# CHAPTER 6

# STUDY OF AVIFAUNA

## INTRODUCTION

The sublime imprints of birds in Indian culture are since Vedic time. Melodies of their songs, majesty of their flight and magic of their colours, have symbolized the infinite spirit of happiness and freedom since ancient times. Our nobel tradition has taught us to accept birds with humility as part of our life. More than 9,600 species of birds occur all over the world, out of these about 2100 species and their subspecies occur in Indian subcontinent (Welty and Baptista, 1988) and about 1200 species are recorded in various habitats of India (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 population) are currently under the threat of extinction (Rahmani, 2003).

Several species of birds inhabit wetlands, one of the most diverse ecosystem in the world. Wetlands are unique habitats that support huge biotic communities involving diverse plants and animals that are adapted to shallow and often dynamic water regimes and form second most productive ecosystem next to tropical forests. Birds form an important component of this biota that depend on vegetation structure (Lack, 1933). The present study focuses on one such system as habitats for birds, viewing it as provider of various resources for their survival and reproduction. According to many ecologists, birds are one of the most visible indicators of the total productivity of such biotic systems. 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 (Hilden, 1965; James, 1971; Cody, 1985), and bird community structure with strong emphasis on 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 are among the richest ecosystems-a hydrobiological system with its interacting physical, chemical and biological components and forming a functional and self-sustaining entity. In a wetland, multiple of sub-habitats or microhabitats are available in a small area which attracts different species or groups of water fowls. The term Water fowl is used commonly for all the aquatic birds of wild species which are ecologically dependent on water. Campbell and Lack (1985) called Anatidae-ducks as water fowl whereas according to the Ramsar convention (Anonymous, 1971) the water fowls are birds belonging to the families Gaviiformes, Podicipediformes, Pelcaniformes, Ciconiiformes, Anseriformes, Gruiformes, Ralliformes and Charadriiformes. As per the definition of the Ramsar Convention, 273 species of waterfowls (Ali and Ripley, 1983) occur in India. The Asian Wetland Bureau's water fowl counts show more than 60 % to be anatids and associated species as water fowls (Bhupathy, 1991). In present study, all the aquatic birds of wild species which are ecologically dependent on water are taken into consideration.

Water and vegetation are the two major factors influencing the abundance of the resident ducks and other water fowls (Chabreck, 1979; Duncan *et al.,* 1982; Vijayan, 1986; Sridharan, 1989; Bhupathy, 1991; Vijayan, 1991). Being ecologically important with high nutritional value and productivity, wetlands support good diversity of birds (Gibbs, 1993; Paracuellos, 2006) and thus wide varieties of birds use wetland habitat either throughout their life or during certain part of their life (Weller, 1981). The microhabitats available in wetland can supply a variety of different food sources which include microscopic plankton to higher plants and animals, influencing the density of water fowls. They in turn form valuable resources utilized economically by men in most parts of the world for food (mainly anatids), and sport (hunting). Wetlands are also aesthetically important as an attraction for the bird watchers, nature lovers and photographers. Many wetlands are identified as Internationally Important Wetlands (Ramsar sites) for water fowl conservation. Management of these wetlands and other wetlands are critical for conservation of nature and natural resources. Since the resident water fowl spend most part of their life, including

breeding, in the wetland, their conservation is given priority in the management of wetlands (Vijayan, 1995). For conservation a habitat needs to be surveyed for its biotic and abiotic components. In the world of scarcity, it is not enough to decry the continual erosion of the earth's biotic niches.

Not withstanding the breadth of the concept of biodiversity, the number of species retained in an ecosystem is most frequently and widely applied measure for assessment of a habitat. According to Gaston, (1996), there are several possible reasons of differing levels of contention and empirical support to the biodiversity. First, the concept of species richness is considered by many workers to capture much of the essence of biodiversity. Second, when the meaning of species richness is widely understood, there is no need to derive complex indices to express it. Third, in practice, species richness is often considered to be a measurable parameter. Fourth, though, species richness of many areas is yet to be documented substantial data already exist.

In addition to species richness, the parameters such as relative density and diversity of bird population are frequently used as indicators of habitat quality (Nilsson and Nilsson, 1978; Weller, 1978; Sampath and Krishnamoorthy, 1990; Nagrajan and Thiyagesan, 1996). International Convention on Biodiversity through National Biodiversity Board and State Biodiversity Board puts emphasis on documenting all the biodiversity upto village level. The present study is an attempt to document one part of it, the avifaunal diversity of Yashwant Lake.

As reviewed by Deshkar (2008), the conservation of water birds is a century old concept wherein the man realized the importance of these species. This is evident by establishment of several National and International level organization, starting from Royal Society for Protection of Birds (RSPB) in United Kingdom followed by the Bird Life International, International Council for Bird Preservation (ICBP), International Wildfowl Research Bureau (IWRB) also known as (Wetland International), World Wide Fund for Nature (WWF) and many others. Eventually all these have taken lead in the declaration of

series of conservation acts and finally the master piece, the Ramsar Convention. Ramsar Convention is the first Modern Global Environment Treaty passed during the conference held in the Caspian Coastal town of Ramsar, Iran, in early 1971. However, in India as early as third century B.C. King Ashoka gave importance to preservation of wildlife and environment (Panjawani, 1994).

As one of the method for conservation of waterfowls, the international counts of water birds were initiated more than two decades ago which has been a key activity of Wetland International, in the form of mid-winter waterfowl Census. This has proved to be the most important information not only of scientific value but also of strategic importance for conservation of wetlands (Boere *et al.*, 2006). In most parts of the world the wetlands were often treated as waste land and were considered useless and unhealthy, dismal places that were hindrance to economic development (Patterson, 1994; Boyer and Polasky, 2004). However, with the awareness for the conservation of wetlands and water birds along with the natural water bodies, the man made wetlands are also given due importance. This led to partially offset loss and degradation of natural wetlands (Belanger and Couture, 1988).

The species occurring in an area are not all of an equivalent status. In particular, many may be present for rather a brief period, may not breed or may not have self sustaining populations in the area. Such species have variously been termed accidentals, casuals, immigrants, incidentals, strays, tourists, transients, vagrants, *etc.* (Gaston, 1996). Altogether they serve to inflate species numbers in an area, constituting what is known as a 'mass-effect (Shmida and Wilson, 1985). Whether it is desirable to include them in measuring the species richness of an area is debatable. In present study, all the water fowl species as well as terrestrial birds observed at Yashwant Lake are included. The species richness, diversity indices like Shannon Wiener and Evenness and density for all the birds observed were evaluated for 2 years. An attempt is made to evaluate the role of Yashwant Lake as an important habitat

with respect to the birds at higher altitude in Eastern Satpura. No scientific record for biodiversity of Yashwant Lake exists. The present work denotes the diversity and species richness (*i.e.* number of individual species found in unit area) of birds and discusses their relation to other elements of diversity found in Yashwant Lake, a high altitude Lake in mid Satpura range of North-West Maharashtra.

## MATERIALS AND METHODS

To study the avifauna of Yashwant Lake, biweekly observations were conducted (monthly average is taken for calculation) from December 2006 to November 2008. During each visit the census of birds was carried out during 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). Simultaneously, the water level and the hydrological conditions were also noted down. To count the waterfowl, the total count method is used. This method provides an overall estimate of the population in the pond and is proved to be the most appropriate method for the estimation of density and diversity of water birds (Rodgers, 1991; Javed and Kaul, 2002; Paracuellos, 2006).

Being a smaller wetland the visibility of birds up to the opposite bank is clear hence the total area is considered for calculation of density. A direct count was carried out with the help of binoculars having the magnification of 8-16 × 40 (Olympus). The birds were identified on the basis of field guide by Grimmett *et al.* (2001).

The Density, species richness, diversity indices *i.e.* Shannon Wiener Index (H') and Equitability (E) of water birds were calculated for each visit. The birds observed in the pond as well as those observed to move in and out of pond to the agricultural fields and terrestrial birds seen in surrounding area upto 50 meter distance were also counted. To make the analysis simpler the birds observed were categorized into terrestrial and aquatic as well as Resident, Resident migratory and Migratory birds. The density is calculated as per $Km^2$ (Rodgers, 1991) and total number of species observed per visit is considered as species richness. To estimate diversity, Shannon Wiener Diversity Index is calculated as $H' = - \sum pi \ln pi$ ( for maximum number of birds) where pi is total sample belonging to the $i^{th}$ proportion of species, calculated as proportion of

the total number of individuals of all the species and (ln) is the natural log. Evenness /equitability is calculated as $E = H'/H_{max}$ where $H_{max}$ is information content of sample (individual birds) = index of species diversity (Krebs, 1985; Javed and Kaul, 2002).

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, Standard Error of Mean (SEM) were calculated for each season and analyzed further using One-way ANOVA as described by Flowler 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 (Detail in chapter 4 and 5) and abiotic factors (Details in chapter 3) 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

During the present study, 58 species of birds were observed at Yashwant Lake from December 2006 to November 2008 (Annexture- III). The variations in the bird density and the species richness are noted according to the seasonal changes.

## DENSITY OF BIRDS

### *Total Birds*

Maximum total density of birds (Table 6.1, Fig.6.1) was observed in winter (530.8 ± 17.6 /Sq.Km.) and minimum in monsoon (172.3 ± 11 / Sq.Km). The density of birds in summer was 295.3 ± 34.4 /Sq.Km. and in post-monsoon 374.3 ± 32.29 /Sq.Km. Highly significant seasonal variations in total density of birds were noted ($F_{3,20}$ 33.92, $P < 0.0001$). When Resident, Resident migratory and migratory birds are considered following results are obtained.

### *Resident Birds*

The density of resident birds was maximum during winter (272.4 ± 6 /Sq.Km) and minimum during monsoon (120.3 ± 7.9 /Sq.Km.) while it was 189.7 ± 14.2./Sq.Km. and 221.6 ± 15.3 /Sq.Km. in summer and post-monsoon respectively (Table 6.1, Fig.6.1). The seasonal variations in total density of resident species were highly significant ($F_{3,20}$ 30.2, $P < 0.0001$.)

### *Resident Migratory Birds*

The total density of resident migratory birds (Table 6.1, Fig.6.1) varied significantly over the seasons with maximum 177.1 ± 5.2 /Sq.Km during winter and minimum 48.9 ± 3 /Sq.Km. during monsoon 94.2 ± 16.7 /Sq.Km. in summer and 104 ± 11.5 /Sq.Km in post-monsoon ($F_{3,20}$ 25.02, $P < 0.0001$.)

### *Migratory Birds*

The density of migratory birds was maximum during winter (81.6 ± 8.9 /Sq.Km) and minimum during monsoon (3.4 ± 0.9 /Sq.Km.) while it was 11.9 ± 4.2 /Sq.Km. and 48.5 ± 7.7 /Sq.Km. in summer and post-monsoon

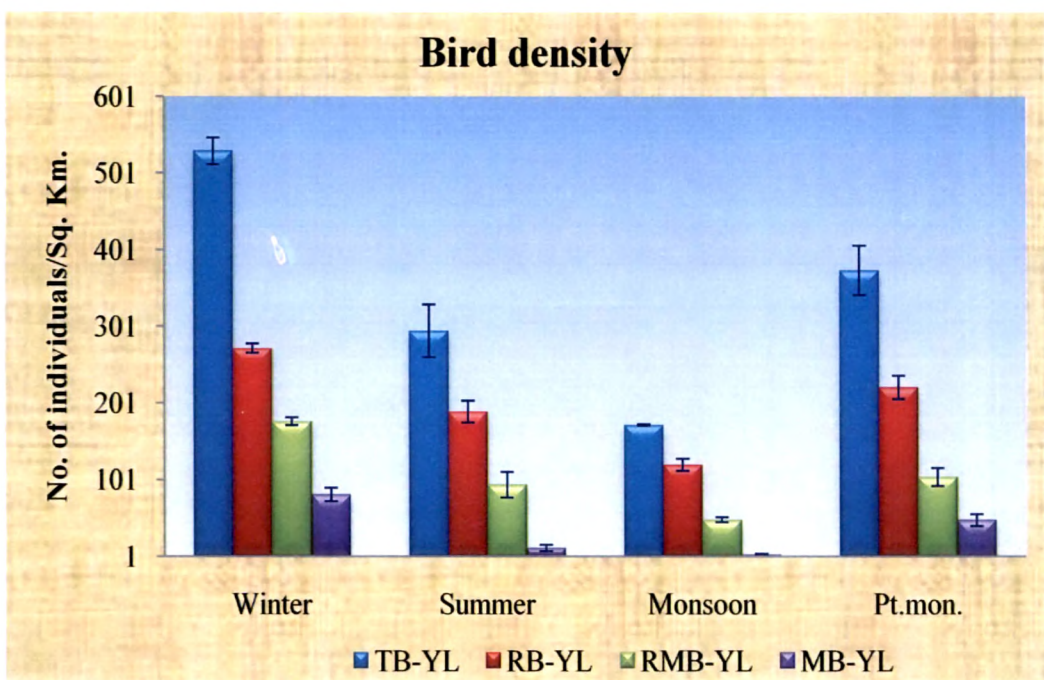
respectively (Table 6.1, Fig.6.1). The seasonal variations were significantly significant with ($F_{3,20}$ 32.66, $P < 0.0001$).

Maximum density of birds for all the three groups were observed during winter which declined through summer to monsoon and started increasing again from post-monsoon.

**Table: 6.1 Density of different groups of birds (individuals/Sq.Km.) over four seasons at Yashwant Lake (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds and YSL-Yashwant Lake) during December 2006 to November 2008**

| Density | Winter | Summer | Monsoon | Ptmonsoon |
|---|---|---|---|---|
| TB-YSL | 530.8 ± 17.6 | 295.3 ± 34.4 | 172.3 ± 11 | 374.3 ± 32.3 |
| RB-YSL | 272.4 ± 6 | 189.7 ± 14.2 | 120.3 ± 7.9 | 221.6 ± 15.3 |
| RMB-YSL | 177.1 ± 5.2 | 94.2 ± 16.7 | 48.9 ± 3 | 104.7 ± 11.5 |
| MB-YSL | 81.6 ± 8.9 | 11.9 ± 4.2 | 3.4 ± 0.9 | 48.5 ± 7.8 |

**Figure: 6.1 Density of different groups of birds (individuals/Sq.Km.) over four seasons at Yashwant Lake (TB- total birds, RB-Resident birds, RMB-Resident migratory birds, MB-Migratory birds and YSL-Yashwant Lake) during December 2006 to November 2008**



## SPECIES RICHNESS

### *Total Birds*

The total bird species richness was maximum in winter (56.67 ± 0.4) and minimum in monsoon (16.17 ± 0.8) while it was 29.33 ± 5.1 and 46.1 ± 4.17 in summer and post-monsoon respectively (Table 6.2, Fig.6.2). When seasonal variations in species richness (No. of species present) at Yashwant Lake were considered, highly significant differences were noted ($F_{3, 20}$ 28.97, $P < 0.0001$).

### *Resident Birds*

Species richness of resident birds was maximum in winter 26.3 ± 0.33 which declined to 18 ± 2.2 in summer and was minimum in monsoon (11 ± 0.5) and 21.3 ± 1.7 species in post-monsoon (Table 6.2, Fig.6.2). Highly significant seasonal variations in species richness of resident birds were noted ($F_{3,20}$ 19.65, $P < 0.0001$).

### *Resident Migratory Birds*

Species richness of resident migratory birds (Table 6.2, Fig.6.2) was also maximum in winter (12.64 ± 0.2) and minimum in monsoon (4.16 ± 0.3) with 7.66 ± 1.7 and 10.33 ± 1.1 species in summer and post-monsoon respectively. ($F_{3, 20}$ 18.91, $P < 0.0001$)

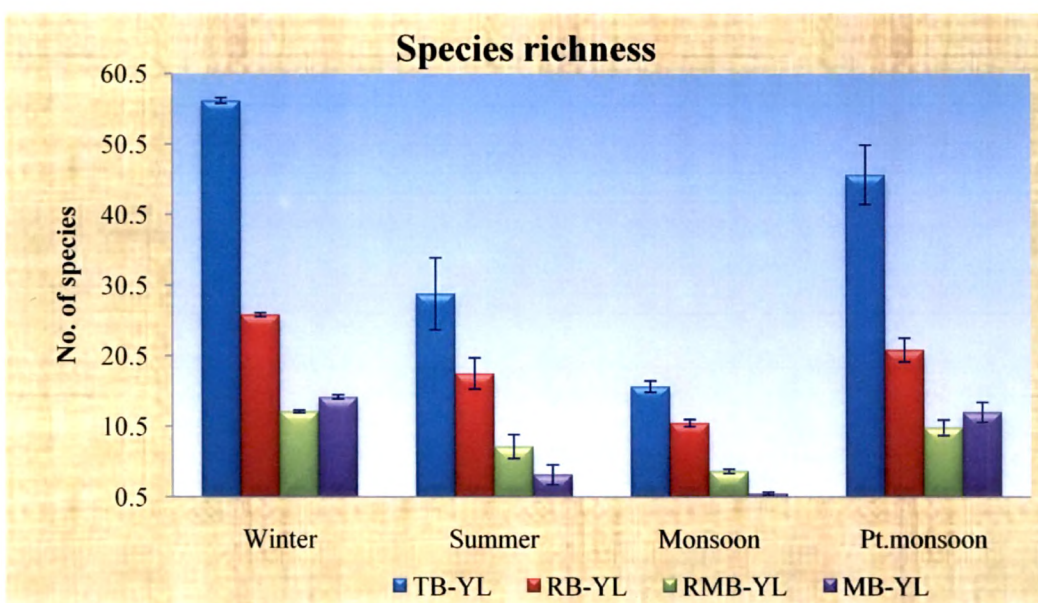
### *Migratory Birds*

Species richness of migratory birds was maximum in winter (14.67 ± 0.33) when the migratory bird population arrives (Table 6.2, Fig.6.2). It declined significantly to 3.66 ± 1.49 on the departure of migratory birds in early summer and was minimum in monsoon 1.0 ± 0.25. It started increasing in post-monsoon 12.5 ± 1.45 with the arrival of early migrants. ($F_{3,20}$ 45.82, $P < 0.0001$).

**Table: 6.2 Species richness (No. of species) of different groups of birds over four seasons at Yashwant Lake during December 2006 to November 2008**

| Species Richness | Winter | Summer | Monsoon | Ptmonsoon |
|---|---|---|---|---|
| TB-YSL | 56.67 ± 0.4 | 29.33 ± 5.1 | 16.17 ± 0.8 | 46.17 ± 4.17 |
| RB-YSL | 26.33 ± 0.3 | 18 ± 2.2 | 11 ± 0.5 | 21.33 ± 1.7 |
| RMB-YSL | 12.64 ± 0.2 | 7.66 ± 1.7 | 4.16 ± 0.3 | 10.33 ± 1.1 |
| MB-YSL | 14.67 ± 0.33 | 3.66 ± 1.49 | 1.0 ± 0.25 | 12.5 ± 1.45 |

**Figure: 6.2 Species richness (No. of species)of different groups of birds over four seasons at Yashwant Lake during December 2006 to November 2008**



## SHANON WIENER DIVERSITY INDEX (H′)

### *Total Birds*

Shanon Wiener index for total birds (H′) at Yashwant Lake was on higher side with maximum during winter (3.5 ± 0.02), minimum in monsoon (2.4 ± 0.02) while 2.8 ± 0.11 and 3.2 ± 0.11 in summer and post-monsoon respectively (Table 6.3, Fig.6.3). Highly significant seasonal variation in H' were noted ($F_{3, 20}$ 31.69, $P < 0.0001$).

### *Resident birds*

Seasonal variation for H′ of resident birds was highly significant ($F_{3, 20}$ 32.09, $P < 0.0001$). It was maximum in winter (2.75 ± 0.01) and minimum in monsoon (2.026 ± 0.02) while it was same 2.39 ± 0.07 in summer as well as post-monsoon (Table 6.3, Fig.6.3).

### *Resident Migratory Birds*

With parallel trend to total birds H′ for resident migratory birds (Table 6.3, Fig.6.3) was maximum in winter (2.19 ± 0.017) and minimum in monsoon (1.2 ± 0.55) with 1.52 ± 0.15 and 1.82 ± 0.01 in summer and post-monsoon respectively. ($F_{3,20}$ 17.78, $P < 0.0001$).

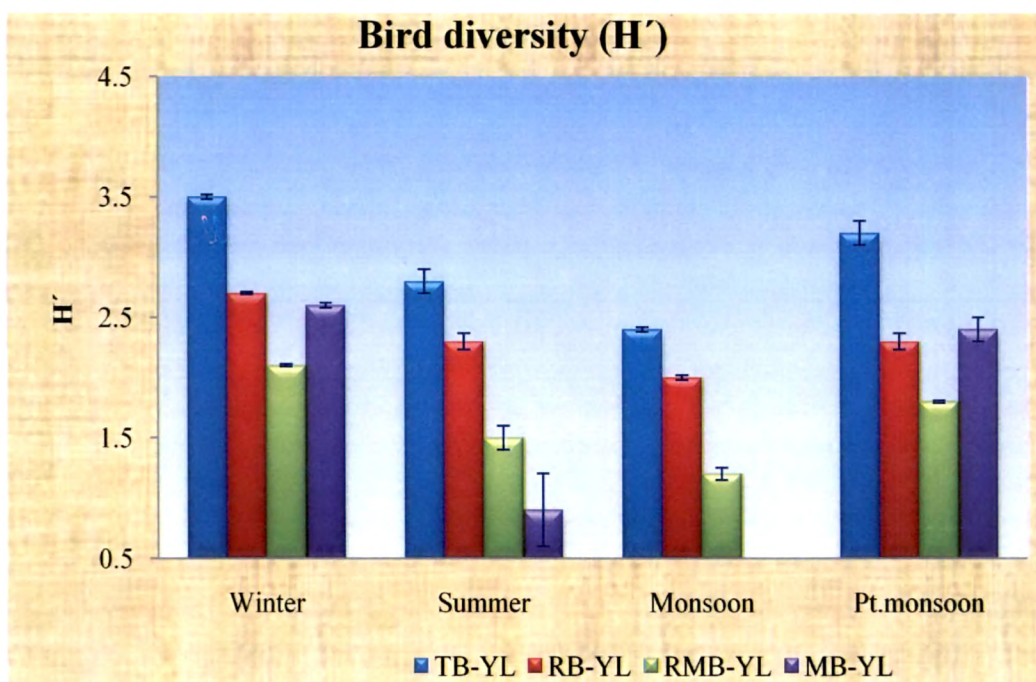
### *Migratory Birds*

H′ for migratory birds (Table 6.3, Fig.6.3) was maximum (2.65 ± 0.026) in winter and minimum (0.093 ± 0.093) in monsoon and 0.93 ± 0.34 in summer and 2.48 ± 0.13 in post-monsoon ($F_{3,20}$ 42.18, $P < 0.0001$).

**Table: 6.3 Shannon-Weiner diversity Index (H´) of different groups of birds over four seasons at Yashwant Lake during December 2006 to November 2008**

| H' | Winter | Summer | Monsoon | Ptmonsoon |
|---|---|---|---|---|
| TB-YSL | 3.5 ± 0.02 | 2.8 ± 0.11 | 2.4 ± 0.02 | 3.2 ± 0.11 |
| RB-YSL | 2.75 ± 0.01 | 2.39 ± 0.07 | 2.02 ± 0.02 | 2.39 ± 0.07 |
| RMB-YSL | 2.19 ± 0.01 | 1.52 ± 0.15 | 1.20 ± 0.55 | 1.82 ± 0.01 |
| MB-YSL | 2.65 ± 0.02 | 0.93 ± 0.34 | 0.09 ± 0.09 | 2.48 ± 0.13 |

**Figure: 6.3 Shannon-Weiner diversity Index (H´) of different groups of birds over four seasons at Yashwant Lake during December 2006 to November 2008**



## EVENNESS (EQUITABILITY)

### *Total Birds*

Shanon Wiener diversity index is reflected with higher evenness too and highly significant seasonal variations ($F_{3,20}$ 31.69, $P < 0.0001$). The evenness was maximum during winter (0.87 ± 0.005) and minimum in monsoon (0.6 ± 0.006), while it was 0.7 ± 0.028 and 0.79 ± 0.02 in summer and post-monsoon respectively (Table 6.4, Fig.6.4).

### *Resident Birds*

For resident birds also evenness (Table 6.4, Fig. 6.4) was maximum in winter (0.835 ± 0.003) and minimum (0.6148 ± 0.007) in monsoon, while it was 0.7266 ± 0.021 and 0.7253 ± 0.022 in summer and post-monsoon respectively ($F_{3, 20}$ 32.09, $P < 0.0001$).

### *Resident Migratory Birds*

Resident migratory birds are most evenly distributed (Table 6.4, Fig.6.4) and E was maximum in winter (0.809 ± 0.006) while less evenly distributed in other season with 0.561 ± 0.057 summer, 0.443 ± 0.020 in monsoon and 0.674 ± 0.042 in post-monsoon ($F_{3,20}$ 17.78, $P < 0.0001$).

### *Migratory Birds*

Though the density of migratory birds (Table 6.4, Fig.6.4) was low at Yashwant Lake they are evenly distributed in winter with 0.955 ± 0.009 while less evenly distributed in monsoon with 0.03 ± 0.03. Evenness was low in summer with 0.33 ± 0.12 while in post-monsoon it was 0.89 ± 0.04. ($F_{3,20}$ 42.18, $P < 0.0001$).

Total 58 species of birds were recorded at Yashwant Lake. Among them 41 species were waterfowls while 17 species were terrestrial, while among waterfowls (41 species), 13 species were resident, 14 were resident migratory and 14 migratory (Annexture-III).

**Table: 6.4 Evenness of different groups of birds over four seasons at Yashwant Lake during December 2006 to November 2008**

| Evenness | Winter | Summer | Monsoon | Ptmonsoon |
|---|---|---|---|---|
| TB-YSL | 0.87 ± 0.005 | 0.70 ± 0.028 | 0.60 ± 0.006 | 0.79 ± 0.02 |
| RB-YSL | 0.83 ± 0.003 | 0.72 ± 0.021 | 0.61 ± 0.007 | 0.72 ± 0.022 |
| RMB-YSL | 0.80 ± 0.006 | 0.56 ± 0.057 | 0.44 ± 0.02 | 0.67 ± 0.042 |
| MB-YSL | 0.95 ± 0.009 | 0.33 ± 0.12 | 0.03 ± 0.033 | 0.89 ± 0.047 |

**Figure: 6.4 Evenness (E) of different groups of birds over four seasons at Yashwant Lake during December 2006 to November 2008**

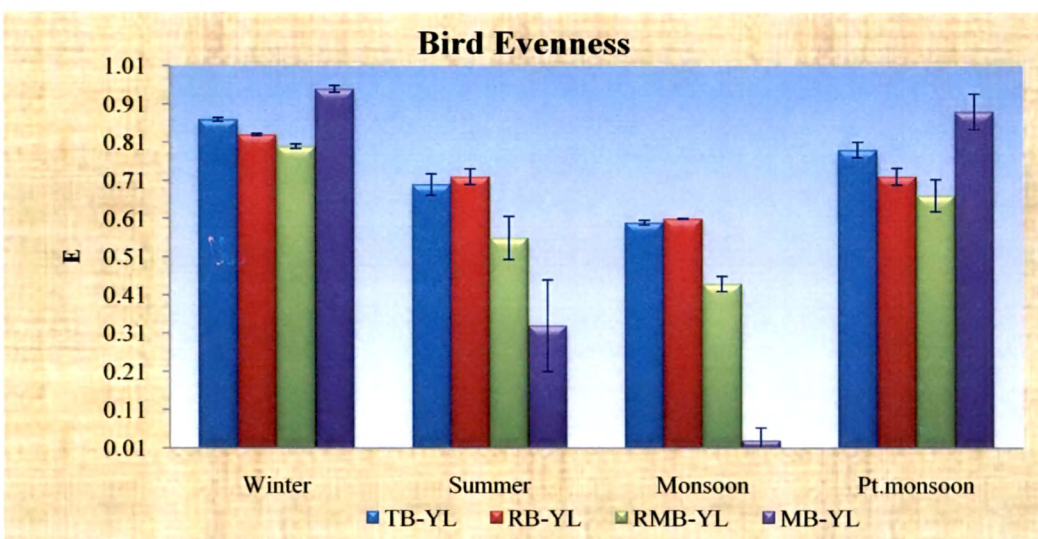


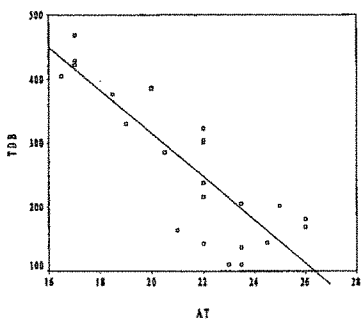
**Table: 6.5 Pearson correlation of bird density with abiotic and biotic parameters of YSLA, YSLB and YSLC at Yashwant Lake during December 2006 to November 2008**

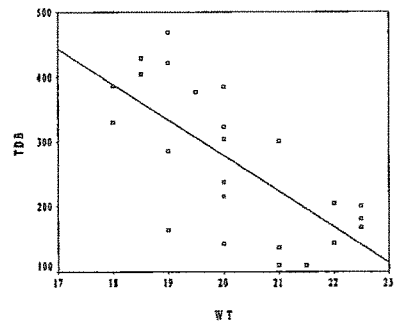
| Sr.No. | Parameter | YSLA | YSLB | YSLC |
|---|---|---|---|---|
| 1 | Acidity | -.738** | -.733** | -667** |
| 2 | Alkalanity | -.639** | -.649** | -.639** |
| 3 | AT °C | -.820** | -.843** | -.783** |
| 4 | Chloride | -.637** | -.645** | -.532** |
| 5 | $CO_2$ | -.833** | -.850** | -.799** |
| 6 | DO | .547** | .544** | .470* |
| 7 | $NO_2$ | -.926** | -.858** | -.875** |
| 8 | $NO_3$ | -.531** | -.354 | -.426* |
| 9 | $p^H$ | -.738** | -.752** | -.681** |
| 10 | $PO_4$ | -.955** | -.953** | -.834** |
| 11 | TDM | -.444* | -.341 | -.424* |
| 12 | TDP | -.701** | -.577** | -.552** |
| 13 | TDS | -.725** | -.640** | -.658** |
| 14 | TDZ | -.636** | -.623** | -.634** |
| 15 | TH | .247 | .361 | .334 |
| 16 | Trans. | .854** | .849** | .876** |
| 17 | TS | -.925** | -.843** | -.886** |
| 18 | TSS | -.646** | -.713** | -.670** |
| 19 | WT °C | -.662** | -.698** | -.707** |
| 20 | WC | .504* | .504* | .441* |

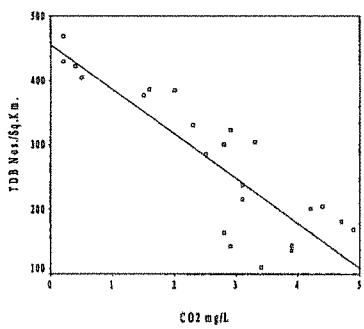
** Correlation is significant at the 0.01 level (two -tailed)
*Correlation is significant at 0.05 level (two –tailed)

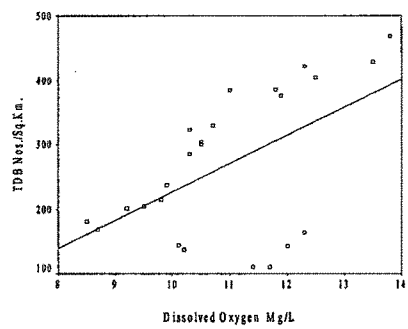
When correlation of bird density was calculated with various biotic and abiotic (physicochemical) parameters of water a negative correlation was established with almost all parameters except DO, Transparency, water cover and total hardness. Among the negatively correlated parameters $NO_3$ and TDM were correlated at varied levels at three stations, other correlated parameters were correlated negatively at 0.01 levels. Among the positively correlated parameters transparency was correlated at 0.01 level at all three stations while DO at 0.01 level at YLA and YLB, at 0.05 level at YLC and Water Cover at 0.05 level whereas correlation of TH was nonsignificant.

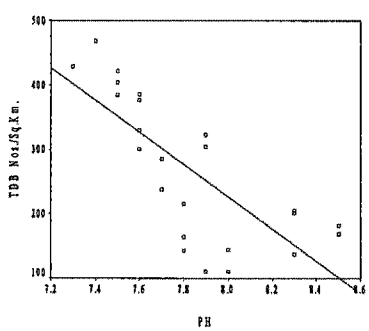
**Figure: 6.5 Correlation between abiotic factors and Birds (from December 2006 to November 2008) Yashwant Lake YLB.**

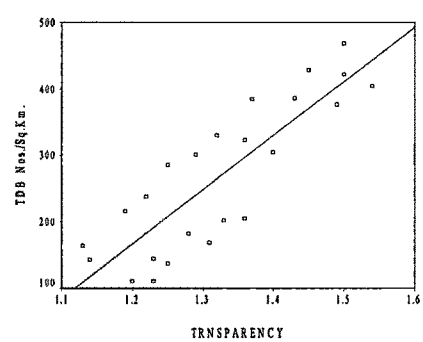


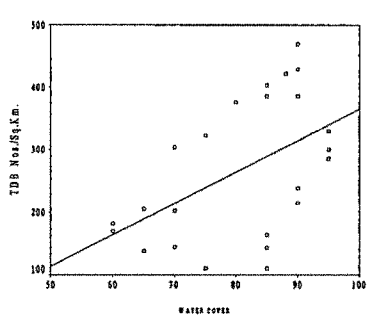
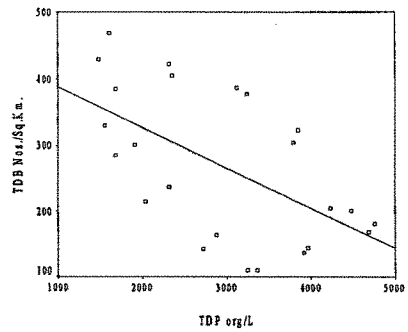
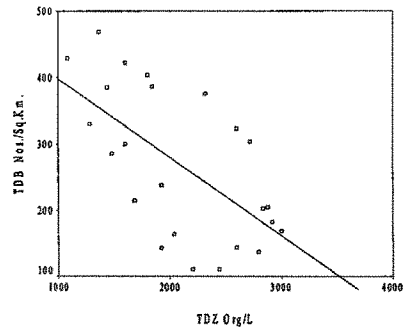
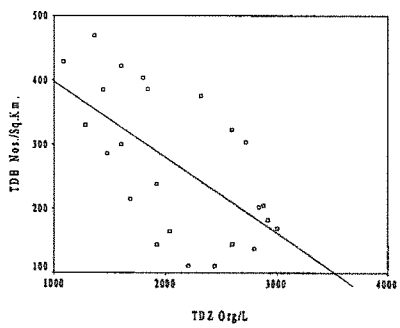



**Figure: 6.5 Correlation between biotic factors and Birds (from December 2006 to November 2008) Yashwant Lake YLB.**



## DISCUSSION

### Density and Species richness

One central objective of ecology is to study the factors affecting the distribution of biodiversity (Andrewartha, 1961; Shmida and Wilson, 1985; Lubchenco *et al.,* 1991; Huston, 1994). The present study has been undertaken mainly from two perspectives *i.e.* global and local. From a global or biogeographical point of view, one of the most widely supported theory of distribution of biodiversity establishes that the main factor affecting diversity is the energy available to the system (Wright, 1983; Scheiner and Rey-Benayas, 1994; Kerr and Packer, 1997). However, from a local perspective, most studies point to the relationship between the number of species present a habitat and its internal structure. Thus, the structural complexity of the habitat, along with competition processes, and disturbance mechanisms, explains the abundance of species in a region. The ecological studies of communities have mostly shown interest in this aspect of diversity that has resulted in significant production of scientific research (Huston, 1994; Andren, 1994; Parish *et al.,* 1995; Burel and Baudry, 1995; Grossi *et al.,* 1995; Berg, 1997; Miller *et al.,* 1997). However such studies at higher altitude in mid Satpura range are lacking.

To study any ecosystem the birds serve as important bio-indicators as they have the ability to fly away and avoid any obnoxious condition. Hence, they are considered as important health indicators of the ecological conditions and productivity of an ecosystem (Newton, 1995; Desai and Shanbhag, 2007; Li and Mundkar, 2007). The most important parameters of the bird study are the species richness (Nilsson and Nilsson, 1978; Weller, 1978; Murphy *et al.,* 1984; Jose and Jose, 2001) their density (Patterson, 1994; Nilsson and Nilsson, 1978) and diversity (Krebs, 1985). However, among avian communities, variations in the components of diversity are known to differ between locations and seasons (Kricher, 1972, 1975; Austin and Tomoff, 1978; Rotenberry, 1978; Rotenberry *et al.,* 1979; Smith and McMohan, 1981; Nudds, 1983; Powell, 1987; Bethke and Nudds, 1993). Present study confirms these results (Table

6.1, 6.2, Fig.6.1, 6.2) as total bird density and species richness at Yashwant Lake are maximum during winter (the peak migratory season) and minimum during monsoon (when the migratory population of birds have not arrived in the area and the resident species are engaged in the nesting activities). The higher density in winter is also reflected by increase in density of resident migratory birds.

The density of migratory birds, though low at higher altitude, Yashwant Lake, as compared to inland wetlands of semiarid plains (Deshkar, 2008), was maximum during winter. Small migratory duck population utilize this small higher altitude Lake as their wintering ground. The duck with different feeding habits, *i.e.* the dabbling duck *e.g.* Gadwall, *Anas strepera*, the diving ducks- various species of Pochards and the Marsh ducks (Grimette *et al.,* 1998), inhabit different microhabitats of the Yashwant Lake especially during winter. This proves that the site is potent enough to sustain the load of small population of migratory ducks feeding at different depths. This is expected to reduce the competition for food resources which is known to be the limiting factor for distribution of ducks (Tramer, 1969; Green, 1998). Studies have addressed vertical partitioning in foraging methods as well as depth in the water column at which feeding occurs (Danell and Sjoberg, 1982; Thomas, 1982).

The density of birds in winter is affected not only by the increase in migratory bird species but simultaneous increase in Resident and Resident migratory species too. The density as well as species richness of resident migratory birds was also maximum in winter. Resident migratory species include marsh birds like Coots and Moorhens, Large Egrets, Grey Heron, Purple Heron, Painted Stork, Black headed Ibis and waders and divers like Indian Shag *etc.* These birds utilize Yashwant Lake equally during winters with other resident and migratory species as they are observed with their higher densities and species richness during the said period. From this one can say that Yashwant Lake at higher altitude in Satpura range has enough productivity to sustain migratory, resident migratory and resident populations of birds. Simultaneously increase

in density and species richness of Resident species is also noted. This indicates that when the pressure of migratory birds increases in plains some resident birds move to higher altitudes to reduce the competition for food resources.

According to Bancroft *et al.* (2002), the water birds are related to vegetation community and vegetation may directly or indirectly affect the bird species abundance. This has also been discussed by Deshkar (2008) for reservoirs and village ponds in semiarid zone of Gujarat. During summer when the algae start drying and the dead algae float over the water, a suitable habitat is created for several microorganisms hence, making it one of the best feeding habitat for resident Birds. Birds like Dabchick, little Cormorant, Herons and Egrets are favoured by this habitat. The exposure of vegetation due to decline in water level during summer creates suitable hiding places too. The density of resident birds is maximum compared to migratory and resident migratory birds during summer. This is probably the time when water bodies at the base of Satpura range dries off and hence the resident birds move to the habitats where water is available. In addition to routine energy demands, these resident birds need high food intake to enable them to build up nutrient reserves for the forthcoming breeding activities. Hence the habitat of Yashwant Lake with good food availability is favourable for resident species of birds during summer. The resident species that congregate at Yashwant Lake probably for such build up of nutrients for forthcoming breeding period are Dabchick, Little Cormorant, Indian Pond Heron, Little Egret and Purple Heron. Species richness of resident birds was maximum, while that for resident migratory birds was moderate and migratory birds minimum as some late migrants were observed till the end of April.

Yashwant Lake being in semiarid zone of North Maharashtra receives heavy rain during South West monsoon. Two monsoons of study period, were heavy and thereby the water of Yashwant Lake was flowing over spillway towards YSLA (Chapter 2 -Study area). This has clearly indicated its impact on the density of the water birds being extremely low in this season. Wading birds

like Herons, Egrets, Lapwings and Plovers prefer shallow water with marshes, where food can be easily procured (Bancroft *et al.*, 2002). During monsoon birds like Egrets and Herons were present in the shallow areas of Yashwant Lake especially at Stations YSLB and YSLC with mud and macrophytes. The habitat on drier side of YSLB is forest where as that on YSLC is traditional agricultural land preferred by the said waders. However, as plovers are migratory they were not present during monsoon and probably Lapwings moved to lower altitude for breeding hence, not present around the lake. Yashwant Lake and surrounding area is under the clouds during monsoon or receive heavy rainfall which may disturb breeding activities of Lapwings. This is also the period when resident ducks are busy in breeding activities resulting in their absence at YSL.

During Post-monsoon when the water level is high the lake is utilized mainly by resident bird population. This is the period when many early migrant and resident migratory species start arriving at Lake. Dabchicks, Egrets and Herons are present in abundance probably with their young. Moreover, by the month of October and November the migratory population of Coots start arriving at the wetland increasing their dominance, that results in increase in overall density of birds.

Seasonal fluctuations in water levels of natural habitats are known to cause cyclic variations in abundance of birds (Powell, 1987; Bancroft *et al.*, 2002). These fluctuations also change the availability of food resources for the water birds. Waders form major group of birds at Yashwant Lake (Annexture-III). Seasonal variations are noted in their population at Yashwant Lake. During winter, the productivity of water body is stabilized and the food is easily accessible. This attracts the migratory species of wading birds that also increases species richness while during summer, though the water level is low, food is aggregated in small area where it becomes easy to obtain. This again creates a favourable foraging habitat for the birds. However, during monsoon and post-monsoon although the water level is high some large waders (Egrets

and Storks) start visiting the Lake and water logged fields around it with their nestlings.

At Yashwant Lake the migratory population is low. In a comparative study of bird population of urban and rural water bodies it is reported that village ponds with human disturbance mainly support the resident species of birds (Traut, 2003; Rathod *et al.*, 2008). Yashwant Lake is a tourist place where crows and mynas are the common terrestrial birds. These species are known to exploit tourist places very well. These species are considered as commensal to human being as they feed on left over food thrown by men especially at picnic spots. As soon as the rains are over and probably picnickers start visiting the spot, increase in number of crows and maynas was observed. Their density was low during monsoon. Rathod (2009) calls them urban adaptors of western part of India.

Population of House sparrow is declining in many areas (Dilwar, 2006) and ornithologist are concerned about the same. As far as Yashwant Lake and surrounding area is concerned an almost constant population of House sparrow was noted over the study period. Their density was low in summer probably because they are busy in nesting activities during this period. In Northern hemisphere majority of birds breed during warmer summer days (Lake, 1968).

**Diversity Indices: Shanan Wiener (H′) and Evenness (Equitability) (E)**

The H′ at Yashwant Lake is comparatively on higher side mainly because of resident species of birds. Heterogeneity is known to be higher in a community when there are more species that are equally abundant (Krebs, 1985). A large number of species increases the species diversity as measured by Shannon Wiener Index H′ and a more even or equitable distribution among species increases the Evenness index (E). This comparatively small Lake is inhabited mainly by resident species of birds all throughout the year and equally well by resident migratory and migratory species of birds especially during migratory season – winter resulting in the higher H′ and E. The diversity during post-monsoon is moderate as this is the season when resident migratory species

inhabit the lake with their young and early migrants start arriving. Birds are more evenly distributed in winter and less evenly distributed in monsoon while utilize Yashwant Lake in moderate numbers in summer and post-monsoon.

**Correlation with abiotic and biotic factors**

Birds living in extreme cold are literally frozen out and must move to more favourable areas. Climatic factors such as temperature are especially important in the timing of water bird migration, as it affects the arrival of the birds at breeding or wintering grounds. In the present study Birds affected by various factors are not correlated with a single common abiotic factor at Yashwant Lake in northern Maharashtra (Table 6.5). The maximum density of total birds were observed in the winter when the average atmospheric temperature and water temperature were 17.25 ± 0.55 °C and 18.42 ± 0.2 °C (Table 3.1) respectively which are favorable for migratory birds. Wetland birds living in moderate temperature regimes where water supply provides resources all throughout the year, would not be forced to migrate and normally maintain year round territories. Hence, the population of resident birds at Yashwant Lake was also maximum in winter. Negative Pearson correlation established between the temperature and total density of birds is due to migratory population.

Large lakes or inland seas rank high in stability, but their value as habitat for migrants depends on their geographical location and adaptability of the taxa to deeper and more truly aquatic habitats. Many man made reservoirs function in this way and have become important stopover or wintering areas for migratory birds. Compared to wetlands located in plains of Central Gujarat on the northern side of Satpura range, (Deshkar, 2008; Rathod, 2009) which support very high densities of migratory and resident birds, Yashwant Lake located above 1000 m above msl has very low density of birds. However, here also bird density is negatively correlated with Atmospheric and Water Temperature.

The total bird density at Yashwant Lake positively correlated with water cover at 0.05 level may be attributed to maximum water cover during post-monsoon

(92.5 ± 1 %) when the migratory and resident migratory birds start arriving. The resident birds are accompanied with their young after completion of their breeding activity further increasing the density. Shoreline configuration is one of the conspicuous features that influence bird use of wetland. Shore line may have edges and meaningful parameters of edges are difficult to relate to birds and other mobile vertebrates (Weller, 1999). Most workers use correlations with the shoreline index, a ratio of shoreline length to water area. According to Nilsson (1978) dabbling Ducks and Coots show a significant relationship to shoreline index, whereas Great Creasted Grebes do not. Similar relationships have been observed by Kaminski and Weller (1992) and have also been demonstrated experimentally (Kaminski and Prince, 1984). The total bird densities in post-monsoon and winter were modest to maximum respectively when the water cover is respectively maximum to fair (Table 3.1). However, large area of shallow water indicates high shore development where food for the birds may be both dense (Carlander, 1955; Ryder *et al.,* 1974; Holopainen and Passivirta, 1977) and easily available. Further, it also indicates that disturbances caused by man are less. This may be applied for the habitats at YSLB and YSLC where human activities are low.

Though the water cover influences the distribution of birds in the wetland most birds of deeper, open water with Shoreline Lake are divers that feed on mobile fish and large invertebrates. These are cormorants, certain grebes and fish eating raptor like Ospreys (Esler, 1992). These species inhabit Yashwant Lake (Annexture- III). Further, water openness seems to be very important, but its relative impact varies with the season and the stage of the bird's life cycle. The regional water dynamics have the potential of influencing the direction and timing of bird movements and colonization. In a Lacustrine wetland or man made reservoir drastic water level fluctuations does not occur as it occurs in a more shallow, seasonal basin. This gives greater opportunity for the establishment of annual or perennial hydrophytes. In the present study the average seasonal fluctuation of water cover is 66.67 ± 1.5 % to 92.5 ± 1.1 %

hence, it forms a stable habitat with good macrophytes that mainly support resident species.

For most species, there are habitat related issues such as water depth, vulnerability of the prey and water clarity. At the Yashwant Lake total density of birds is positively correlated with the transparency of water at 0.01 level. The most aquatic plants of wetlands are those that are rooted and often submerged at some stage, therefore associated either with shallow waters or with the littoral zone of lakes or ponds where light penetration is greatest. Dense mats can inhibit its use by diving birds *e.g.* Cormorants, while others can walk on it (*e.g.* Jacanas) and search for food. More transparency also favours the photosynthetic activities which influence the trophic structure in the wetland. TS, TSS and TDS are negatively correlated with the total density of birds (Table 6.5). The TSS is maximum in monsoon due to the inflow of rain water to the lake from neighbouring agricultural fields and this is the season when the density of birds was also minimum. In addition, absence of migratory birds as well as the resident birds due to their involvement in breeding activities can not be overlooked. Many factors such as food found within a wetland, bottom substrate materials, vegetation at all levels (layers); water depth, water temperature or oxygen supply in the water on spatial distribution also influence bird density and diversity. Further, Dissolved oxygen concentration indicates status of water quality and productivity. It is positively correlated with total density of birds at Yashwant Lake. The maximum density of birds recorded in winter may be correlated with macrophytes that are exposed due to reducing water cover as well as exposed substrate providing countless invertebrates of varying sizes which occured as food resources. Emerging vegetation such as *Cattail* provides emergence sites for insects like damselflies, dragonflies and flying adults of other species that forms food for various species (Weller, 1999). Minimum oxygen level recorded in the summer reflects the lower water depth and higher temperature of water where in the fish or invertebrate species come to surface and are easy to catch, thus declining water depth and low oxygen level make invertebrates and fish

vulnerable to predation by Egrets, Herons and Cormorants (Kushlan, 1976). This can be noted for Yashwant Lake in the summer months with moderate density of birds like Egrets, Herons and Cormorants. Herons and other fish eating birds undoubtedly take enormous numbers of fish, but much of such feeding seems to be most efficient when water levels decline and oxygen is reduced so that fish come to the surface to get air/oxygen. An estimated take of 76% of the fish of a declining pond has been reported with a 93% loss during total drying (Kushlan, 1976).

When $O_2$ rises $CO_2$ declines. Maximum $CO_2$ were recorded in summer when the decomposition is high. Dead and drying vegetation is suitable for detritivores that help in recycling the nutrients. Detritivores typically are dominant organisms in energy cycles of wetlands. Therefore they are likely to be the major food items for many species of birds. As said earlier invertebrates and fish are vulnerable to predation by only few species like Ibises, Egrets and Herons especially in summer hence total bird density negatively correlated with the free carbondioxide.

In the present study the total density of birds is also negatively correlated with pH and alkalinity. However, pH and alkalinity are positively correlated with phytoplankton and zooplankton (chapter 4a and 4b) densities as the alkaline pH favours their growth. Though in present study the density of plankton was high in summer the total bird density and species richness were moderate, a direct evidence of absence of the migratory population and presence of resident and resident migratory birds. Extensive studies of Finish lakes with reference to a wide range of nutrients and vegetation have provided evidences of strong linkages of water bird species to certain limnological characteristics (Kauppinen, 1993). In the present study the nutrients such as nitrates, nitrites and phosphate are negatively correlated with the density of total bird (Table 6.5). These nutrients are recorded maximum in monsoon. This may be attributed to rainfall which carries organic matter, animal waste and agro waste (Parashar *et al.,* 2006) from surrounding area to the Lake. The nutrients are

then utilized in the further succession of biota in post monsoon and winter which favours the higher density of total birds. Further, the water birds are also expected to influence the quality of water. The role they have in the turnover of nutrients has been discussed by many authors (Snow, 1960; Dunn, 1976; Barlow and Bock, 1984; Gere, 1992; Mukherjee and Borad, 2001). In a wetland ecosystem the detrivores play important role in initiating the cycling of nutrients. These nutrients may return back via consumers like birds. Detrivores are the tiny crustaceans, nematodes and annelids which inhabit the fluid mud which offer a unique habitat or mudflats for carnivorous foragers like plovers and sandpipers.

Availability of food is of great importance but is often difficult to relate to bird population. The birds are known to depend on the mollusc, to meet their calcium demand (Eeva and Lehikoinen, 1995; Nisbet, 1997; Brenninkmeijer *et al.,* 1997). Many species of waterfowls feed on mollusc (Stanzykowska *et al.,* 1990; Grimmitt *et al.,* 1998). During winter molluscan density was lowest at Yashwant Lake (chapter 5). This is the period when the ambient temperature in the area falls below 10 °C forcing mollusc to hibernate/ move to deeper soil. Studies have shown a pattern of presence – absence relationships between prey and predator, for example, Snail Kites occur only where there are Apple snails (Stiles and Skutch, 1989). The birds like Ibises and storks known to feed on mollusc though found in small numbers (Cramp and Simmons, 1977; Ali and Ripley, 1983) are few of the species probably benefited because of their long beak in collecting mollusc from deeper soil of the Yashwant Lake.

The study indicates that the Yashwant Lake though a smaller lake has a balanced ecosystem with stabilized abiotic and biotic components that support higher trophic species like birds in sizable numbers.