* 1992). Landscape structure also influences organisms that can fit their territories in preferred habitat (Capin *et al*., 1998) while forest management influences both stand structure (*e.g*. the abundance and distribution of structures such as living trees, snags and shrubs and

landscape elements such as patches, corridors and matrix) and landscape structure (*e.g*. the composition and configuration of landscape elements such as patches, corridors and matrix) at local scale (Flemming *et al*., 1999).

With this background while studying biodiversity of Toranmal area a study of Avifauna was also considered. Present chapter discusses the bird diversity in Lotus Lake, an aquatic habitat, as well as surrounding forested tracts in Toranmal area to attempt and generate baseline information against which changes can be assessed and monitored in future.

MATERIAL AND METHODS

Study Area

The study was carried out at three habitats in the Toranmal area. They are as follows**:**

1. Lotus Lake Area (LL)

This area is about 900 m AMSL on the Toranmal Plateau. The selected transect started from south-west bank of Lotus Lake downstream towards North-East direction towards origin of Sitakhai stream for 500 Meters with 20 m width on either sides. The vegetation here is mix type with, herbs, shrubs and tall trees. The trees include *Terminalia arjuna, T. belirica, T. chebula, Syzygium heyneanum, Butea monosperma, Mangifera indica, Ficus bengalensis, etc*., while the weeds include *Plectranthus mollis, Tridax procumbens, Lantana camera, etc*. with various grasses. Various emergent and littoral vegetation is present in the Lake while agricultural plots are present on the northwest side of transect.

2. Kalapani area (KP)

The transect length at KP is also 500 m long with 20 m width on either side and located at 21^{o} 51′ 03′′ N latitude, 74^{o} 28′ 06′′ and 822 m AMSL. It is a hilly tract with slope. Transect frequently passes and cuts the Kalapani stream. It is a natural forested area dominated by *Tectona grandis* (Teak). Among the tall trees, gaps are present at few places where shrubs and herbs grow. Cattle grazing were observed in this area. The wild weeds include *Achyranthes aspera, Cassia tora, Vernonia cinerea, etc*.

3. Khadki area (KH)

A transect of 500 m length and 20 m width, located at 21˚ 51’ 04” N and 74˚ 28 07” E and at 824 m AMSL, 10 Km before Toranmal village in a forested hilly area. Natural vegetation here is dry deciduous type mainly with *Tectona grandis* amidst which many herbs, shrubs and grasses are present. The wild weeds include *Achyranthus aspera, Cassia tora, Vernonia cinerea, Tridax procumbens, Andropogon spp. etc.* The ground was moderately covered with leaf litter. Cattle grazing was also observed in this area.

Methodology

These three habitats were visited once in a month from December 2006 to November 2008, in morning hours half an hour after sunrise which is known to be the best time for the observation of birds. It is known that to minimize the variance associated with indices of abundance; census should be conducted at times when there is little change in the conspicuousness of birds (Dawson, 1981). Birds were observed using binocular having the magnification of 8-16 × 40 (Olympus) and identified on the basis of standard books by Ali (1996) and Grimmett *et al*. (1998). The birds were counted using transect method (Rodgers, 1991) having area of two hectares. The densities were calculated as D = n/2w × L, where, n= Total number of birds, w= width and L= Length of transect and converted to hectare. The species richness is the number of species recorded per visit. To make the analysis simpler the birds recorded were categorized into terrestrial and wetland and further resident, resident migratory and migratory species. Abundance of birds is categorized according to Buden (1992) as: Common (10-15 sightings/day), Occasional (5-10 sightings/day), Uncommon (1-5 on most days) and Rare (1-3 per season).

For the statistical analysis, the data for three months was pooled according to the seasons as-Summer- March, April, May; Monsoon- June, July, August; Post-monsoon- September, October, November and Winter- December, January and February. Further, the Mean and Standard Error of Mean (SEM) were calculated for each season and seasonal variations were analyzed using One-way ANOVA as described by Fowler and Cohen with no post test for various parameters using Graph Pad Prism Version 3.00 for windows (Graph Pad Software, San Diego California USA). The correlation between bird density and various biotic and abiotic factors

were carried out using SPSS 7.5 software. The P value for ANOVA is non significant if $P > 0.05$ (ns), Significant if $P < 0.05$ (*), significantly significant (**) if $P < 0.001$ and highly significant (***) if $P < 0.0001$.

RESULTS

Total 127 species of birds belonging to 91 genera and 38 families were recorded during the study period in three different habitats of Toranmal reserve forest (Annexture-VII).

1. Lotus Lake area (LL)

At the Lotus lake area, total 76 species of birds were recorded. Of these 51 species (67.1%) were resident, 6 species (7.9%) resident migratory and 18 species (23.7%) migratory (Table 8.1, Fig. 8.1). When habitat wise groups are considered, 35 species (46%) were associated with wetland and 41 (54%) with terrestrialhabitats (Table 8.1, Fig. 8.2). 35 wetland associated species had presence of 14 migratory, 3 resident migratory and 18 resident birds.

When all the species observed are categorized as per abundance (Annexure-VII) (Table 8.1, Fig. 8.3) 42 species (55.2 %) were Common (C), 24 species (31.6 %) Occasional (O), 05 species (6.6%) Uncommon (U) and 05 species (6.6%) rare (R).

According to feeding guilds, 29 species (38.1%) were carnivores (Cv), 13 (17.1%) Omnivores (Om), 07 (09.2%) Graminivores (Gr.), 21 (27.6%) Insectivores (In), 2 each (2.6%) of Frugivores (Fr) and Scavanger (Sc) and 1 each (1.3%) of Nectarivore (N) and Picivore (P) (Table 8.1, Fig. 8.4).

When seasonal variations are considered (Table 8.2, Fig. 8.5), maximum density of total birds were recorded in winter (239.3 ± 21.54 /2 hectare). Density of total birds declined to minimum in summer (101.7 ± 7.93 /2 hectare), increased in monsoon (142.7 ± 22.27 /2 hectare) and further increased to 216.3 ± 9.64 /2 hectare in post-monsoon ($F_{3\ 20}$ 14.66) However, density of resident birds was maximum in post monsoon (147.5 ± 2.75 /2 hectare) which declined in winter (129.3 ± 9.91 /2 hectare), was minimum in summer (85 ± 2.28 /2 hectare) and increased again in monsoon (122.3 ± 16.16 /2 hectare) ($F_{3\ 20}$ 7.14). Resident birds contributed to density in post monsoon with some resident migratory birds. However, density of resident migratory

birds was maximum (34.67 ± 4.26 /2 hectare) at Lotus Lake during winter which declined significantly in summer (9.67 ± 4.26 /2 hectare) but increased from monsoon (11.57 ± 2.28 /2 hectare) to post monsoon (26.33 ± 2.75 /2 hectare) ($F_{3\ 20}$ 9.65). Density of migratory birds was maximum (76 ± 7.85 /2 hectare) as expected in winter which declined in summer (7 ± 2.75 /2 hectare), as few late migrants were present in early summer, was maintained (8.5 ± 3.90 /2 hectare) in monsoon as early migrants started arriving and increased (42.5 ± 4.32 /2 hectare) in post monsoon ($F_{3\ 20}$ 41.49) as migratory birds started arriving. All the categories of birds showed significant seasonal variations.

Species richness followed same trend (Table 8.2, Fig. 8.6). At Lotus lake area maximum species richness of total birds was recorded in winter (49 ± 1.46), while minimum in summer (29.13 ± 3.51) ($F_{3\ 20}$ 14.54). However, maximum species richness of resident birds was recorded in post monsoon (36.07 ± 1.67) while minimum in summer (25.3 ± 2.15) ($F_{3\ 20}$ 6.84), maximum resident migratory species in winter (4.37 ± 0.21) and minimum in monsoon (1.06± 0.33) ($F_{3\ 20}$ 18.93), and maximum migratory bird richness in winter (11.27 ± 0.73) and minimum in monsoon (1.83 ± 0.55) ($F_{3\ 20}$ 33.43) with significant seasonal variations (Table 8.2, Fig. 8.6).
The Pearson correlations was carried out (Table 8.5) for Lotus Lake birds with environmental parameters like temperature, rainfall, humidity and biotic components like Molluscan density (Chapter 5), Odonate density (Chapter 6) and Butterfly density (Chapter 7). The atmospheric temperature showed negative significant correlation at 0.01 level with all four categories of bird densities and species richness. The rainfall showed significant negative correlation with density and species richness of migratory and species richness of resident migratory birds at the level of 0.05. Humidity was significantly positively correlated only with species richness of resident birds, while it was non-significantly correlated with all other categories.

Among biotic parameters density and species richness of birds did not show any correlation with molluscan density (Chapter 5). However densities of Total birds and resident birds were positively correlated with odonate density of the area (chapter 6) at the level of 0.01 while at level of 0.05 with densities of Resident migratory birds and migratory birds. Similarly, Total birds as well as resident birds were positively correlated at 0.01 with density of butterfly (Chapter 7) while negatively at 0.05 with resident migratory birds and correlation with migratory birds was absent.

2. Kalapani Area (KP)

At the Kalapani area, total 60 species of birds were recorded (Table 8.1). Of these 49 (81.7%) were resident, 2 (3.3%) resident migratory and 9 (15%) migratory (Table 8.1, Fig. 8.1), while 7 species (11.7%) were wetland birds and 53 species (88.3%) terrestrial birds (Table. 8.1 Fig. 8.2).

Further, when categorized according to their abundance (Annexture-VII) in the habitat 46 species (76.66 %) were common (C), 7 (11.7 %) occassional (O), 5 (8.3%) uncommon (U) and 2 (3.3%) rare (R) (Table 8.1, Fig. 8.3).

According to feeding guilds, 14 species (23.3%) were carnivores, 11 (18.3%) Omnivores, 06 (10%) Graminivores, 24 (40%) Insectivores, 3 (5%) Frugivores with 1 each (1.6%) Scavanger and Nectarivore (Table 8.1, Fig. 8.4).

At Kalapani area, maximum density of total birds (Table 8.3, Fig. 8.7) was recorded in the post monsoon (190.3 ± 6.48 /2 hectare), while minimum in summer (65.13 ± 4.71 /2 hectare) ($F_{3\ 20}$ 19.03) with similar trend shown by resident birds with maximum (168.7± 7.63 /2 hectare) in post monsoon and minimum (58 ± 2.79 /2 hectare) ($F_{3\ 20}$ 21.87) in summer. However, the maximum density of resident migratory birds was recorded in the winter (17 ± 3.81 /2 hectare), while lowest in the monsoon (2 ± 2 /2 hectare) ($F_{3\ 20}$ 22.76) and maximum density of migratory birds was also noted in winter (23.4 ± 3.34 /2 hectare), but as expected it was minimum in summer (2.8 ± 0.8 /2 hectare) ($F_{3\ 20}$ 23.23). All the categories of birds showed significant seasonal variations at Kalapani area.

When species richness is considered, maximum species richness (Table 8.3, Fig. 8.8) of total birds were recorded in post-monsoon (41.33 ± 0.26), while minimum in summer (25.17 ± 1.82) ($F_{3\ 20}$ 9.76). Among the three groups maximum species richness of resident birds were recorded in post-monsoon (37.13 ± 0.18), while minimum in summer (22.4 ± 0.9) ($F_{3\ 20}$ 11.37). Resident migratory birds had highest and lowest species richness in winter (1.93 ± 0.13) and monsoon (0.24± 0.11) respectively ($F_{3\ 20}$ 4.6) and migratory birds also had same trend with maximum species richness in winter (4.06 ± 0.37) and minimum in monsoon (0.33 ± 0.21) ($F_{3\ 20}$ 25.85). All categories of bird showed significant seasonal variations in species richness.

The species richness and density of total birds, migratory and resident migratory birds were significantly negatively correlated with AT at the level of 0.05 or 0.01 while density and species richness of Resident birds had no effect of temperature (Table 8.5). The rainfall and humidity showed significant positive correlation with density of resident birds at 0.05 and 0.01 level respectively. Significant negative correlation was established for rainfall and humidity with species richness of migratory birds at the level of 0.01 and 0.05 respectively. Positive correlation at level of 0.01 was established between humidity and species richness of Resident birds.

The density of land molluscs of Kalapani area were non-significantly correlated at all the four categories of bird densities. However, the butterfly and dragonfly density showed significant negative and positive correlation with density of total birds and resident birds at level of .01 respectively.

3. Birds of Khadki Area (Kh)

Of the total 52 species of birds recorded at the Khadki area (Table 8.1) 38 species (73%) were resident, 4 species (7.7%) were resident migratory, while 10 species (19.2%) were migratory (Table 1, Fig. 8.1) with 4 (7.7%) wetland birds and 48 (92.3%) terrestrial birds (Table 1, Fig. 8.2).

With reference to their Abundance (Table 8.1) 31 species (59.6 %) were Common, 12 (23.1 %) Occasional, 06 (11.5%) Uncommon and 03 (5.7%) rare (Table 8.1, Fig. 8.3).

According to the feeding guilds, 9 species (17.3%) were carnivorous, 11 (21.1%) Omnivorous, 10 (19.2%) Graminivorous, 19 (36.5%) Insectivorous, 1 (1.9%) Frugivore and 2 were (3.8%) Scavangers (Table 8.1, Fig. 8.4).

At the Khadki area, maximum density of total birds (Table 8.4, Fig. 8.9) were recorded in the post monsoon (157± 7.04 /2 hectare), while minimum in summer (52± 7.67 /2 hectare) ($F_{3\ 20}$ 15). Maximum resident birds were also recorded in post monsoon (130 ± 7.6 /2 hectare) and minimum in summer (45 ± 6.1 /2 hectare) ($F_{3\ 20}$ 14.28). However, resident migratory and migratory birds were maximum in the winter (12 ± 2.13 /2 hectare, 26 ± 5.68 /2 hectare, $F_{3\ 20}$ 10.2) for Resident migratory and migratory birds and lowest in the summer (3 ± 0.8 /2 hectare, 3.7 ± 0.82 /2 hectare, $F_{3\ 20}$ 9.78). All categories of birds showed significant seasonal variations for density.

Maximum species richness (Table 8.4, Fig. 8.10) of total birds was recorded in winter (34.5 ± 1.85), while minimum in summer (18.47 ± 1.60, $F_{3\ 20}$ 18.01). High species richness of resident birds was maintained at 28.77 ± 0.87, 27.7 ± 0.35 and 25.37 ± 1.35 over major part of the year during monsoon, post monsoon and winter while it was minimum 16.03 ± 0.75 in summer ($F_{3\ 20}$ 42.37). Maximum resident migratory species richness were recorded in winter (2.6 ± 0.20) while minimum in monsoon (0.16± 0.10, $F_{3\ 20}$ 33.49) and for migratory birds in winter (6.53 ± 0.50) and monsoon (0.66 ± 0.4, $F_{3\ 20}$ 27.4). The species richness of birds showed significant seasonal variations.

At Khadki area (Table 8.5), the atmospheric temperature established significant (negative) correlations with density and species richness of all four group of birds except species richness of total resident birds, while rainfall established positive correlation only with species richness of resident birds and negative correlation with species richness of resident migratory and migratory at 0.01. Humidity was positively correlated with density and species richness of resident birds (0.01) and negatively with species richness of resident migratory birds and species richness of migratory birds at the level 0.05. The density of different categories of birds was non-significantly correlated with rainfall. The mollusc, butterfly and odonate diversity was not studied at Khadki area hence no correlation could be established with them.

When comparison between the density and species richness among three sites is made, it was found that maximum density and species richness was observed at Lotus Lake and minimum at Khadki area. Further, of the 127 species observed Oriental white Ibis *Threskiornis melanocephala* is near threatened species, Egyptian Vulture *Neophron percnopterus* is endangered species while Long billed Vulture *Gyps indicus* and Red headed Vulture *Sarcogyps calvus* are critically endangered species as per IUCN (2011).

Table: 8.1 Average percentage (%) of different Categories of birds at Lotus Lake (LL), Kalapani Area (Kp) and Khadki Area (Kh) during December 2006 to November 2008

Different groups of Total Birds according to status	LL	Kp	Kh
Total species observed	76	60	52
Resident	(51) 67.1	(49) 81.7	(38) 73
Resident Migratory	(06) 7.9	(02) 3.3	(04) 7.7
Migratory	(18) 23.7	(09) 15	(10) 19.2
Total according to habitat			
(Wetland Birds)WL	(35) 46	(07) 11.7	(04) 7.7
(Terrestrial Birds)T	(41) 54	(53) 88.3	(48) 92.3
According to Abundance			
Common (C)	(42) 55.2	(46) 76.66	(31) 59.6
Occasional (O)	(24) 31.6	(07) 11.7	(12) 23.1
Uncommon (U)	(5) 6.6	(05) 8.3	(06) 11.5
Rare (R)	(05) 6.6	(02) 3.3	(03) 5.7
According to Feeding guilds			
Carnivorous (Cv)	(29) 38.1	(14) 23.3	(09) 17.3
Omnivorous (Om)	(13) 17.1	(11) 18.3	(11) 21.1
Graminivorous (Gr)	(07) 9.2	(06) 10	(10) 19.2
Insectivorous (In)	(21) 27.6	(24) 40	(19) 36.5
Frugivorous (Fr.)	(02) 2.6	(03) 5	(01) 1.9
Scavanger (Sc)	(02) 2.6	(01) 1.6	(02) 3.8
Nectarivorous (N)	(01) 1.3	(01) 1.6	-
Picivorous (Pi)	(01) 1.3	-	-

Table 8.2 Density (individuals/2 hectare) and species richness (No. of species) of Total and different groups of birds over four seasons at Lotus Lake (LL) during December 2006 to November 2008

	F value	Winter	Summer	Monsoon	Ptmonsoon
Density					
TB	$F_{3\ 20}$, 14.66	239.3 ± 21.54	101.7 ± 7.93	142.7 ± 22.27	216.3 ± 9.64
RB	$F_{3\ 20}$, 7.14	129.3 ± 9.91	85 ± 2.28	122.3 ± 16.16	147.5 ± 2.75
RMB	$F_{3\ 20}$, 9.65	34.67 ± 4.26	9.67 ± 4.26	11.57 ± 2.28	26.33 ± 2.75
MB	$F_{3\ 20}$, 41.49	76 ± 7.85	7 ± 2.75	8.5 ± 3.90	42.5 ± 4.32
Species richness					
TB	$F_{3\ 20}$, 14.54	49 ± 1.46	29.13 ± 3.51	34.5 ± 3.03	46.03 ± 0.84
RB	$F_{3\ 20}$, 6.84	33.63 ± 0.54	25.30 ± 2.15	31.6 ± 2.17	36.07 ± 1.67
RMB	$F_{3\ 20}$, 18.93	4.37 ± 0.21	1.50 ± 0.54	1.06 ± 0.33	2.76 ± 0.15
MB	$F_{3\ 20}$, 33.43	11.27 ± 0.73	2.33 ± 0.95	1.83 ± 0.55	7.13 ± 0.78

Table 8.3 Density (individuals/2 hectare) and species richness (No. of species) of Total and different groups of birds over four seasons at Kalapani Area (Kp) during December 2006 to November 2008

	F value	Winter	Summer	Monsoon	Ptmonsoon
Density					
TB	$F_{3\ 20}$, 19.03	149 ± 12.36	65 ± 4.71	125 ± 18.93	190 ± 6.48
RB	$F_{3\ 20}$, 21.87	109 ± 7.17	58 ± 2.78	118 ± 15.27	168 ± 7.63
RMB	$F_{3\ 20}$, 22.76	17 ± 3.8	4 ± 1.2	2 ± 2	10 ± 0.71
MB	$F_{3\ 20}$, 23.23	23 ± 3.34	2.8 ± 0.8	4 ± 1.79	11 ± 0.51
Species richness					
TB	$F_{3\ 20}$, 9.76	38.87 ± 2.1	25.17 ± 1.82	32.13 ± 3.33	41.33 ± 0.26
RB	$F_{3\ 20}$, 11.37	28.87 ± 1.63	22.4 ± 0.91	31.43 ± 3.05	37.13 ± 0.18
RMB	$F_{3\ 20}$, 4.6	1.9 ± 0.13	0.63 ± 0.53	0.24 ± 0.12	0.96 ± 0.17
MB	$F_{3\ 20}$, 25.85	4.07 ± 0.36	1.13 ± 0.38	0.33 ± 0.21	2.23 ± 0.27

Table 8.4 Density (individuals/2 hectare) and species richness (No. of species) of Total and different groups of birds over four seasons at Khadki Area (Kh) during December 2006 to November 2008

	F value	Winter	Summer	Monsoon	Ptmonsoon
Density					
TB	$F_{3\ 20}$, 15	130 ± 8.09	52 ± 7.67	105 ± 18.88	157 ± 7.04
RB	$F_{3\ 20}$, 14.28	95 ± 2.28	45 ± 6.1	94 ± 16.13	130 ± 6.08
RMB	$F_{3\ 20}$, 9.78	12 ± 2.13	3 ± 0.80	5 ± 1.48	10 ± 0.72
MB	$F_{3\ 20}$, 10.2	26 ± 5.68	3.7 ± 0.82	9 ± 2.29	16 ± 0.34
Species richness					
TB	$F_{3\ 20}$, 18.01	34.5 ± 1.85	18.47 ± 1.60	26.6 ± 2.15	32 ± 0.71
RB	$F_{3\ 20}$, 42.37	25.37 ± 1.35	16.03 ± 0.75	28.77 ± 0.81	27.7 ± 0.35
RMB	$F_{3\ 20}$, 33.49	2.6 ± 0.20	0.66 ± 0.27	0.16 ± 0.1	1.1 ± 0.03
MB	$F_{3\ 20}$, 27.4	6.53 ± 0.50	1.76 ± 0.59	0.66 ± 0.42	2.87 ± 0.40

(TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds)

Table: 8.5 Pearson correlation of Total and different groups of birds with different abiotic factors at Lotus Lake (LL), Kalapani (Kp) and Khadki Area (Kh) during December 2006 to November 2008

Lotus Lake	DTB	DRB	DRMB	DMB	SRTB	SRRB	SRRMB	SRMB
AT	-.825**	-.519**	-.883**	-.918**	-.841**	-.531**	-.951**	-.940**
Rain fall	- ns	+ ns	- ns	- .410*	- ns	+ ns	-.430*	- .454*
Humidity	- ns	+ ns	- ns	- ns	+ ns	+.431*	- ns	- ns
DM	- ns	+ ns	- ns	- ns	-	-	-	-
DBf	.633**	.864**	- .420*	+ ns	-	-	-	-
DOd	.684**	.837**	.515*	.426*	-	-	-	-
Kalapani Area								
AT	- .531*	- ns	- .901**	- .895**	-.590**	- ns	- .857**	- 928**
Rain fall	+ ns	.456*	- ns	- ns	+ ns	+ ns	- ns	- .562**
Humidity	+ ns	.596**	- ns	- ns	+ ns	.520**	- ns	- .497*
DM	+ ns	+ ns	+ ns	+ ns	-	-	-	-
DBf	- .916**	.946**	+ ns	+ ns	-	-	-	-
DOd	- .940**	.986**	+ ns	+ ns	-	-	-	-
Khadki Area								
AT	-.616**	-.462*	-.812**	-.796**	-.811**	- ns	-.942**	-.945**
Rain fall	+ ns	+ ns	- ns	-ns	+ns	.525**	-.528**	-.529**
Humidity	+ ns	.412*	- Ns	-ns	+ns.	.629**	-.481*	-.494*

**** P < 0.01 *P < 0.05; AT**: Atmospheric Temperature, **DTB**: Density of Total Birds, **DRB**: Density of Resident Birds, **DRMB**: Density of Resident Migratory Birds, **DMB**: Density of Migratory Birds, **SRTB**: Species Richness of Total Birds, **SRRB**: Species Richness of Resident Birds, **SRRMB**: Species Richness of Resident Migratory Birds, **SRMB**: Species Richness of Migratory Birds, **DM**: Density of Mollusc, **DBf**: Density of Butterfly, **DOd**: Density of odonates.

Fig. 8.1 Average percentage (%) of different groups of birds at Lotus Lake (LL), Kalapani Area(Kp) and Khadki Area (Kh) during December 2006 to November 2008

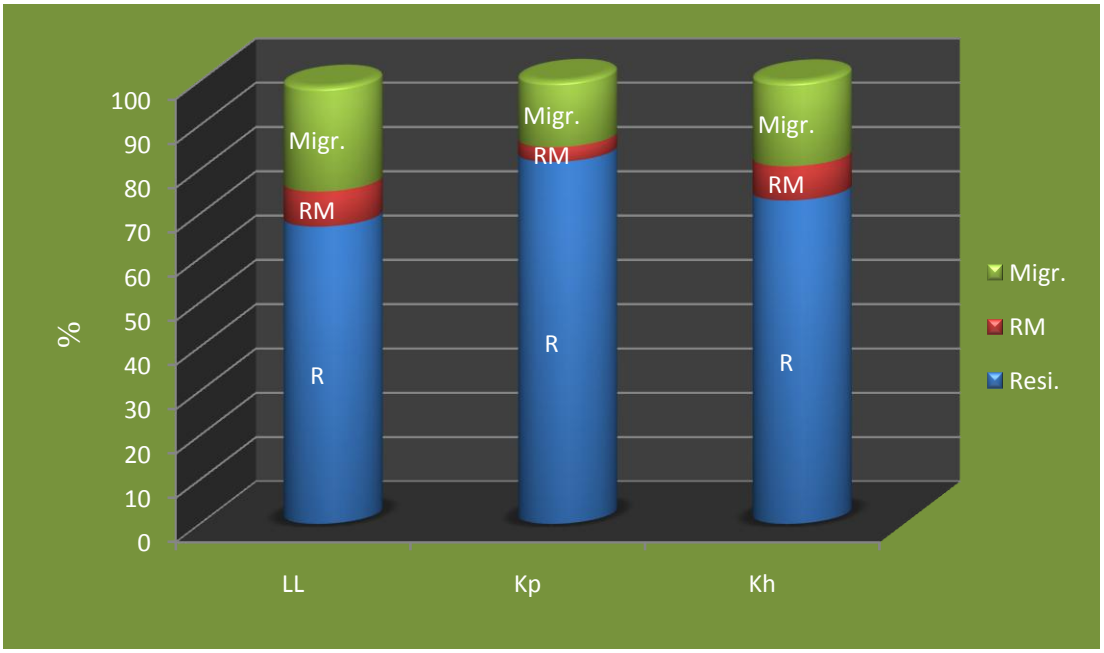


Fig. 8.2 Average percentage (%) of Wetland and Terrestrial birds at Lotus Lake (LL), Kalapani Area (Kp) and Khadki Area (Kh) during December 2006 to November 2008

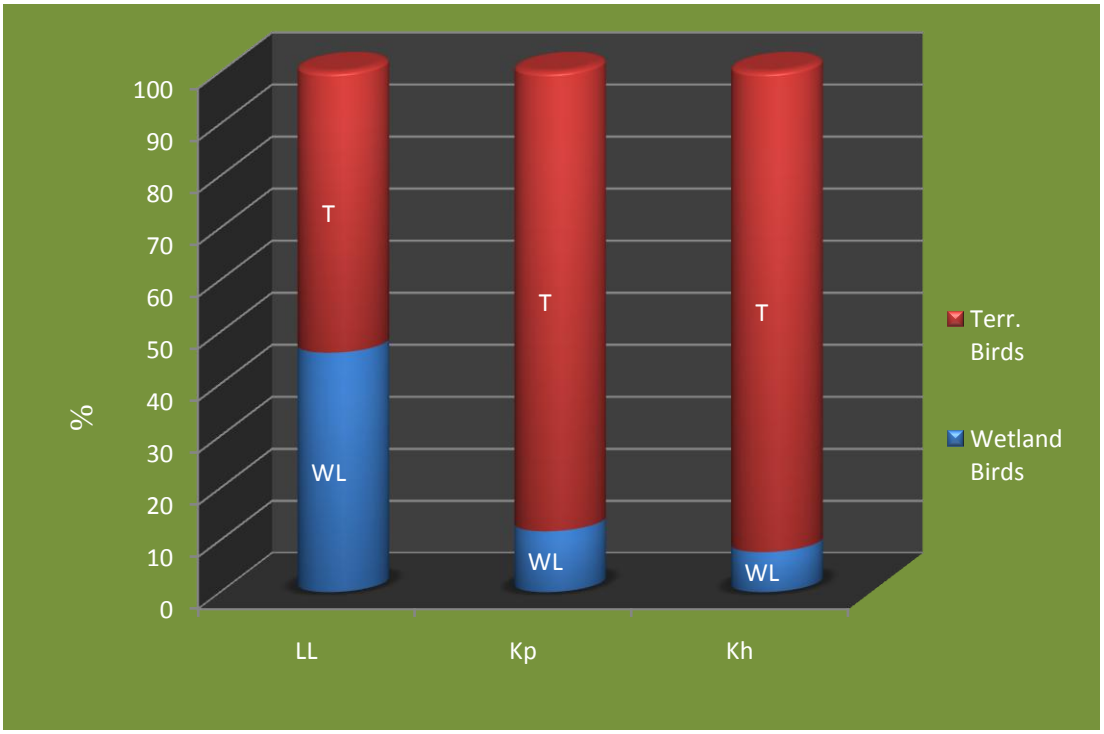


Fig. 8.3 Percentage (%) Abundance of differently rated groups of birds at Lotus Lake (LL), Kalapani Area (Kp) and Khadki Area (Kh) during December 2006 to November 2008

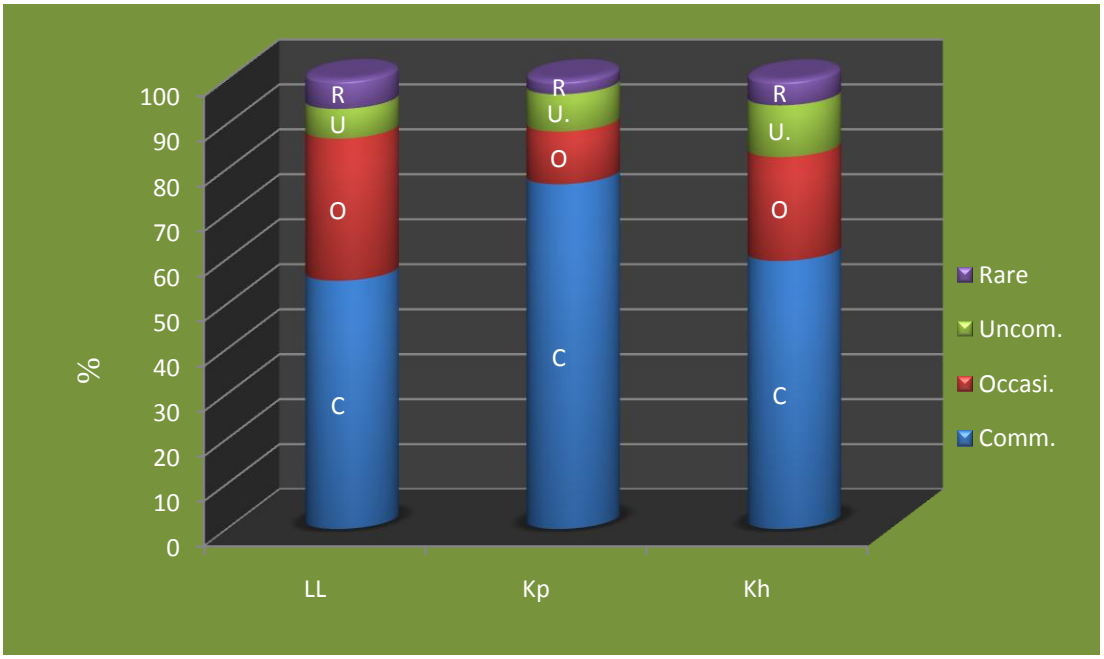


Fig. 8.4 Average Percentage (%) Abundance of differently rated groups of birds at Lotus Lake (LL), Kalapani Area (Kp) and Khadki Area (Kh) during December 2006 to November 2008

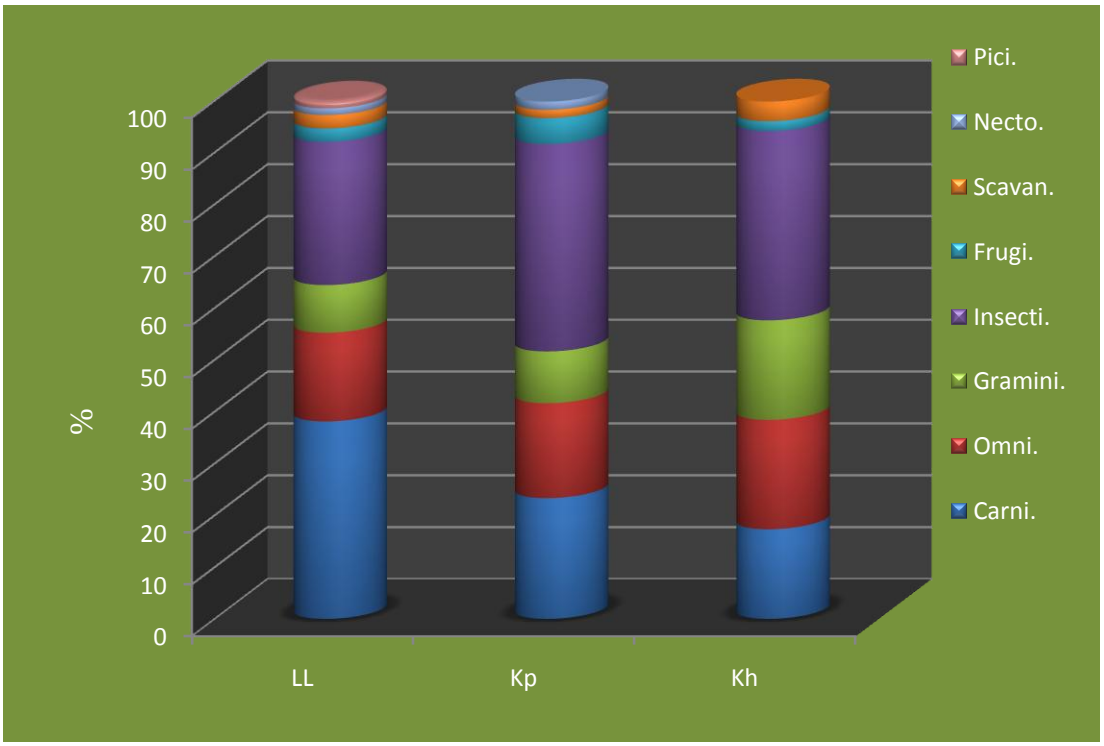


Fig. 8.5 Density of Total different groups of birds (individuals/2 hectare) over four seasons at Lotus Lake (LL) (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds) during December 2006 to November 2008

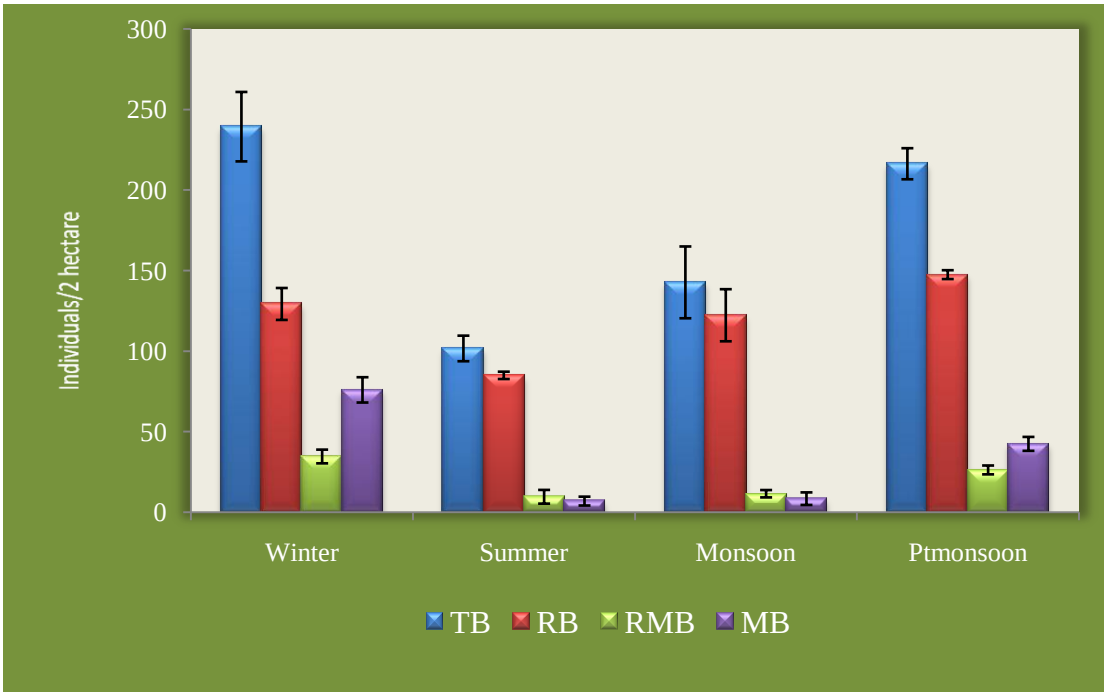


Fig. 8.6 Species richness of Total and different groups of birds (No. of species) over four seasons at Lotus Lake (LL) (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds) during December 2006 to November 2008

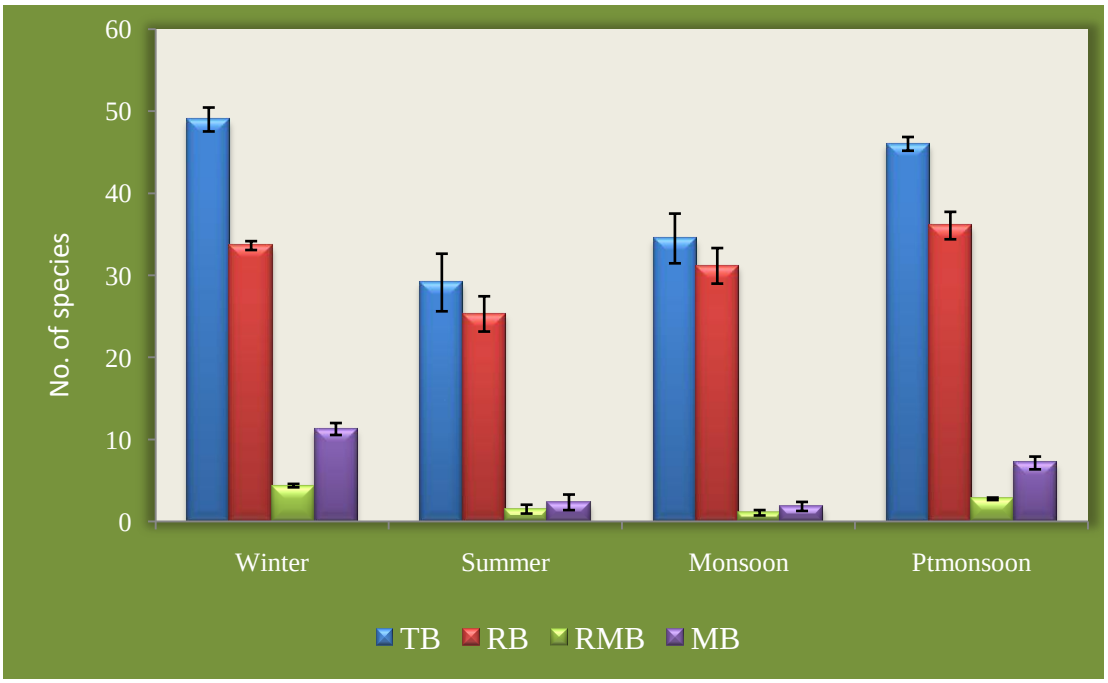


Fig. 8.7 Density of Total and different groups of birds (individuals/2 hectare) over four seasons at Kalapani Area (Kp) (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds) during December 2006 to November 2008

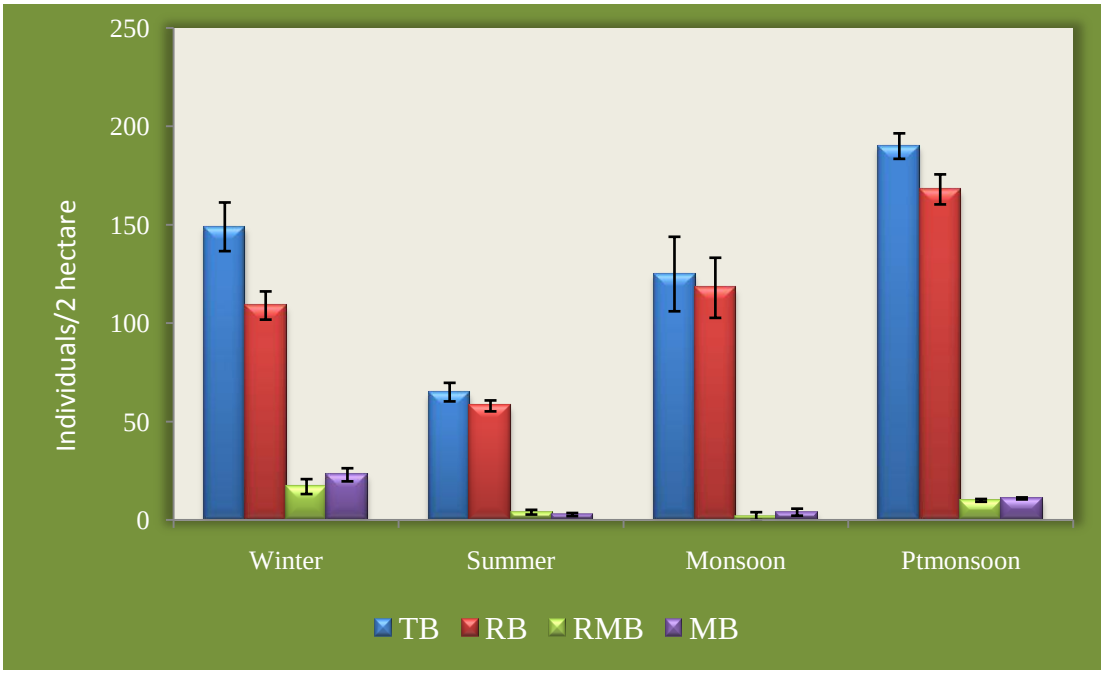


Fig. 8.8 Species richness of Total and different groups of birds (No. of species) over four seasons at Kalapani Area (Kp) (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds) during December 2006 to November 2008

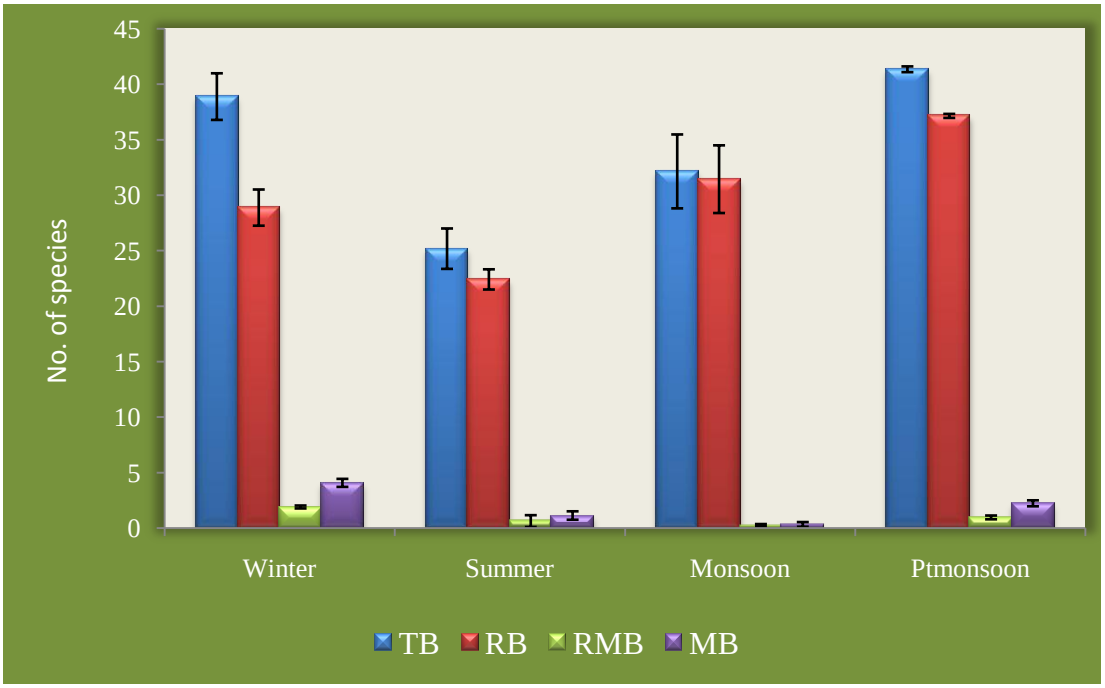


Fig. 8.9 Density of Total and different groups of birds (individuals/2 hectare) over four seasons at Khadki Area (Kh) (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds) during December 2006 to November 2008

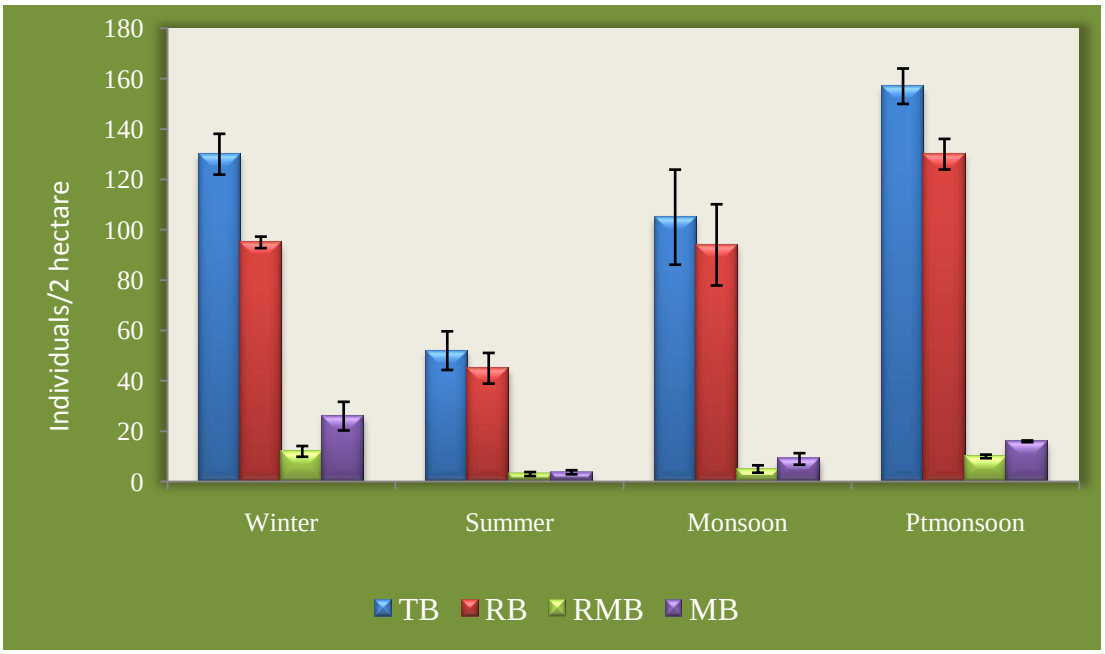
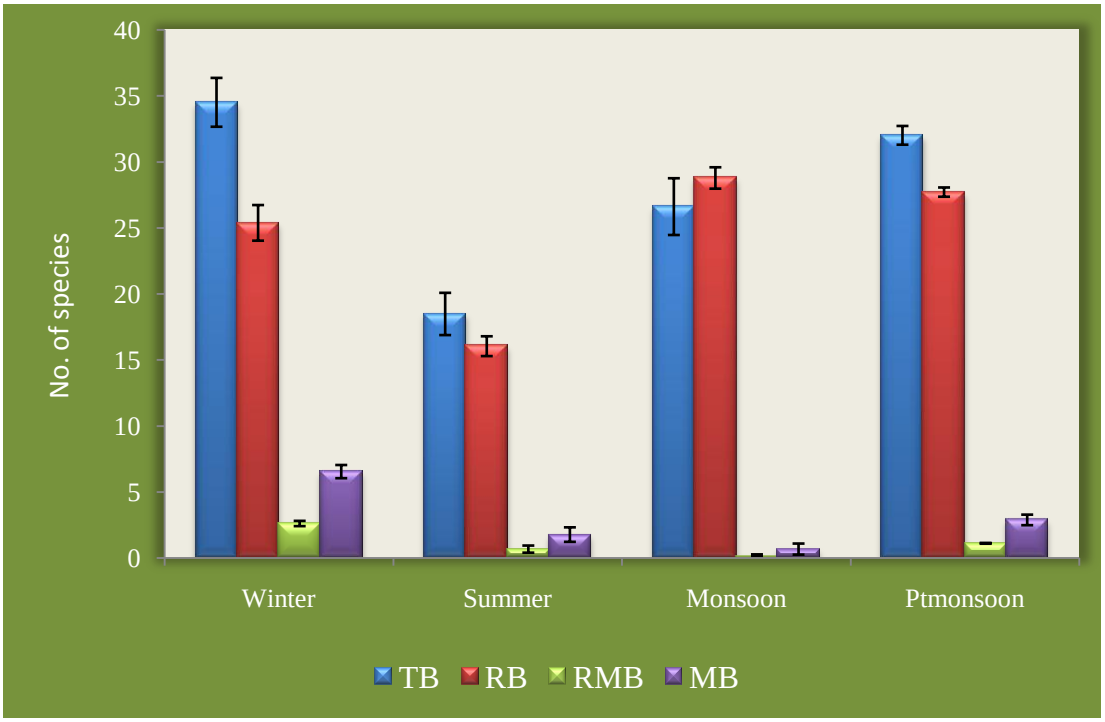


Fig. 8.10 Species richness of Total and different groups of birds (No. of species) over four seasons at Khadki Area (Kh) (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds) during December 2006 to November 2008



DISCUSSION

The idea that conclusive climate is a key factor promoting tropical diversity, goes back to the earliest naturalists Von Humboldt, (1808). Discussion on the effects of energy flow on diversity by Hutchinson (1959) has its roots in the development of the trophic structure of an ecosystem. Being located in the sub tropics where environmental fluctuations are pronounced, the density and species richness of birds (kept at higher trophic levels) at the Toranmal area showed significant seasonal variations (Table 8.2, 8.3, 8.4). Three different forms of recognized energy, the radiation energy (sun), the thermal energy (*e.g*. temperature) and the Gibbs free energy (Chemical energy) contribute to the energy availability in an ecosystem. The seasonal change in the first two can influence the third, influencing the primary productivity which in turn influences the density of species like birds at the end of food web. A mechanism by which there is an increase in diversity is the availability of balanced resources that lead to higher biodiversity. This butters the species against extinction, the risk of which is an inverse and non-linear function of population size (Lande, 1993). This is "the more individuals hypothesis" used by several workers to explain why areas with greater resources support higher diversities (Wright, 1983; Srivastava and Lawton, 1998; Evans *et al*., 2005).

The Toranmal area receives more than 70 % of the annual rainfall in four months (June to September) through the southwest monsoon. This rainfall creates favourable conditions for higher growth and diversity of plants in presence of optimum temperature and humidity in this dry deciduous forest of Toranmal. This vegetation growth in monsoon cannot be directly translated into the higher density and richness of birds as all birds recorded are not herbivores. However, modest increase in density and richness of birds was recorded in monsoon at all the three habitats studied. In present study, the recorded birds utilizing different resources other than plants are insectivores, omnivores and carnivores. But to increase the food resources for these groups, plants, the primary producers, are crucial. The food for these groups increases by post-monsoon. The insect density (butterfly and dragonfly) was positively significantly correlated with the density and richness of birds at Lotus Lake and Kalapani area. The maximum density of total birds at Kalapani and Khadki area were

noted in post-monsoon, while at Lotus Lake density was moderate in post-monsoon and maximum in winter.

The warmer temperature favours more biodiversity. This explanation has its origin in the intuitive feeling that warmer habitats are easier places to make a living than colder ones, a view which has been summarized scientifically by Currie (1991). It may be approached in number of ways including the physiological tolerance hypothesis (Currie *et al*., 2004), the range limitation hypothesis (Evans *et al*., 2005) and the thermoregulatory load hypothesis (Lennon *et al*., 2000). Temperature undoubtedly affects the activity and distribution of many organisms (Turner *et al*., 1987) and also has a powerful influence on energetics (Clarke, 2003). Majority of studies on birds are carried out in temperate Northern hemisphere (Welty and Baptista, 1988). However, in tropics at Toranmal total density and species richness of birds were significantly negatively correlated with atmospheric temperature at 0.01 level at all the three habitats studied. It means that the temperature of Toranmal area may regulate bird density and richness through different mechanisms. The availability of water may increase availability of prey base affecting the ability of birds to exploit their food resources easily. These correlations are generally indirect, mediated through the effects of water availability and temperature on plant diversity (Clarke and Gaston 2006). In case of present study the total density and richness of birds were minimum in summer due to low availability of water (dry soil) which affects the vegetation. Less amount of water in summer in the tropical dry deciduous forest leads to reduction in vegetation the basic resource for herbivores. In a food web this is expected to lower the availability of food resources for the birds at higher trophic levels and thus lower their density and richness. In the previous chapters the density and richness of insects and molluscs (food resource) were lowest in the summer hence it can be concluded that depleted food resources (plant and heterotrophs) in the summer affect the density and richness of birds through trophic cascades.

In the present study, total 127 species of birds were recorded. The local and regional species richness relationship is an empirical relationship between the number of species at the local scale and the number in the region within which each local assemblage occurs, and from which it is presumed to draw its members (He *et al*., 2005). The change in the local scale may reflect the change in the intensity of local

interactions such as competition, the size of the regional species pool and species dispersal abilities (Shurin *et al*., 2000). However, the species richness of local communities are actually composed of two potentially discrete groups of species one of core (or source) species which maintains viable populations at a site because they are well suited to all the local ecological conditions and second of occasional species that periodically explore the site through random colonization events but fail to persist in the system (Magurran and Henderson, 2003; Belmaker, 2009). The present study area, located at 1000 m AMSL may restrict dispersal abilities of certain birds. At Toranmal, this is reflected as 55 to 77 % species were common in the area and only 3 to 7 % were rare. Generally in a habitat number of common species is small while that of rare species is high (Krebs, 1985).

Avifauna and Habitat

The landscape approach for the conservation of forest fragments requires an assessment of the conservation values per se of lands outside conservation reserves that may include habitat fragments, secondary forest, private lands and countrywide habitats such as agricultural plantations (Brown and Lugo, 1990; Daily, 2001). Studies of tropical forest fragmentation are providing increasing evidence that the ability of species to survive in fragments may depend on surrounding habitats and whether the species uses such habitats (Stouffer and Bierregaard, 1995; Renjifo, 2001).

Among avian communities variations in the components of diversity are known to differ between locations and seasons (Kricher, 1972; Rotenberry *et al*., 1979; Bethke and Nudds, 1993). At Toranmal, three different habitats have been studied, where 55% species were common and 31 % occasional at Lotus lake indicating that movements of birds are limited in this area because of suitable environmental conditions prevailing in the area. Here only 6.6 % species each were uncommon and rare. In this wetland habitat, majority of bird species are carnivorous (38.1%) followed by insectivorous (27.6%) which are mainly resident species (67 %) showing limited movement and probably site fidelity. The rare and uncommon species could be the migratory or resident migratory occurring seasonally in the area. Total bird density and species richness in this habitat were maximum during winter (the peak migratory season) and minimum during summer (when the migratory populations of

birds leave the area). The high density in winter is reflected by the increase in presence of migratory and resident migratory birds (Table 8.2). The Lotus Lake area recorded maximum density and richness among all the three habitats studied. It has a forested area, lake and agricultural plots along the northwest boundary of Lake. Greater species richness of plants translates into enhanced structural complexity; allowing a greater diversity of organisms favouring such habitats (Hutchinson, 1959, Lee and Rotenberry, 2005). These structural complexities around Lotus Lake provide different niches to the different bird species.

The density of migratory birds at the Lotus Lake was low as compared to wetlands of semiarid plains (Deshkar, 2008) probably showing altitudinal effect. Only three species of migratory ducks were recorded at Lotus Lake utilizing it as their wintering ground. They were Eurasian Wigeon (*Anas Penelope*), Common teal (*Anas crecca*), Common pochard (*Aythya ferina*). The Eurasian Wigeon and Common Pochard are widespread and require more permanent waters, where they feed seasonally on invertebrates and submergent plant material, while the Common Teal is a graminivore and surface feeder. These ducks were benefited by the resources available at Lotus Lake in the form of macrophytes, submergent as well as emergent vegetation. The other migratory birds include Sandpipers (*Tringa ocropus*, *T. glareola*, *T. hypoleucos*). These are the birds of shallow, open or grassy water, mud flats or sandy shores, feeding on live invertebrates, small fish or amphibians (Weller, 1999). The Lotus lake is a shallow perennial Lake having muddy shore with vegetation which can provide the desired microhabitat for Sandpipers. The Common snipe (*Gallinago gallinago*) and Little stint (*Calidris minuta*) which were also recorded at Lotus Lake show similar type of habit and prefer similar type of habitat.

The terrestrial migratory insectivore birds like Common Swallow (*Hirundo rustica*), White Wagtail (*Motacilla alba*), Grey Wagtail (*Motacilla cinerea*) and Brown Rock Pipit (*Anthus similis*) equally used the microhabitats available at Lotus Lake. The local migratory species recorded in this area were Grey heron (*Ardea cinerea*), Purple Heron (*Andrea purpurea*) and Common Coot (*Fulica atra*). The herons being carnivores feed on various groups of animals found on the western marshy area of Lotus Lake. The common coot is basically herbivore but prefers other food too and forages chiefly among aquatic vegetation as well as in open waters, mainly by diving

(Hansson *et al*., 2010). Though the number of Coot was low they were regular visitor to Lotus Lake arriving by post monsoon and staying up to late winter.

The density and richness of birds in winter were equally contributed by resident birds which were associated with wetland. Many of them were carnivores (Annexture-VII). These birds includes divers such as Little Grebe (*Tachybaptus ruficollis*), Little Cormorant (*Phalacrocorax niger*) and Waders like pond herons (*Ardea grayii*) and Egrets (*Cosmerodius albus* and *Bubulcus ibis*). Little Cormorant (*Phalacrocorax niger*) were recorded with low density at Lotus Lake probably due to the shallowness and smaller size of the Lake which does not provide diving depth. Another group of selective divers the Kingfishers having worldwide distribution (Fry *et al*., 1996) and far more strict in habitat choice and feeding habits than generally appreciated, were represented by three species. Among these Eurasian Kingfisher (*Alcedo athis*) and Stork-billed Kingfisher (*Halcyon capensis*) were occasionally seen while White Throated Kingfisher (*Halcyon smyrnensis*) were commonly seen throughout the year. Though omnivores, they are specialized to feed on fish, but consume large invertebrates and amphibians of various sizes too with prey body size often related to bird body size (Remsen, 1990).

The Frugivore resident birds and graminivore birds are known to be benefited due to edge effect. Neighboring forested tracts can enhance the use of fruiting trees by a wide range of frugivores (Luck and Daily, 2003) while as little as 5% native canopy cover can attract 100% of bird species that use forest edges (Peh *et al*., 2006). The retention of native canopy cover in agricultural areas can promote seed dispersal and pollination activities (Tscharntke *et al*., 2008). Edge effects can penetrate 200 m into tropical forests and effectively reduce the acreage of the primary forest habitat, while the use of less intensive agricultural practices, such as coffee, along the habitat boundaries and in buffer zone can meliorate the environmental characteristics that produce the edge effect (Perfecto *et al*., 2007). However, 3 species of parakeets *Psittacula eupatria, P. krameri* and *P. cyanocephala* and one species of Hornbill were the frugivore observed at Toranmal, but in small numbers. The lower density of parakeets can be the effect of higher altitude.

Some species of Raptors found around Lotus lake were Black Kite (*Milvus migrans*), Brahminy kite (*Haliastur indus*), Egyptian Vulture (*Neophron perchopterus-*

Endangered) and Long Billed Vulture (*Gypus indicus-critically Endangered*) and Red headed Vulture (Sarcogyps calvus – CE) which were rarely seen. Many of these species have declined because of habitat loss and probably through pesticide poisoning (Brown and Amadon, 1968). The presence of three species of vultures needs to be further explored. Other two species Marsh Harrier (*Cirus aeruginosus*) and Osprey (*Pandian haliaetus*) both migratory were occasionally recorded in the habitat near the Lake. Jathar (2004) has recorded presence of Forest Owlet from nearby area of Toranmal Reserved Forest but at Higher altitude near Toranmal village this species was not be spotted over two year study. One more species that is called near threatened species according to IUCN (2011) Oriental white Ibis (*Threskiornis melanocephala)* was also observed in the region but rarely.

Among the three categories of birds according to their status (Resident, Resident migratory and Migratory), for resident species post monsoon was favourable while for the resident migratory and migratory birds winter was the favourable season. Many of the resident migratory and migratory species start arriving at Lotus Lake in the post monsoon with attaining peak by winter and leave by summer when the resources of vegetation dries up due to higher temperature affecting the food chain cascade. However, few common resident birds utilize the habitat in summer too.

Birds of Kalapani Area

77% of species observed at Kalapani were common in the area showing more site fidelity then LL as well as Kh. This can be substantiated with the presence of 82 % resident species and nearly 88% are terrestrial species with 40% of them insectivorous. The structural complexity of habitat with tall trees and streams with understory vegetation at Kalapani area provide various resources and microhabitat mainly to the terrestrial, residential and insectivorous bird populations in this area. Only seven species of wetland birds (at stream) were recorded (Annexure-VII) here. These include Little Egret (*Egretta garzetta*), Cattle Egret (*Bubulcus ibis*), Indian Pond Heron (*Ardeola grayii*), White Throated Kingfisher (*Halcyon smyrnensis*) and Large Pied Wagtail (*Motacilla maderaspatensis*) while uncommonly Brahminy Kite were (*Haliastur indus*) also observed here. All these wetland associated species are carnivorous except Large Pied Wagtail (Insectivore) preferring the rocky streams. These species may be seen feeding at the edge of the stream on various invertebrates

(Arthropods, Worms, Annelids, *etc*.) and vertebrates (frogs, lizards, *etc*.). Among the three major habitats studied, minimum resident migratory and migratory species were observed here.

Kalapani area is preferred by birds of all types as various feeding guilds are present here. At Kalapani 40% insectivores species with 18 % omnivorous are benefitted because of availability of insects. It is known that environments (or study sites) with many guild members meet both the species minimal and resource requirements that can support biological diversity through joint coexistence within a particular functional group (Karr *et al.*, 1990). In Kalapani area many insectivores can co-occur by vertical stratification *i.e*. by distributing themselves in relation to the vertical stratification of foliage (Holmes and Sturges, 1974) from ground to top canopy of trees that can be divisible in to four strata. Here species use the resources at same time either by feeding on the ground cover, (Babblers, Wagtails, Robins, *etc*.) under storied vegetation (Flycatchers), Middle story vegetation (Woodpeckers, Faintail Flycatchers *etc*.) and canopy cover (Cuckoo-Strikes, Minivets, Paradise Flycatchers, Great Tits, *etc*.). This diversity of foraging opportunities reduces the competition among the insectivore species. Arthropods tend to be more numerous in the areas where total annual rainfall is higher as their temporal fluctuations are linked to seasonal rainfall. Arthropod abundance can be closely associated with the activity of ground-feeding species that might explain additional variations in species richness or abundance (Karr and Brown, 1990). However, in response to the drought period, many insects aestivate as nymph, some remains as active adults in reproductive diapauses and others migrate (Wolda, 1977). This depleted food resources limits the bird population in summer and thus lowers the density and richness.

Among the three habitats studied, maximum 11 species of raptors out of total 16 noted, were observed at Kalapani. Of these Black Kite (*M. migrans*) the omnivore and Red-Headed Vulture (*Sacrogyps calvus*) the scavenger (carrion feeders) were rare. More rare species are expected in continuous forests because birds communities in disturbed forests typically consists of species that are relatively abundant and adaptable (Frumhoff, 1995). Rare species are more extinct-prone than common species (Goerck, 1997). The other commonly found raptors were Crested Serpent-Eagle (*Sarcogyps cheela*), Shikra (*Accipiter badius*), White-Eyed Buzzard (*Butastur*

teesa), Common Kestrel (*Falco tinnunculus*) while Bonelli's Eagle (*Hieraaetus fasciatus*) and Booted Eagle (*Hieraaetus pennatus*) were occasionally recorded and Tawny Eagle (*Aquila rapax*) was uncommon species. These Raptors prefer the habitat where the availability of their food such as mammals (Rodents, Bats etc.), chicks and nestlings of other birds, reptiles (snakes and lizards), amphibians (frogs and toads), fish and large insects is high. Most of the bird of prey strictly prefer canopy stratum from where they can detect their prey.

As expected the density and richness of migratory and resident migratory species at Kalapani Area were maximum in winter when they arrive at the wintering ground. 15% of the total birds were migratory and only 3.3% resident migratory. These include maximum insectivore species. They are Pied Crested Cuckoo (*Clamator jacobinus*), Eurasian Tree Pipit (*Anthus trivialis*), Western Crowned Warbler (*Prinia occipitalis*), Red- Throated Flycatcher (*Ficedula parva*), Asian Paradise-Flycatcher (*Terpsiphone paradisi*) and Ashy Drongo (*Dicrurus leucophaeus*). The presence of migratory and resident migratory species indicate that the habitat have the potential enough to sustain increased population load. The density and richness of migratory and resident migratory populations were found to be minimum in summer when they leave the habitat. Minimum density and richness of total and resident birds recorded in summer may be correlated to the lowest resource availability due to higher temperature, low humidity and dry soil in the dry deciduous forest of Kalapani Area. Local processes hypothesized to limit richness include competition for limited resources (Brown, 1981), limited niche space (Mac-Auther,1964; Tilamen, 2004) all of which make it more difficult for species to persist in the area where large number of species already occur.

Khadki Area:

Degradation of tropical forests through selective logging and shifting agriculture is both widespread and continuing yet, despite several decades of research into this problem, the impacts of such disturbance on the diversity of fauna within tropical forests are only poorly understood (Hill and Hammer, 2004). Severe disturbance (*e.g.* clear felling and conversion of forest and grassland) usually reduces diversity (Holloway *et al*, 1992). This was the status of forest at Khadki area too. Though the density and species richness of Khadki Area showed similar seasonal pattern to the

birds of Kalapani Area, with maximum density in post-monsoon and minimum in summer, comparatively lower density and richness were noted here, lowest among the three habitats studied. The Khadki area is characterized by degraded forest with sparse tall trees, few shrubs and gaps covered with herbs and grasses (particularly in monsoon and post monsoon). The physical structure of the habitat has long been reported to be an important factor determining the distribution and abundance of bird species, presumably through its role as a major niche dimension (Roth, 1976). The Khadki area is located on extreme North-West of Toranmal plateau having low capacity due to large changes in vegetation composition effecting growth and hence habitat structure. With changes in the vegetation structure, the distribution and abundance of birds is also expected to change.

Maximum 48 species recorded from this habitat were of terrestrial bird (92.3%) with only four species (7.7%) associated with wetland. These were Cattle Egret, Common Swallow, Yellow Wagtail and Brown Rock Pipit. All these species feed on insects.
Maximum density and species richness of resident species at Khadki area were recorded in post monsoon and minimum in summer. In all the seasons the resident birds formed the major component of the total species recorded. Resident birds utilized this area maximally in post monsoon when density and richness of resident migratory and migratory species were lower which started arriving at end of season and their density and richness reached maximum by winter. Of the 14 migratory and resident migratory species, 9 were insectivore, 3 carnivore (migratory) and 2 graminivores (resident migratory), with maximum abundance in post monsoon and winter when the insect and other invertebrate populations increase, in turn increasing food resources. In the next season *i.e.* in summer these birds leave the area and thus lower the density and richness. The resident migratory and migratory birds are not equally dominant but five species of them were common, five were occasional, three were uncommon and one rare. The birds visiting Khadki area indicate that though it is a degraded forested tract it has some potential to support the diverse bird populations.

Minimum resident species (38) compared to other two habitats were recorded from this area. These resident birds also exhibited preference to different feeding guilds and dominance. In this small area of Toranmal the variation of species richness may be related to degradation of habitat and the instability of species richness. A stability or steady state of the new and reduced species assemblage can only be achieved when

the remaining species are able to reproduce successfully and thus persist in the altered environment over the time (Sodhi, 2002). As, the bird species diversity has been linked to both vertical (Karr and Roth, 1971) and horizontal (Roth, 1976) indices of habitat heterogeneity the Khadki area having sparse tall trees could not offer resources of multistory vegetation affecting the density and richness. Thus more horizontal and lower vertical heterogeneity of this habitat (Khadki Area) supported lower population.

Correlations

The density and species richness of four categories of birds showed seasonal variations at this habitat. Maximum density and species richness of total birds and Resident Birds were recorded in the post-monsoon while minimum in summer (Table 8.2, 8.3 and 8.4). The density of resident birds was significantly positively correlated (Table 8.5) with rainfall which indirectly (positively) influences vegetation in this dry deciduous forest and creates favorable conditions for the birds and other animals leading to higher densities and richness. The mechanisms, the more individuals hypothesis (Shrivastava and Lawton, 1998), prey specialization (Gaston, 1996) and habitat complexity (Lee and Rotenburry, 2005) that allow for greater diversity at higher levels does not exists at Khadki Area.

In summary, the density and species richness of birds at various habitats showed seasonal variations with terrestrial species found during post-monsoon whereas migratory aquatic species in winter. Majority of species observed were resident species probably having limitation for dispersal because of higher altitude cut off from neighboring forests. Either they are core species adapted to the area over centuries or vagrant which have found habitat suitable and established themselves in the area.

In summary, the density and species richness of birds at various habitats of Toranmal area showed seasonal variations with terrestrial species found during postmonsoon whereas migratory aquatic species in winter. Majority of species observed were resident species probably having limitations for dispersal because of higher altitude or cut off from neighboring forests. Either they are core species adapted to the area over centuries or vagrants which have found habitat suitable and established themselves in the area.

GENERAL CONSIDERATION

For a Nation having the status as 6th megabiodiversity region, documenting the identity and geographical distribution of species it supports is perhaps the most important information available in its attempts to preserve and use its biodiversity. This knowledge comes primarily from inventories of various kinds and provides basic information for making day to day decisions for management regarding maintaining balance of natural resources. Government agencies can use such information for protected areas and ownership species distribution and natural vegetation to determine gaps in protected area coverage and to propose new area for protection (Gaston, 1996).

Information from species inventories may be used in biogeographical analysis to understand patterns of diversity, the processes that have produced the Earth's biological variety and present day distributions, and to predict how biodiversity may change with altered environment (Stork and Samways, 1995). Biogeographical information may also assist in discovering the origins of agricultural pests and diseases leading to the identification of their natural predators and parasitoids. Inventories also contribute to the education and training of scientists and therefore help in building up biodiversity science capacity. Moreover, in the long run inventories invariably contribute to educating general public about biodiversity and conservation. Further, taxonomic and functional biotic data may be related to the abiotic data such as climate, weather, water chemistry, pollutants and available nutrients to find out status of a habitat and possible implications due to climate changes.

Biodiversity inventorying is the surveying, sorting, cataloging, quantifying and mapping of entities such as genes, individuals, populations, species, habitats, biotopes, ecosystems and landscapes or their components and the synthesis of the resulting information for the analysis of patterns and processes. Monitoring consists of repeated inventorying over time and space and hence it measures change. However, a number of considerations are important prior to investment in inventorying and monitoring. How well these are considered reflect on the statistical and biological validity, reliability and comparability of the resulting data. In turn, these considerations determine the benefits of the programmes concerned. For example, the

temporal and geographical scale of operation needs to be considered with other components of the sampling design. Particular consideration is to decide which taxa needs to be examined (e.g. Keystone, indicator, threatened, umbrella, flagship, agriculture, medical or commercial species) and at what level (e.g. gene, species, population, ecosystem).

Monitoring of biological diversity aims to develop a strategic framework for predicting the behavior of key variables in order to improve management, increase management options and provide an early warning of system change. Success in monitoring depends on various factors (Castri *et al*., 1992) such as using an appropriate taxon. Various taxa may also provide the information needed to illustrate pertinent changes.

The present study documents biodiversity of Toranmal area, a so far undisturbed area with second highest peak inMaharashtra State. It is located on the Western part of Satpura range in Nandurbar district of North Maharashtra. Toranmal Area includes aquatic and terrestrial ecosystems. To study biodiversity of the area Lotus Lake is consider aquatic fauna. It is a perennial water body in the Toranmal plateau. It forms a major life supporting system in the area. It fulfills the domestic requirement of water of Toranmal village. Hence, it was felt necessary to monitor abiotic and biotic components of this undocumented lake and its surrounding area. The Government of Maharashtra is giving attention to develop Toranmal as a tourist centre. This is expected to increase human interference in future and may create adverse impact on biodiversity due to deterioration and neglecting sustainability. Hence, to generate scientific baseline data the present work was undertaken.

The taxa studied includes plankton of Lotus Lake with its physicochemical parameters, and terrestrial as well as Land molluscs with odonates, butterflies and birds in surrounding area upto 10 kms. from Toranmal Village. These are sensitive to the environmental changes which reflect in their density, species richness and temporal variations.

The data collected over a two year period is divided into 4 seasons and subjected to appropriate statistical methods. The study has collected baseline data for physicochemical parameters of Lotus Lake. Baseline data are fundamental units of basic inventory information that are crucial for biodiversity conservation planning and

management. The physicochemical variable influencing biotic communities were studied using standard methods for sample analysis (*e.g*. APHA for physicochemical analysis).

Biotic and abiotic parameters of an ecosystem are the building blocks that make possible meaningful interpretations about spatial and temporal patterns in the distribution of biodiversity and the degree to which these are determined by natural and human influenced environmental variations (Heywood and Watson, 1995). When properly selected, carefully sampled and appropriately statistically analysed the data can illustrate patterns of biodiversity. Further, the consideration of the physicochemical factors in the study of limnology is basic to the understanding of trophic dynamics of the waterbody. Each factor does play its individual role but at the same time the final effect is the actual result of the interaction of these factors. All the physicochemical variables influence gross primary productivity; however the magnitude of their influence differs significantly (Murugavel *et al*., 2000) the metabolic activities of phytoplanktons- the producers of the ecosystem depend on the physicochemical factors of the aquatic environment (Hulyal *et al*., 2009). The changes in the physicochemical parameters lead to changes in the plankton density, that can lead to the change in diversity of fauna dependent on it. The changes may also start supporting some immigrant species in the lentic zone of the reservoir (Ayoade *et al*., 2009). Hence, considering the overall influence of the physicochemical parameters on shaping the biotic communities of aquatic ecosystem the analysis of physicochemical parameter is carried out. This is discussed in detailed in chapter 3. This has helped in understanding the seasonal changes. Ecological assessment by the way of analysis of all the components of the ecosystem helps in arriving at conclusions. The present study indicates that it is the cumulative influence of the physicochemical parameters which govern the biotic components of the Lotus lake because no single common abiotic parameter could be correlated to biotic parameters studied. The physicochemical parameters are within the permissible limit as per WHO and ISI standards of drinking water.

The following chapters include density and species richness of plankton; both phytoplankton and zooplankton; Molluscs, Odonates, butterflies and birds in various habitats around the Lake in Toranmal area. The species is regarded in many quarters as the fundamental unit of biodiversity while species richness as the fundamental

meaning of biodiversity, and the high level of species extinction as the main manifestation of the biodiversity crisis. Species richness is at best a measure of one aspect of biodiversity that helps in understanding the biodiversity and there is no need to derive complex indices to express it (Gaston, 1996). However, the species richness is not as readily measurable parameter as one might be led to believe. Most discussions center on the relative rather than absolute measures and both are severely complicated by issues of spatial and temporal scales and efforts of recorder.

Plankton at the base of an aquatic ecosystem are important component of an aquatic ecosystem. Among the two types, the phytoplankton- the primary producers shows different patterns of distribution in the wetland. They constitute the basis of nutrient cycle. Being primary producers they play an important role in maintaining equilibrium between organisms and abiotic factors. As discussed in chapter 4a, highest phytoplankton density was recorded in summer, when the water level reduces and the plankton get concentrated while minimum during post-monsoon when the water level was high and plankton get more distributed. Highly significant seasonal variations of total phytoplankton density as well as species richness were recorded over the year. The Lotus Lake is located at higher altitude but in the subtropics which receives maximum photoperiod during summer invigorating growth of the aquatic autotrops. Total 40 species of phytoplankton were recorded out of which 7 belong to Cyanophyceae, 9 to Chlorophyceae, 20 to Bacilariophyceae (Diatoms), and 4 to Euglenophyceae (Annexture-II). Their densities also occurred in similar order.

Chapter 4b discusses density and diversity of zooplankton. Zooplanktons constitute an important link in food chain as grazers (primary and secondary consumers) and serve directly and indirectly as food for fishes and higher organisms. Highly significant seasonal fluctuations were also recorded in the density and species richness of zooplankton. Maximum density and species richness of microcrustaceans (Cladocera and Copepoda) were observed in summer while they were minimum in post-monsoon. The microcrustaceans are known to be more dominating in the lentic conditions. The higher microcrustacean density can be related to the availability of food in the form of phytoplankton, thus reducing the competition. The density of zooplankton is positively correlated with the total density of phytoplankton. The zooplanktons were observed qualitatively and quantitatively in the decreasing sequence of Rotifers, Cladocera and Copepoda.

Total 35 species of zooplankton were recorded at Lotus Lake which were considered into 3 groups Rotifera (20 species), Cladocera (9 species) and Copepoda (6 species) (Annexture- III). The plankton community of this higher altitudinal Lotus Lake of semiarid region of Maharashtra is rich and reflects the status of water body. Though some pollution tolerant genera of plankton were observed at Lotus Lake their number were low so the water body may be considered as unpolluted.

Benthic animals are extremly diverse and are represented by nearly all phyla from protozoans through large macroinvertbrates. In present study representetive of benthic fauna Molluscs are consider (Chapter 5). Molluscs form one of the major part of the macroinvertebrates in wetlands. Many water birds (waterfowl) feed primarily on aquatic invertebrates like mollusc for their calcium requirements.

Molluscan diversity of Toranmal area is considered as aquatic mollusc inhabiting Lakes and Land mollusc inhabiting moist terrestrial tracts along stream. Total 9 species of aquatic molluscs and 5 species of Land mollucs were recorded from Toranmal area (Annexture IV).The density and species richness of aquatic molluscs showed significant seasonal variations. Maximum density and species richness of aquatic molluscs were noted in post-monsoon due to their fruitful breeding performance when the water level stabilizes after South-West monsoon of Indian climatic conditions and minimum in winter. Similarly their minimum density was recorded in winter that may be attributed to their aestivating habit in the cold higher altitude conditions. During post-monsoon water cover is also high favouring the growth of vegetation that can provide shelter for the larvae of molluscs and probably lead to good breeding performance. The moderate temperature of post-monsoon may also favour the performance.

The Land snails (molluscs) are regarded typically as generalist herbivores, frugivores and detritivores (Burch and Pearce, 1990) that exhibit weak levels of intraspecific competition (Barker and Mayhill, 1999). Their local-scale community patterns are less well known, especially in the tropical and sub-tropical environments where densities are often low, leading to acute sampling problems (Cameron and Pokryszko, 2005). Patterns are even more obscured because of sampling problems as many tropical and subtropical forests are oligotrophic and support only very low densities of snails (Cameron *et al*., 2003). Three habitats were selected for sampling of land molluscs. The density and diversity of land molluscs at Toranmal area were weak

which include three species of snails and two species of slugs. Significant seasonal variations were recorded in density and species richness. The three habitats studied showed variations in the richness, density and relative abundance of these species. Maximum density and species richness of land molluscs were recorded at the Yashwant Lake area and minimum at Khadki area. These variations can be attributed to the characteristics of soil, leaf litter distribution and biotic factors such as vegetation cover and anthropogenic pressures such as land use and cattle grazing. Hence, from molluscs conservation point of view, proper management of vegetation cover and land use pattern should be considered.

Next group of fauna studies is Odonates. Destruction of tropical forest is probably the most important threat to global odonate diversity potentially resulting in the extinction of numerous species. Unfortunately these species are often poorly known, making it difficult to say whether a species is genuinely rare or merely overlooked. Examples of data deficiency of odonates are more common from oriental region (Orr, 2004). Hence, more field-work has been proposed to establish the true ranges of these species and to determine area of endemism within larger tropical forest areas. No data on odonate is available from the dry deciduous forest of Toranmal area. The issues on biodiversity and conservation have been instrumental in motivating the present study of odonates. Hence chapter 6 includes density and diversity of odonates of Toranmal area.

To study Odonates of Toranmal Area four biotopes were selected. Line transect method was used to count density and species richness. Odonate fauna of Toranmal area is rich with total 24 species recorded during the present study (Annexure-V). Of the two suborders the suborder Anisoptera (Dragonflies) appeared to be dominant quantitatively as well as qualitatively in four biotopes surveyed. Seventeen species of Anisoptera were recorded from Toranmal area belonging to three families, of which Libellulidae stood as dominant family with 14-species, while among three families of sub-order Zygoptera (Damselflies), family Coenagrionidae appeared dominant with five species.

Next chapter, chapter 7 includes butterfly density and diversity. To study seasonal variations in density and species richness of this group ‘Pollard Walk’ method was adopted. Significant seasonal variations were recorded in the three habitats selected. Maximum density and species richness of butterflies were recorded in post monsoon

while minimum in summer. Though this pattern was evident in all the three habitats studied, the variations in density and species richness were found in all.

The butterfly fauna of Toranmal is rich with total 51 species (Annexture-VI) belonging to 38 genera recorded during the two year study. Qualitatively and quantitatively the families recorded in the decreasing order are the family Nymphalidae the most dominant family with 25 species belonging to 17 genera with average 49 % species richness; 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 %).

For proper functioning of any ecosystem, the main driving component is the primary productivity, which is mainly governed by the southwest monsoon in this subtropical Toranmal Area. From the studies on butterflies it can be said that southwest monsoon determines the density and distribution of plants and other fauna dependent on it at Toranmal. Butterfly being herbivorous the distribution of larval and nectar host plants have a distinct impact on the status of butterflies. The abundant growth of plants in monsoon; after summer decline; favours the developmental stages as well as adults of butterflies leading to increase in their density and richness from monsoon to peak in post monsoon. Toranmal receives negligible rains from North-East monsoon in winter when most of the vegetation starts getting dried. Factors such as scarcity of water, poor nectar availability and dry vegetation result in low butterfly abundance and lower survival ability of most species leading to lowest density and richness in summer.

To study any ecosystem the birds serve as important bio-indicators as they have the ability to fly away and avoid any obnoxious conditions. Hence, they are considered as important health indicators of the ecological condition and productivity of an ecosystem. Bird density and diversity may be affected by cumulative effect of biotic as well as abiotic factors.

To study avifauna of Toranmal area three habitats were selected. Transect method was used to estimate density and species richness of avifauna. Total 127 species of birds belongs to 90 genera and 39 families were recorded during the study (Annexture-VII) in three selected habitats. All the birds observed at Toranmal area were grouped into three categories as resident, resident migratory and migratory. Total bird density and richness were maximum in winter and minimum in summer at

Lotus Lake area, maximum in postmonsoon and minimum in summer at Kalapani area and Khadki area, while the density and richness of resident migratory and migratory birds mainly observed at Lotus Lake were higher in winter and lower in summer. Maximum species of birds were recorded at Lotus Lake area and minimum at Khadki area. The average percentage of three categories of birds showed that all the three habitats were maximally utilized by resident birds followed by migratory and resident migratory birds. As expected wetland associated birds were recorded maximum at the Lotus Lake area while very few were recorded from Kalapani and Khadki area. Most of the species of birds were common (observed more than 50 % times) followed by occasional, uncommon and rare. According to the feeding habits maximum carnivore species were recorded at Lotus Lake area while insectivores from Kalapani and graminivores and omnivore from Khadki area.

A baseline data of biological diversity is useful in providing a basis for the scientific research necessary for understanding the world in which we live (both inside and outside protected areas), to define the current and future options available for meeting human needs and to guide immediate and long term management, policy and decision making. Inventories and monitoring of biodiversity should be carried out in the areas in which the biological diversity is conserved. It is essential for providing information necessary for the sustainable management of natural resources, understanding ecosystem processes so that the ecological services essential for human survival can be maintained. Defining the impact of human activities on biodiversity so as to help reduce undesirable effects on the environment is also important with determining the aesthetic benefits of diversity so as to preserve the quality of human life.

In the present study good numbers of species of various groups of organisms were recorded so it is evident that the Toranmal Forest has good potential to support biodiversity and it is still a balanced habitat. From biodiversity conservation point of view the conservation of habitat is of prime importance and the present study proves that the Lotus Lake and Toranmal Area are still undisturbed habitat to supporting good biodiversity.

Scarcity of water is becoming a serious problem everywhere. At Toranmal plateau also, the Lotus Lake is one of the two perennial water bodies which forms a major life supporting system in the area. This Lake fulfils the domestic requirement of water of

Toranmal village too. In the summer this is one of the water bodies that have the potential to support the wild life. Though the population of the village is very low their washing and bathing activities are carried out on the eastern bank of the Lake. The study indicates that water of Lotus Lake is at present unpolluted but any increase in the human activities around the Lake due to increasing tourism in near future may produce adverse effects on the system if proper steps are not taken in time before it loses its carrying capacity. The forested tracts on Toranmal plateau are showing signs of deforestation. The Forest should be protected so that whatever biodiversity is present can survive for long.

The baseline information so collected in the study of Lotus Lake and Toranmal Area can be utilized for planning the conservation and management strategies of the Lake and the Toranmal Reserve Forest. In the light of information and to understand the Lotus Lake and Toranmal Area as an ecosystem, following studies can be undertaken: Plant diversity in the area, Benthic fauna, soil macro/micro fauna around the lake, fishes of Lotus Lake, Amphibians and reptiles, mammals in the area and regularly monitoring the biodiversity that has been documented.

Summary and Conclusion

Physico-chemical Parameters

The monitoring of quality of surface water with the help of evaluation of hydro biological parameters is an important environmental requisite as it permits direct assessment of the condition of aquatic ecosystems that are exposed to deleterious anthropogenic factors. Various physicochemical factors are known to show significant seasonal variations. During present study of Lotus Lake, water temperature and atmospheric temperature showed a range of fluctuations in accordance to each other as well as the season, with maximum recorded in summer and minimum in winter. The water cover; which depends principally on monsoon in Indian climatic conditions and determines the littoral formation; showed seasonal fluctuations. It was maximum in post monsoon when input of water through streams continues after the rains are over while minimum in summer because of evaporation due to warmer temperature as well as consumption over the year. Similarly, the total solids that comprises of total suspended solids and total dissolved solids, also showed seasonal variations and were maximum in monsoon showing effect of mixing due to rain runoff. As expected, minimum transparency was recorded in monsoon when water runoff along with suspended solids was brought to Lotus Lake disturbing the settled solids. As input slowed down, maximum transparency was achieved by winter. Hence, Lotus Lake at higher altitude in subtropics is showing all the typical characters of the water bodies in the area.

Coming to chemical parameters the pH of Lotus Lake remained alkaline throughout the study period. Maximum Free carbon dioxide was recorded in summer while Dissolved Oxygen in winter as they are known to be inversely related. Total Hardness and Chlorides were maximum in summer and minimum in monsoon exhibiting seasonal effects of evaporation and dilution respectively.

Though the three Nutrients studied (NO_2^-, NO_3^-, PO_4^-) were maximum in monsoon, NO_2^- and PO_4^- were minimum in winter and NO_3 in summer. In monsoon, rain water runoff from the catchment added the nutrients to the Lake. Thus, the physicochemical parameters showed significant seasonal fluctuations due to climatic conditions indicating that it is the cumulative effect of climate which governs the abiotic components of the Lake. Most of the physico-chemical parameters of Lotus Lake are

within the permissible limit as per WHO and ISI standards of drinking water. However, as this high altitude Toranmal area is developing as hill station, the increasing anthropogenic pressure may influence the lake in future, hence with conservation point of view regular monitoring is proposed.

Phytoplankton

Being primary producers, they play an important role in maintaining equilibrium between higher living organisms and abiotic factors. Significant seasonal variations were recorded for the density and species richness of total phytoplankton with maximum density and species richness recorded in summer while minimum in post monsoon. The Lotus Lake, located in subtropics, receives maximum photoperiod during summer that invigorates growth of the phytoplankton. In post monsoon the water cover and water level were higher which distribute the phytoplankton and leads to decrease in their density, while opposing situations occurs in summer leading to increase in density of total phytoplankton. Four groups of phytoplankton studied quantitatively and qualitatively also followed seasonal fluctuations. Their density and species richness in decreasing order were as Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyta with the first being most common and the last least. Further, of the total 41 species of phytoplankton (Annexure II) observed during the study period, seven belonged to Cyanophyceae, nine to Chlorophyceae, twenty one to Bacillariophyceae and four to Euglenophyta.

The Bacillariophyceae appeared to be the most dominant group which was recorded maximum qualitatively as well as quantitatively in summer and minimum in post monsoon. Maximum density and species richness of Cyanophyceae were recorded in winter while minimum in monsoon. Maximum density of Chlorophyceae was recorded in winter while minimum in monsoon. The Euglenophyta density and richness were maximum in post monsoon and minimum in winter. Various abiotic factors were significantly, non-significantly, positively or negatively correlated at the level of 0.05 and 0.01 (two tailed) with the phytoplankton. Hence, it can be concluded that it is the cumulative effect of physico-chemical parameters of Lotus Lake which influences the phytoplankton density and species richness.

Zooplankton

Zooplankton constitutes an important link in food chains as grazers (primary and secondary consumers) of phytoplankton and prey base to higher organisms in the food chain. At Lotus Lake maximum density and species richness of total zooplankton were recorded in summer while minimum in post monsoon. Probably the warm surface water temperature and maximum alkaline pH of the Lotus Lake in summer is preferred by zooplankton that leads to higher density and richness. The highest density of total phytoplankton in summer creates favourable conditions for the herbivorous zooplankton as well. Moreover, during summer the littoral vegetation is exposed creating the best habitat for zooplankton particularly for rotifers which formed the major quantitative and qualitative components (41.7 % and 49.2 % respectively) of total zooplankton at Lotus Lake. The density of total zooplankton was negatively significantly correlated with water cover of the Lotus Lake. This physical factor may be attributed to the maximum density of total zooplankton in summer, when due to higher rate of evapo-transpiration the water cover as well as level decline and the zooplankton get concentrated. Inverse relations ascertain in post monsoon may be attributed to the least density of total zooplankton due to dilution effects. The zooplanktons were recorded qualitatively and quantitatively in the decreasing sequence as Rotifers, Cladocera and Copepoda. The microcrustaceans (Cladocera and Copepoda) are known to be more dominating in the lentic conditions. The higher microcrustaceans density can be related to the availability of food, thus reducing the competition. These conditions in summer favour the microcrustaceans and their increased density and richness in the same season. Thus, temporal variations in abiotic and biotic parameters of Lotus Lake influence the seasonal variations of zooplankton density and richness.

Total 35 species of zooplankton (Annexture III) were recorded at Lotus Lake, of which twenty species belonged to Rotifera, Nine to Cladocera and six to Copepoda. Though some pollution tolerant species were recorded from Lotus Lake their density and richness were low and temporary.

Molluscs

Aquatic and land molluscs of Toranmal area were studied over the two year period. For aquatic molluscs Lotus Lake was consider where three sampling stations LL1,

LL2 and LL3 were selected while to study land molluscs areas surrounding Streams and Lake were selected.

Maximum density and species richness of aquatic molluscs were recorded in post monsoon, while minimum in winter at all the three sampling stations of the Lotus Lake. Maximum density and species richness were recorded at LL-1 and minimum at LL-2 while moderate at LL-3. Total nine species of molluscs were recorded which include seven species of Gastropoda and two species of Bivalvia. These nine species of molluscs showed variation in their relative abundance at the three sampling stations.

Significant seasonal variations were recorded in the density and species richness of molluscs. The seasonality of molluscs may also be correlated with temporal variations of abiotic and biotic parameters that produce cumulative effects. The biotic factors also influence the molluscs directly by providing different architecture and periphyton substrate which are essential for various activities of molluscs. Further, the molluscan community of the Lake is also influenced by predators such as waterfowl. Molluscs occur primarily in the shallow near shore areas of the Lake hence are also particularly vulnerable to disturbance causing changes in these microhabitat due to human activities.

To study land molluscs, three different habitats were selected. The molluscs observed in these areas include three species of snails and two species of slugs. Significant seasonal variations were recorded in their density and species richness. Maximum density and species richness of Land molluscs were recorded in monsoon, while minimum in summer. The influence of abiotic factors such as rainfall, humidity and temperature, were noted variously. The rainfall and humidity were significantly positively correlated with the density and species richness of Land molluscs while atmospheric temperature was non-significantly correlated with the same.

The three habitats studied showed variations in richness, density and relative abundance of species. Maximum density and species richness of land molluscs were recorded at the Yashwant Lake area and minimum at Khadki area. These variations can be attributed to weather, characteristic of soil, leaf litter distribution and biotic factors such as vegetation cover and anthropogenic pressures such as land use and

cattle grazing. Hence, from molluscs' conservation point of view, proper management of vegetation cover and land use pattern may be considered.

Odonata

To study Odonates of Toranmal Area four habitats were selected. Odonate fauna of Toranmal area is rich with total 24 species recorded during the present study (Annexure V). Of the two suborders, the suborder Anisopte (Dragonflies) appeared to be dominant quantitatively (68.4%) as well as qualitatively (68.2%) over suborder Zygoptera (Damselflies) in all four biotopes studied. The seventeen species of Anisoptera recorded from Toranmal area belonged to three families, of which Libellulidae was dominant with 14 species, while among Zygoptera family Coenagrionidae appeared dominant with five species.

Seasonality is a common phenomenon in insect populations. In the present study of Odonate at Toranmal area also significant seasonal variations in density and species richness were noted at all the four habitats studied. Odonate density and richness increased from beginning of monsoon till the early winter and declined from late winter up to the end of summer. Rainfall pattern is the most important factor affecting the seasonality of tropical insects. In present study also rainfall and humidity were correlated with Odonate density and richness. The rainfall governs the predaceous Odonate through the food chain. As the Odonates are predaceous and mostly prey on herbivore insects which depend on plants that are regulated by the rainfall, odonate density was also governed by rainfall. Thus, maximum availability of prey in monsoon and post-monsoon at Toranmal may be attributed to lead to increase in Odonate density and species richness. However, at Toranmal the summer is dry and hot (minimum humidity and maximum temperature) with a severe drought like conditions that limit growth of majority of plants in the dry deciduous forest. Summer maxima has a predictably adverse effect on prey on which Odonates feed. Thus, indirectly the higher temperature in summer led to decreased density and species richness of total Odonates. The variations in community composition of Odonates at various habitats were also recorded which may be attributed to the habitat heterogeneity particularly associated with vegetation (riparian forest in lotic habitats and littoral aquatic vegetation in lentic habitats). The vegetation provides an important

biotic structure for several key activities (foraging, roosting/sheltering, predator avoidance, oviposition, *etc*.) in the life history of Odonates.

Butterflies

To study seasonal variations in density and species richness of butterflies, 'Pollard Walk' method was adopted. Maximum density and species richness of butterflies were recorded in post monsoon, while minimum in summer. Though this pattern was evident in all the three habitats studied, the significant seasonal variations in the density and species richness of butterflies were found in all the three habitats.

The butterfly fauna of Toranmal is rich with total 51 species (Annexure VI) belonging to 38 genera and 5 families recorded over the two year study. Qualitatively and quantitatively the families recorded in the decreasing order are the family Nymphalidae the most dominant family with 25 species belonging to 17 genera and averaging 49 % of species richness; 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 %).

As said earlier seasonality is a common phenomenon in insect populations. Seasonality of butterfly density and species richness in present study were influenced by humidity which is consistent with earlier work showing that these factors have a strong influence on the distribution and abundance of butterflies. The humidity and rainfall were positively significantly and atmospheric temperature was non-significantly negatively correlated with the total density of butterflies.

For proper functioning of any ecosystem, the main driving component is the primary productivity, which is mainly governed by the southwest monsoon in the subtropical Toranmal Area. Thus, southwest monsoon determines the density and distribution of plants and other fauna dependent on it. Butterfly being herbivorous the distribution of larval and nectar host plants have a distinct impact on the status of butterflies. The abundant growth of plants; after summer decline; favours the developmental stages of butterflies as well as adults leading to increase in their density and richness from monsoon to peak in post monsoon. Toranmal receives negligible rains from North East monsoon in winter when most of the vegetation starts drying up. 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 lowest density and richness in summer.

Avifauna

While studying biodiversity of Toranmal area a study of Avifauna was also considered. To study avifauna of Toranmal area three habitats were selected. Transect method were used to estimate density and species richness of avifauna. Total 127 species (AnnexureVII) of birds belonging to 91 genera and 38 families were recorded during the study period in three habitats of Toranmal Reserve forest. Total birds of Toranmal area were grouped into three categories such as resident, resident migratory and migratory. Total birds density and richness were maximum in winter and minimum in summer at Lotus Lake area, while maximum in post-monsoon and minimum in summer at Kalapani and Khadki areas. The density and richness of resident migratory and migratory birds were higher in winter and lower in summer. Maximum species of birds were recorded at Lotus Lake area and minimum at Khadki area. Average percentage of different categories of birds showed that all the three habitats were maximally utilized by resident birds followed by migratory and resident migratory birds. Wetland associated birds were maximum at the Lotus Lake area while very few at Kalapani and Khadki areas. When abundance of a species in area is considered, most of the species of birds were common (more than 50 %) followed by occasional, uncommon and rare. According to the feeding habits maximum carnivore species were recorded at Lotus Lake area while insectivores from Kalapani and graminivores and omnivore from Khadki area.

The density and species richness showed significant seasonal variations that may be attributed to the availability of energy (resources) into the ecosystem. The major resource in the forest ecosystem is the vegetation which is regulated by rainfall. The maximum rainfall received in monsoon causes growth of the herbivore supporting vegetation. This increase in food resource (vegetation and herbivores) at Toranmal area may lead to increased density and species richness at higher trophic levels like birds. At the Lotus Lake area, maximum density and richness noted in winter due to the presence of migratory waterfowl supported by the Lake and terrestrial birds supported by the forest. Higher temperature and absence of rains in summer have adverse effect on the vegetation which leads to reduced density and richness of birds

through food chain cascade. Apart from the general influence of abiotic factors the habitat heterogeneity is more determining factor for density and richness of birds at local level. For example, the lotus lake area is more heterogeneous having aquatic habitat, forest and agricultural plots. This heterogeneity provides various resources and niches, with the benefit of edge effect it has higher density and richness compared to Kalapani and Khadki areas.

While concluding it can be said that the Toranmal area is having rich ecosystem with various microhabitats that support good diversity and density of fauna. As the baseline information all together 397 species of plants, plankton, invertebrates and birds could be listed in the area. There are all possibilities of missing out some species in all the groups studied. However, as this area is developing very fast as a higher altitude ecotourism centre in North Maharashtra, the management should consider protecting the flora and fauna of the area to prevent degradation of habitat due to anthropogenic pressures.

Future plan

The present work may be continued in future for study of fishes, amphibians, reptiles and mammals of the area with study of nocturnal species of insects like moths, other groups of insects like spiders, ants and also benthic fauna of lake along with soil characteristics.