PART II

A Comparative Study In and Around Two Water Bodies In Relation To Different Anthropogenic Pressures

CHAPTER IV

INFLUENCE OF URBAN PRESSURES ON BIRD DIVERSITY

INTRODUCTION:

Birds are cosmopolitan communities that occur in different types of habitats such as dense forests to extreme urban habitats. They form one of the major fauna in urban area. Human civilization has always grown around the water bodies (ponds) besides they have also constructed reservoirs for their daily needs of water around their settlements. These ponds and reservoirs generally represent a habitat condition somewhere on a continnum between natural and urban environments possessing great potential for supporting varied bird communities (WEI-TA FANG, 2005). Birds of wide varieties are known to use water bodies either throughout their life or during part of their life span (Weller, 1981). The development of civilization, farm land and industrial development have resulted in pollution and pesticides runoff with rainwater to these water bodies (Sahasrabuddhe *et al.*, 2003). These changes affect the quality of water and alter the dependent flora and fauna. Birds being one of the most important indicators of health of an ecosystem, respond to such secondary changes resulting from primary causes and can be monitored relatively inexpensively (Hilden, 1965; Morrison, 1986; Koskimies, 1989; Fuller *et al.*, 1995).

Ponds form important habitats and home not only for birds but also to diverse communities of prey bases like plankton and invertebrate (Gledhill, 1999). Balanced microfauna tend to support balanced macrofauna like avifauna. In addition, ponds also provide nesting, roosting and wintering habitats for large

number of bird species (Mathias and Moyle, 1992). Urban ponds are no exception and do sustain diverse water bird communities during both the breeding and wintering seasons, and apparently provide functional habitat for a variety of seasonal needs (Traut & Hostetler, 2003). These authors have indicated that the presence or absence of various avian species within urban and natural areas change as per habitat structures. Birds being sensitive to habitat changes, their population study can provide proper guidelines for measures for restoration, conservation and management of these water bodies (Patel et al., 2008). Inspite of the number of studies that describe avian responses to urbanization are immense and increasing (Marzluff, 2001), the number of such studies in Asia and particularly in India are meagre. The majority of these bird studies examine the direct effects of development and habitat alteration on community composition by focusing on changes in parameters like avian abundance, species diversity, richness, and evenness (Tilghman, 1987; Clergeau et. al., 1998).

In the present study, these parameters are studied but with reference to urban development and by comparing avifauna of two ponds exposed to similar type of weather conditions but different human pressures. These two water bodies are located in Savli Taluka of Vadodara district (Plate XIV) just about a kilometre away from each other and face similar type of climatic conditions but different type of anthropogenic pressures. The two water bodies selected are Savli Pond (SVP) and Jawala irrigation reservoir (JIR). The chapter includes a comparative study of species richness, density, diversity indices like Shannon- Wiener (H´) and evenness (E) as well as similarity index for total, terrestrial and water bird communities.

MATERIALS AND METHODS:

Savli is a developing town with a pond at its eastern boundary- the Savli Pond (SVP). It is under varied pressures of urban development. The second water body, located near Jawala, now a suburb of Savli is Jawala Irrigation Reservoir (JIR), surrounded by agricultural matrix. It is exposed to natural environmental conditions. Both the water bodies were visited twice in a month from July 2005 to June 2007. Birds were counted using transect method while walking on the parallel road (Savli Pond, SVP) or on the earthen dam (Jawala Irrigation Reservoir, JIR) in the morning, 2 hours from sunrise. The bird identification is based on standard books by Ali (2002) and Grimmett et al., (2001). Similarity index was calculated by Jacquard's formula $J = C/ (A+B)-C$ as describe in Chapter I. However, it was calculated in two different ways, that is, for all species observed during two years of study as annual index and a twice in a month comparison pooled together as seasonal similarity index. As described in Chapter 1, Species richness (number of species), diversity indices like Shannon Wiener (H′ = $\sum$ pilogpi) and equitability (E=. H′/ H max) (Kreb, 1985; Javed and Kaul, 2002) were calculated and Densities (D) of birds were calculated by using formula n/ 2W*L (Rodgers, 1991) for each visit. All the bird parameters were evaluated for total birds and total birds further divided as Terrestrial birds and Water birds to find out the preferred niches. Total 10 to 12 visits were made per season; altogether 48 visits were made at SVP and 44 at JIR in two years. The data collected for the study areas were compared using t-test (Graph Pad Prism 3 and Excel). The monthly data pooled for four seasons are pre-winter (September to November), winter (December to February),

summer (March to May) and monsoon (June to August). The data collected was considered for total species, terrestrial birds and water birds. The results given are in the form of Mean ± SEM. The seasonal variations at both the water bodies were analyzed using one-way ANOVA. The p value for t-test and ANOVA are insignificant if $P > 0.05$, significant if $P < 0.05$ (*), significantly significant if $P < 0.001$ (**), highly significant if $P < 0.0001$ (***) as described by Fowler and Cohen. The Pearson correlation is calculated by keeping birds as dependent variable and plankton and other abiotic factors as independent variable with the help of SPSS 7.0. Further, details for plankton and water quality are discussed in Chapter V and VI respectively.

RESULTS

Comparison of birds between two water bodies:

Total 85 species of terrestrial as well as water birds were observed in and around SVP and 89 species at JIR during the study period of two years.

Annual Comparison of birds (Fig 4.1):

Jaccard's index: The annual Jaccard's index between two water bodies was 0.72 (0.28 ± 0.02) for total species of birds, 0.61 (0.29 ± 0.02) for terrestrial species and 0.37 (0.24 ± 0.02) for water birds.

Species richness: The mean species richness of total birds at SVP was 19 ± 0.9 and at JIR it was 17 ± 1.2. The mean species richness of terrestrial birds at SVP was 9 ± 0.4 and at JIR it was 7 ± 0.4 and that of water birds at SVP was 10 ± 0.6 and at JIR it was 10 ± 1.0. T-test ($P > 0.05$) showed insignificant differences for the total and water birds between the two ponds but for terrestrial birds the difference was differing significantly significantly ($P < 0.001$).

Density: The mean density of total birds at SVP was 547.40 ± 57.74 birds/Km^2

and at JIR it was 388.90 ± 62.84 birds/Km^2. The mean density of terrestrial

birds was 1066.0 ± 11.7 birds/Km^2 at SVP and 251.4 ± 39.59 birds/Km^2 at JIR.

The mean density of water birds at SVP was 605.71 ± 78.19 birds/Km^2 and at

JIR it was 340.9 ± 47.09 birds/Km^2. Insignificant differences ($P > 0.05$) were

noted for total birds, while that for Terrestrial and water birds were highly

significant ($P < 0.0001$) and significantly significant respectively ($P < 0.001$).

Shannon wiener index: The mean diversity index of total birds was 2.16 ± 0.07

at SVP and 1.79 ± 0.1 at JIR. The mean diversity index of terrestrial birds at

SVP and JIR were 1.61 ± 0.06 and 1.39 ± 0.06 respectively and that for water

birds were 1.47 ± 0.07 at SVP and 1.26 ± 0.11 at JIR. Results of t test indicated

difference as significantly significant ($P < 0.001$) for total birds, significant for

terrestrial birds ($P < 0.05$) and insignificant for water birds ($P > 0.05$).

Evenness: The mean evenness of total birds at SVP was 0.72 ± 0.02 and at JIR

0.67 ± 0.03. The mean evenness of terrestrial birds was 0.72 ± 0.03 at SVP and

0.71 ± 0.02 at JIR and that for water birds was 0.62 ± 0.03 and 0.55 ± 0.04

respectively. Insignificant differences ($P > 0.05$) were noted in the evenness for

total, terrestrial and water birds at SVP as well as JIR.

Seasonal Comparison:

Total Birds (Fig. 4.2)

Jaccard's index (J) for the total birds between SVP and JIR was higher in

monsoon (0.32 ± 0.05) and lower during pre-winter (0.28 ± 0.02), winter (0.24

± 0.02) and summer (0.27 ± 0.05) with insignificant seasonal variations ($P >$

0.05, $F_{3, 32}$ 0.527) (Fig 4.2). Though the differences in the *species richness*

between the two water bodies per season were insignificant ($P > 0.05$) in all the seasons, the differences in bird *densities* were significantly significant ($P <$ 0.001) during monsoon and pre-winter, insignificant ($P > 0.05$) in winter and significant ($P < 0.05$) during summer. Differences in the *Shannon-Wiener indices (H')* of total birds were significant ($P < 0.05$) in monsoon and pre-winter and insignificant ($P > 0.05$) during the rest of the two seasons. Differences in *Evenness* of total birds were insignificant ($P > 0.05$) in summer, monsoon and pre-winter whereas significant ($P < 0.05$) in winter.

Terrestrial birds (Fig. 4.3): *Jaccard's Similarity indices* of terrestrial birds were oscillating being during 0.36 ± 0.03 pre-winter, lower 0.21 ± 0.04 in winter while increased 0.33 ± 0.06 in summer but declined to 0.25 ± 0.03 during monsoon with insignificant seasonal variations ($P > 0.05$, $F_{3,40}$ 0.402). The *species richness* differed significantly ($P < 0.05$) in pre-winter and winter, and insignificantly ($P > 0.05$) in summer and monsoon. The difference in *Density* of birds were significantly significant ($P < 0.001$) during monsoon, pre-winter and winter and highly significant ($P < 0.0001$) in summer. For *Shannon-Wiener indices (H')* significant differences ($P < 0.05$) were noted during pre-winter, significantly significant difference ($P < 0.001$) in winter and insignificant difference ($P > 0.05$) in summer and monsoon. The differences in *evenness* were insignificant ($P > 0.05$) during all seasons.

Water birds (Fig. 4.4): The *Jaccard's similarity* index of water birds was minimum in monsoon (0.19 ± 0.07). It increased progressively through pre-winter (0.21 ± 0.05), winter (0.24 ± 0.02) and reached to highest level in summer (0.34 ± 0.04) but with insignificant seasonal variations ($P > 0.05$, $F_{3,32}$

1.317). The *species richness* differed insignificantly (P > 0.05) in monsoon, summer and pre-winter whereas significantly (P < 0.05) in winter. The differences in the *density* of water birds were significantly significant (P < 0.001) in summer and monsoon, significant (P < 0.05) in pre-winter and insignificant (P > 0.05) in winter. The *species diversity indices Shannon-Wiener index* and *evenness* differed insignificantly (P > 0.05) in all the seasons.

Savli Pond (SVP)

Total Birds (Fig. 4.2)

Total 85 species of birds were observed at SVP of which 46 species were terrestrial and 39 species were water birds. The total species richness ranged from 7 to 33. Maximum 65 species of terrestrial and water birds were observed during pre-winter and minimum 44 species in summer. However, the mean *species richness* for total birds was minimum during monsoon 16.6 ± 1.2, it gradually increased in pre-winter 18.3 ± 2.1 and reached to highest level in winter 22.7 ± 1.7 and was almost maintained in summer at 21.3 ± 1.5 with insignificant seasonal variations (P > 0.05, $F_{3, 41}$ 2.342). Contrarily, highly significant seasonal variations (P < 0.0001, $F_{3, 41}$ 6.637) were noted in the density of total birds. Minimum *density of birds* was noted during monsoon (345.6 ± 47.52 birds/Km^2) which gradually increased in pre-winter (656.8 ± 100.7 birds/Km^2) and reached to maximum level during winter (945.7 ± 169.1 birds/Km^2) but decreased in summer (473.5 ± 40.53 birds/Km^2). Species diversity, *Shannon-Wiener index (H')* of birds was maintained throughout the year with 2.34 ± 0.05 during summer, 2.12 ± 0.11 in monsoon, 2.16 ± 0.13 in pre-winter and 2.22 ± 0.16 in winter with insignificant seasonal variations (P >

0.05, $F_{3, 41}$ 0.666). *Evenness* (E) of total birds was also almost constant in all the seasons with 0.75 ± 0.04 in pre-winter, 0.71 ± 0.04 in winter, 0.77 ± 0.01 during summer and 0.7 ± 0.06 in monsoon. Thus, seasonal variations in evenness ($P > 0.05$, $F_{3, 41}$ 0.585) remained insignificant.

Terrestrial Birds (Fig. 4.3)

Total 46 species of terrestrial birds were observed during study period. The *species richness* ranged from 1 to 15 per visit. Maximum 38 species of terrestrial birds were observed in winter and minimum 28 during summer. The higher species richness for terrestrial birds were noted in pre-winter (10 ± 1) and winter (11.1 ± 0.5) that decreased through summer (8.8 ± 0.8) and reached to minimum level in monsoon (7.3 ± 0.07) with significant ($P < 0.05$, $F_{3, 40}$ 3.646) seasonal variations. The *density* of the terrestrial birds was minimum in monsoon (596. 1 ± 119.3 birds/Km^2), that increased gradually through pre-winter (1328 ± 240.2 birds/Km^2) which reached to highest level in winter (1541 ± 299.8 birds/Km^2) but decreased in summer (907.2 ± 91.29 birds/Km^2) with significant ($P < 0.05$, $F_{3, 44}$ 4.227) seasonal variations. The *Shannon-Wiener indices (H')* of birds was maintained throughout the year with 1.55 ± 0.07 in summer, 1.51 ± 0.17 in monsoon, 1.76 ± 0.07 in pre-winter and 1.80 ± 0.05 in winter ($P > 0.05$, $F_{3, 40}$ 1.849). Evenness of the birds were also maintained with 0.79 ± 0.02 in pre-winter, 0.71 ± 0.06 in winter, 0.73 ± 0.02 in summer and 0.73 ± 0.07 in monsoon ($P > 0.05$, $F_{3, 40}$ 0.402).

Water Birds (Fig. 4.4)

When water birds are considered the species richness ranged from 2 to 20 per visit. The minimum was 15 during monsoon and maximum 27 in winter. Total

39 species of water birds were observed during this study period. Minimum *species* of water birds were noted during monsoon (8.2 ± 1.1) that gradually increased through pre-winter (9.5 ± 1.3), reached to highest level in winter (12.2 ± 1) but was maintained in summer (12.3 ± 1) with significant seasonal variations (P < 0.05, $F_{3, 42}$ 2.886). The *density* of water birds was minimum during monsoon (359.8 ± 91.73 birds/Km^2) and gradually increased through pre-winter (575.3 ± 137.1 birds/Km^2) reaching to the highest level in winter (1061 ± 254.5 birds/Km^2) but decreased in summer (504.9 ± 55.98 birds/Km^2) with significant seasonal variations (P < 0.05, $F_{3, 43}$ 4.089). *Shannon-Wiener indices (H')* for water birds were maintained from monsoon (1.33 ± 0.18) to pre-winter (1.31 ± 0.15), winter (1.49 ± 0.1) and summer (1.77 ± 0.08) (P > 0.05, $F_{3, 42}$ 2.025). The *evenness* of water birds was insignificantly lower in monsoon (0.57 ± 0.08) and winter (0.59 ± 0.06) and higher during pre-winter (0.64 ± 0.04) and summer (0.65 ± 0.06) (P > 0.05, $F_{3, 42}$ 0.3729).

**Jawala Irrigation Reservoir (JIR)**

Total Birds

Total 89 species of birds with 47 terrestrial and 42 water birds were observed at JIR that ranged between 5 to 30 per visit. At the irrigation reservoir, maximum 62 species of birds were observed in winter and minimum 36 in monsoon. The Mean minimum *species richness* of total birds for monsoon was 12 ± 2.4, that gradually increased through pre-winter (13.2 ± 1.8) and reached to highest level in winter (25.5 ± 1.3) however it again decreased in summer (17.7 ± 2) with highly significant seasonal variations (P < 0.0001, $F_{3, 34}$ 9.504). When *density* is considered minimum density of birds was also noted during monsoon

(137.3 $\pm$ 37.01 birds/Km^2), that gradually increased in pre-winter (283.6 $\pm$ 61.98 birds/Km^2) and reached to maximum level during winter (790.3 $\pm$ 163.8 birds/Km^2) and decreased in summer (289.6 $\pm$ 69.92 birds/Km^2) with highly significant seasonal variations (P < 0.0001, F $_{3, 37}$ 8.074). *Shannon-Wiener index (H')* for total birds was also minimum during monsoon (1.52 $\pm$ 0.26), it increased gradually through pre-winter (1.66 $\pm$ 0.15) to winter (1.71 $\pm$ 0.21) and reached to highest level in summer (2.25 $\pm$ 0.11) with significant seasonal variations (P < 0.05, F $_{3, 34}$ 2.904). The *evenness* was non-significantly lower during winter (0.53 $\pm$ 0.06), it increased in summer (0.74 $\pm$ 0.06) and monsoon (0.76 $\pm$ 0.06) but decreased in pre-winter (0.66 $\pm$ 0.05, P > 0.05, F $_{3,34}$ 2.724).

Terrestrial Birds

At JIR 38 species of terrestrial birds were observed during the two years of study period which ranged between 2 and 13 per visit. Minimum 21 species were observed during summer and maximum 39 during winter. The mean *species richness* was minimum in monsoon (5.6 $\pm$ 0.5), it increased in pre-winter (6.6 $\pm$ 1), reached to highest level in winter (8.8 $\pm$ 0.6) and decreased in summer (7 $\pm$ 0.6) with significant seasonal variations (P < 0.05, F $_{3, 34}$ 2.913). The *density* of terrestrial birds was also minimum in monsoon (162.7 $\pm$ 37.36 birds/Km^2), it gradually increased through pre-winter (268 $\pm$ 39.92 birds/Km^2) and reached to maximum level in winter (425.8 $\pm$ 127.9 birds/Km^2) and declined in summer (173.2 $\pm$ 25.5 birds/Km^2) with insignificant seasonal variations (P > 0.05, F $_{3, 36}$ 2.642). The *Shannon Weiner diversity index* varied insignificantly during all the seasons with 1.47 $\pm$ 0.07 in winter, 1.40 $\pm$ 0.11 in summer, 1.39 $\pm$ 0.08 in monsoon and 1.30 $\pm$ 0.17 in pre-winter (P > 0.05, F $_3$,
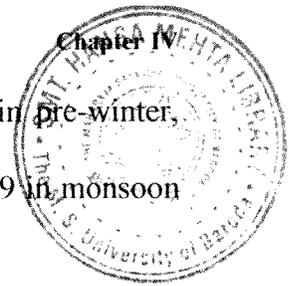
$_{33}$ 0.3043). The evenness was also maintained with 0.7 $\pm$ 0.05 in pre-winter, 0.68 $\pm$ 0.02 during winter, 0.72 $\pm$ 0.04 in summer and 0.69 $\pm$ 0.09 in monsoon (P > 0.05, F $_{3,33}$ 0.1231).
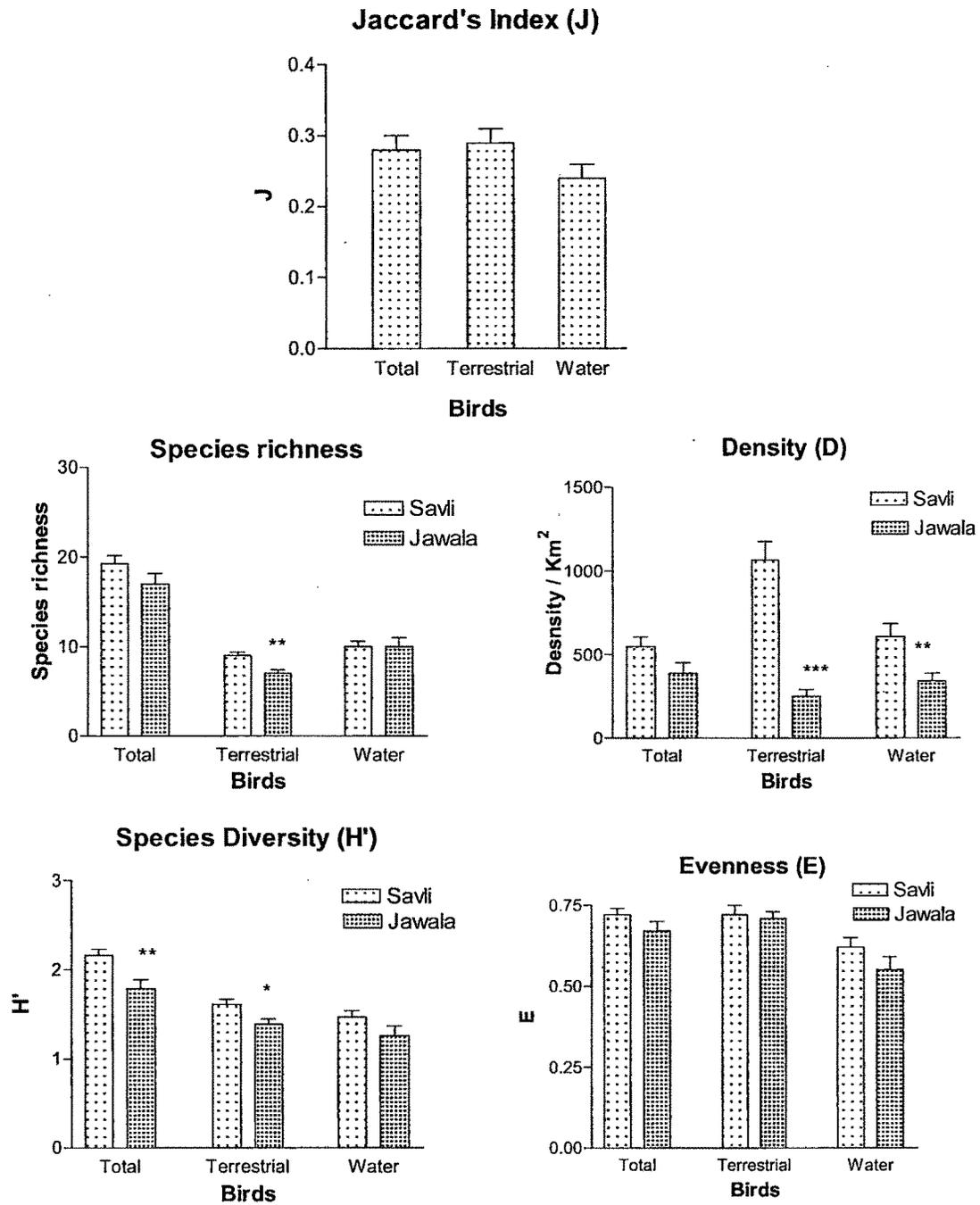
Water birds (Fig. 4.4)

At JIR 42 species of water birds were observed during study period which ranged between 0 to 30 per visit. Minimum 12 species were observed during monsoon and maximum 23 in winter. The highest mean *species richness* was noted during winter (16.6 $\pm$ 1.1) that gradually decreased through summer (9 $\pm$ 2.1) to monsoon (6.4 $\pm$ 2) and was minimum in pre-winter (6.3 $\pm$ 1) with highly significant (P < 0.0001, F $_{3,36}$ 6.928) seasonal variations. The water bird *density* was maximum in winter (765.5 $\pm$ 106.7 birds/Km^2), but declined in summer (194.7 $\pm$ 60.01 birds/Km^2) and finally dropped to minimum in monsoon (62.12 $\pm$ 23.12 birds/Km^2) however, it increased during pre-winter (219.6 $\pm$ 56.06 birds/Km^2) with highly significant seasonal variations (P < 0.0001, F $_{3,42}$ 10.6). The *Shannon-Weiner index (H')* was minimum in pre-winter (0.85 $\pm$ 0.15), it increased in winter (1.49 $\pm$ 0.1) and was maintained in summer (1.41 $\pm$ 0.25) but decreased insignificantly in monsoon (1.01 $\pm$ 0.33, P > 0.05, F $_{3,36}$ 1.731). *Evenness* was minimum in monsoon (0.40 $\pm$ 0.13) and gradually increased in pre-winter(0.49 $\pm$ 0.06), winter (0.53 $\pm$ 0.03) and reached to maximum of 0.6 $\pm$ 0.09 during summer (P > 0.05, F $_{3,36}$ 1.193).

When the Pearson correlation is carried out keeping the bird density as dependent factor and abiotic parameters as independent factors (Details in Chapter VI) it is noted that the parameters that are correlated, vary according to the type of water bodies. At SVP the Pearson correlation between bird density
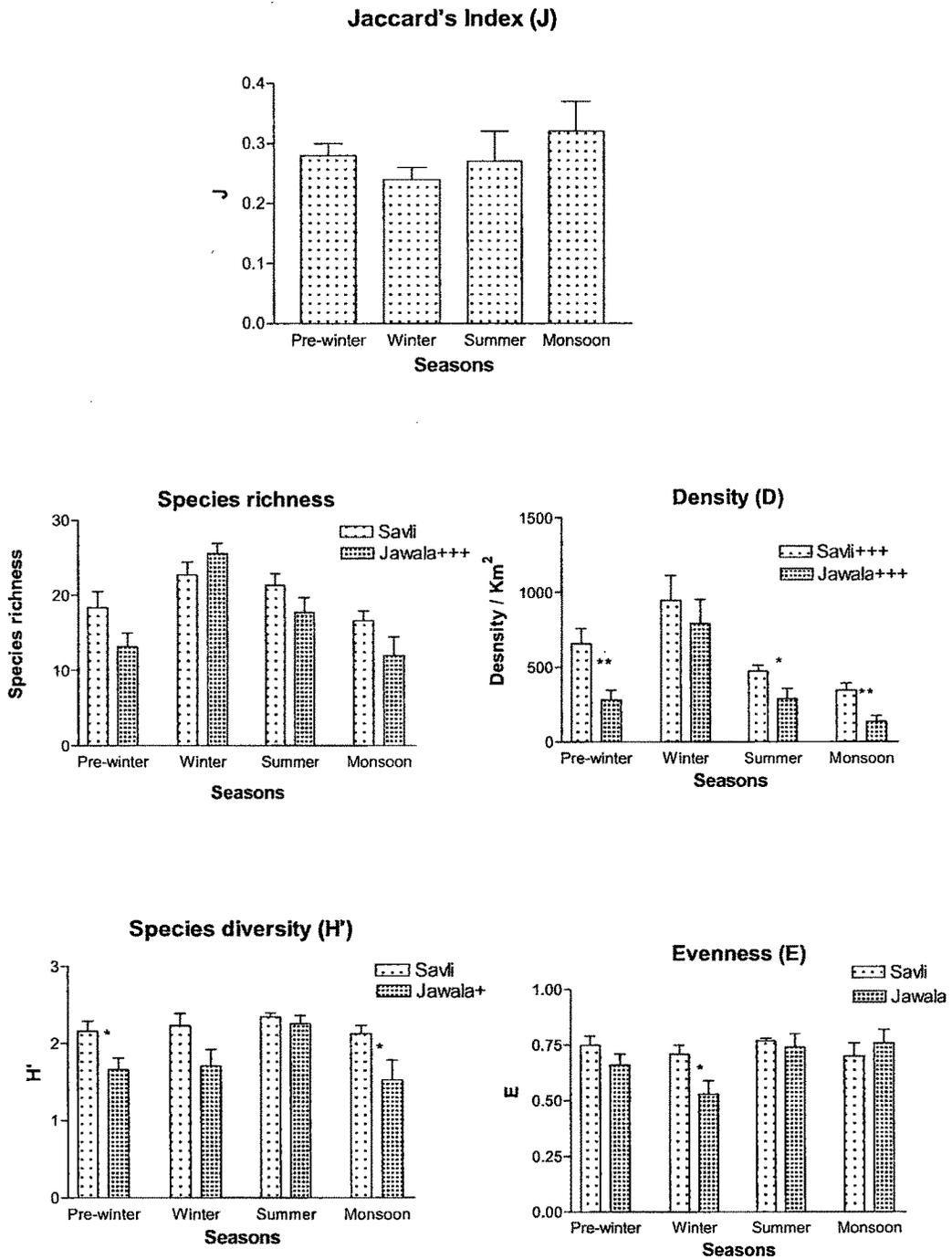
and Nitrate (-0.294) was negatively correlated at the level of 0.05, whereas bird density and oxygen (0.311) was positively correlated at the level of 0.05, while it was significantly negatively correlated with temperature (-0.444) and nitrite (-0.373) at the level of 0.01. At JIR the Pearson correlation between bird density and bicarbonate alkalinity (0.52), hydroxyl alkalinity (0.422) and pH (0.501) showed significant positive correlation whereas temperature (-0.394) showed negative correlation at the level of 0.01 and calcium hardness showed positive correlation (0.356) at the level of 0.05 (Table 4.1 a&b).

Fig 4.1 Annual Comparisons of Total birds, Terrestrial birds and Water birds at Savli Pond (SVP) and Jawala Irrigation Reservoir (JIR).


Jaccard's Index (J)

Species richness

Density (D)

Species Diversity (H')

Evenness (E)

*/ + P< 0.05, ** /++ P< 0.001, *** / +++ P < 0.0001
*For T-test, + For ANNOVA

103

Fig. 4.2 Comparison and seasonal variations in Total birds at Savli Pond (SVP) and Jawala Irrigation Reservoir (JIR).

Jaccard's Index (J)

Species richness

Density (D)

**Species diversity (H')**

Evenness (E)

*/ + P< 0.05, ** /++ P< 0.001, *** / +++ P < 0.0001
*For T-test, + For ANNOVA

104

Fig 4.3 Comparison and seasonal variations in Terrestrial bird communities at Savli Pond (SVP) and Jawala Irrigation Reservoir (JIR).

Jaccard's Index (J)

Species richness

Density (D)

Species diversity (H')

Evenness (E)
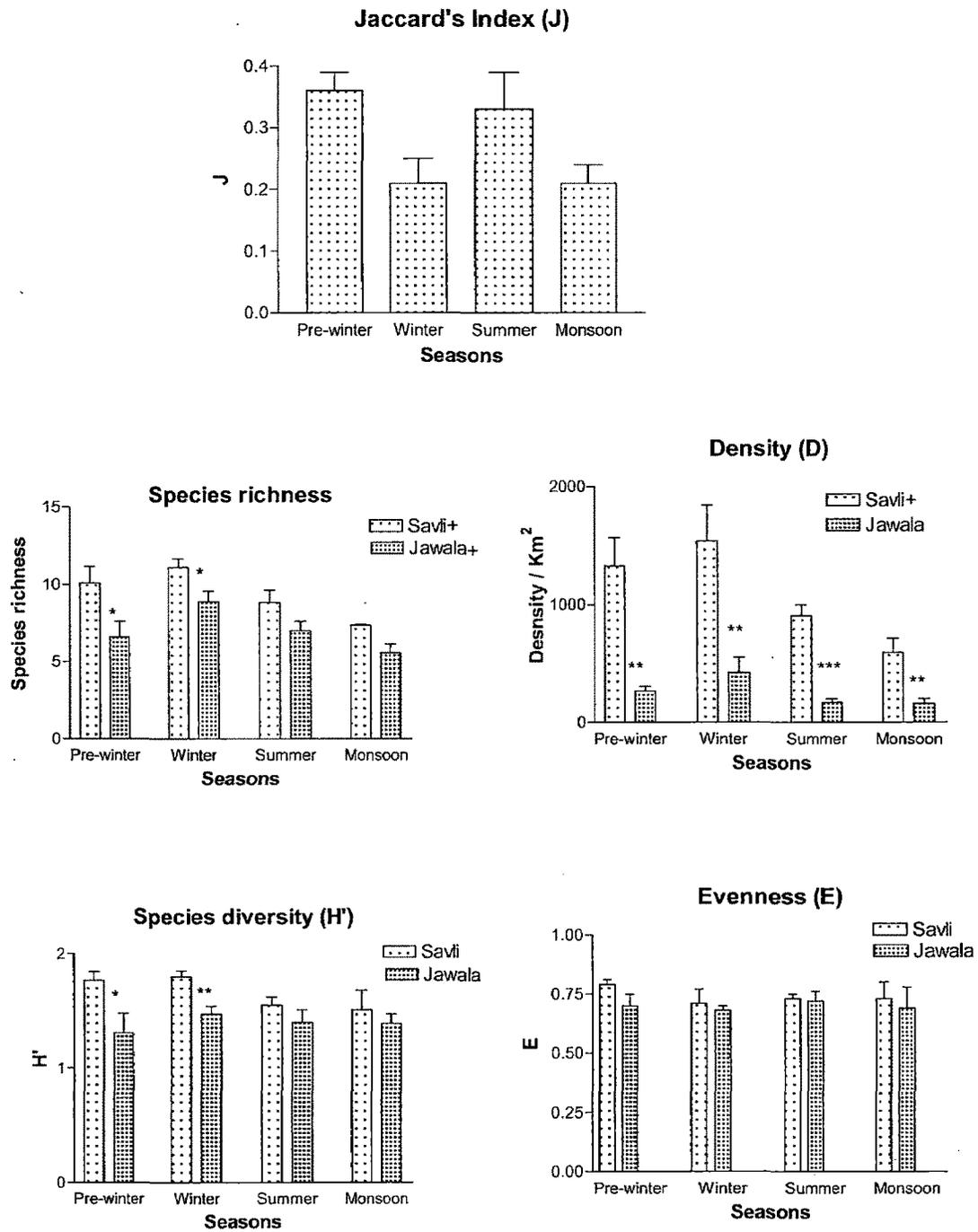
*/ + P< 0.05, ** /++ P< 0.001, *** / +++ P < 0.0001
*For T-test, + For ANNOVA

Fig 4.4 Comparisons and seasonal variations of Water bird communities at Savli Pond (SVP) and Jawala Irrigation Reservoir (JIR).

Jaccard's index (J)

Species richness

Density (D)

Species diversity (H')

Evenness (E)
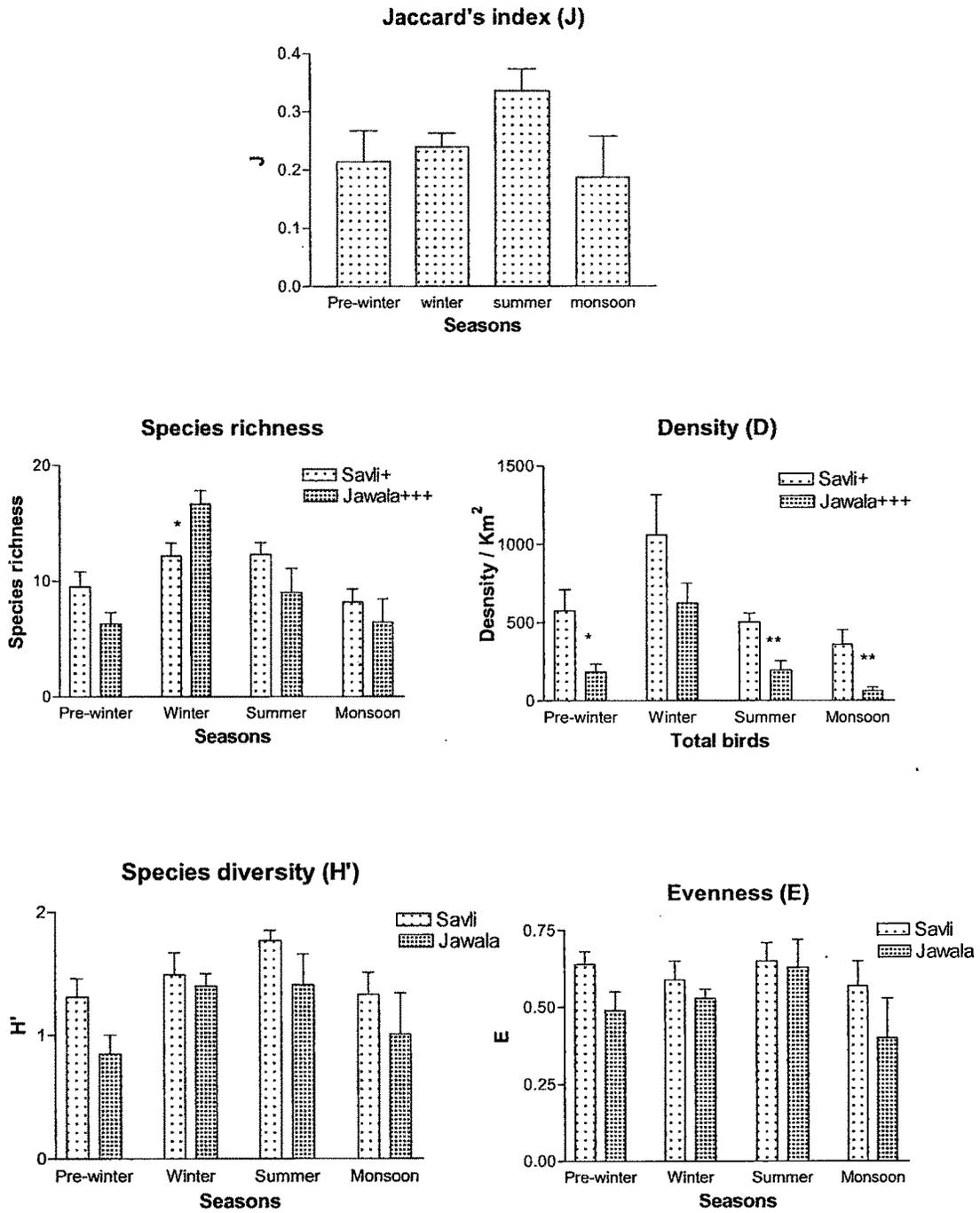
*/ + P< 0.05, ** /++ P< 0.001, *** / +++ P < 0.0001
*For T-test, + For ANNOVA

Table 4.1 Correlation of various abiotic factors and total Bird density at two study areas.

Abiotic Factors	SVP	JIR
Acidity	-0.103	-0.290
Bicarbonate Alkalinity	0.025	0.520**
Calcium Hardness	0.104	0.356*
Chloride	0.207	0.084
Carbon dioxide	0.243	
Hydroxyl alkalinity	-	0.422**
Magnesium Hardness	0.074	0.269
Nitrate	-0.294*	-0.47
Nitrite	-0.373**	-0.293
Oxygen	0.311*	0.186
pH	-0.218	0.501**
Phosphate	-0.200	-0.148
Plankton	0.258	0.280
Salinity	0.207	0.084
TDS	0.062	-0.106
Temperature	-0.444**	-0.394**
Total Hardness	-0.013	0.084
TS	0.036	0.202
TSS	0.027	0.035

Fig 4.5a. Pearson Correlation between Bird density and Temperature, Oxygen, Nitrite and Nitrate at Savli Pond (SVP).
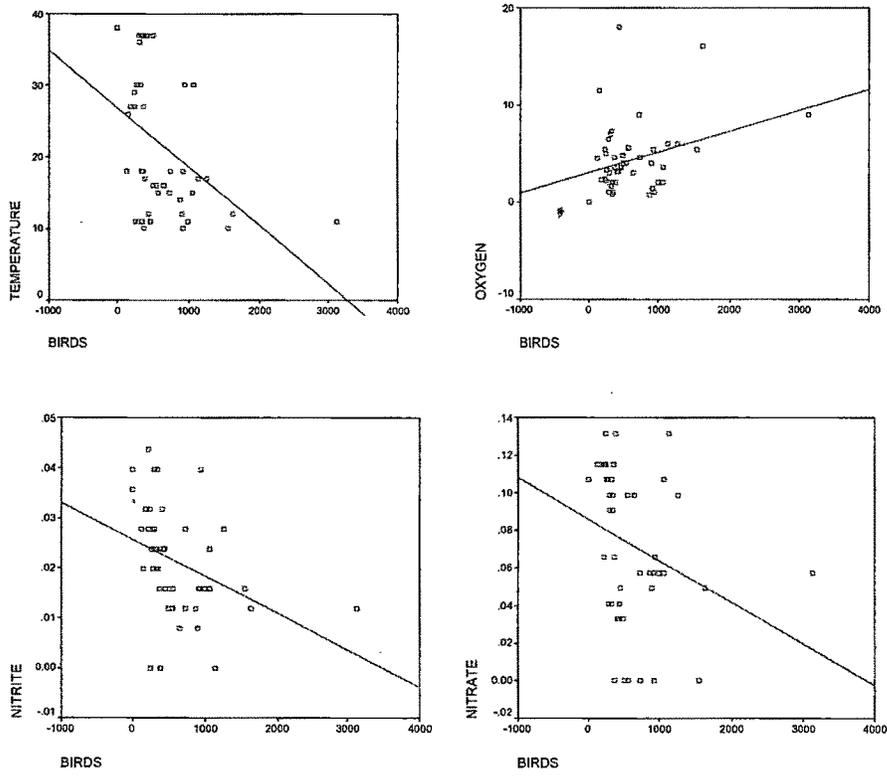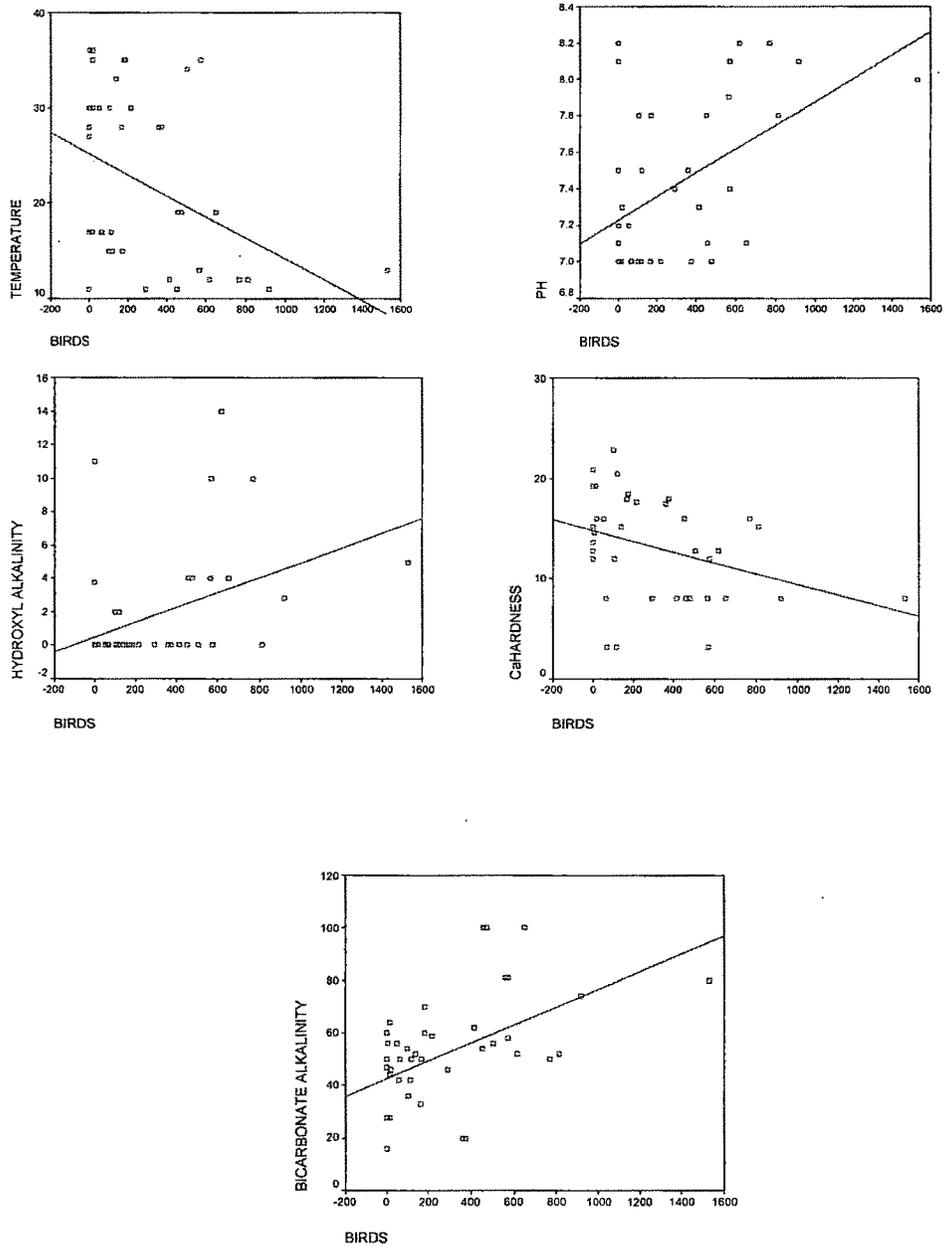
Fig 4.5b. Pearson Correlation between Bird density and Temperature, pH, Hydroxyl alkalinity, Bicarbonate alkalinity and Calcium Hardness at Jawala Irrigation Reservoir (JIR).

DISCUSSION:

Birds are one of the indicators that indicates the status of a habitat. The quality of an aquatic habitat affects the bird species richness (Nilsson and Nilsson, 1978; Weller, 1978; Murphy *et al.*, 1984), density (Nilsson and Nilsson, 1978) as well as diversity (Krebs, 1985) supported by the habitat. As far as the number of species is concerned, no significant difference was found between the species inhabited in two water bodies during present study period. The similarity index of Total species observed during each season showed that 70% of the species were common between the two water bodies. Both the water bodies are just about a Kilometer away from each other and are present in the same geographical area and face similar type of conditions. Hence, movement of various species of birds do occur between the two water bodies.

The higher total species richness at JIR among the two water bodies during winter was due to the high species richness of water birds where, mainly the migrants were attracted to the undisturbed irrigation reservoir. JIR supports more species of migratory birds as compared to SVP which is under the pressures of different human activities. Migrant water birds display a greater sensitivity to human disturbances than resident species (Traut, 2003; Van der Zande *et al.*, 1980; Klein *et al.*, 1995). However, the species richness of terrestrial birds was high during winter at SVP. This difference was mainly due to the urban birds; the "urban exploiters" (Kark *et al.*, 2007) that are not common around the undisturbed reservoir. Important observation of birds are 120 Grey lag Geese (*Anser anser*) among the migratory birds at JIR and 80 Comb ducks (*Sarkidiornis melanotos*) and 200 Little Cormorants (*Phalacrocorax niger*) among residential birds at Savli

Pond during winter. However, SVP being perennial pond with submergent and emergent vegetation as well as large trees, provides breeding ground for the residential species like Cattle Egret, Little Egret, Pond Heron, Black Ibis and Cormorant as well as Little Greeb, Jacana and Moorhens. The higher density of breeding birds is present at lakes that have high productivity as compared to less productive ones (Nilsson and Nilsson, 1978). Little cormorant and Black winged Stilt are the pollution tolerant birds (Sahasrabuddhe *et al.*, 2003) and were recorded more frequently at SVP. Some of the species of birds like Indian Pond heron (*Ardeola grayii*), Cattle egret (*Bubulcus ibis*), Little egret (*Egretta garzetta*), Blue rock pigeon (*Columba livia*), Common myna (*Acridotheres tristis*), Bank myna (*Acridotheres ginginianus*), House crow (*Corvus splendens*), Long-billed crow (*Corvus macrorhynchos*), Rose ringed parakeet *(Psittacula krameri)*, Redvented bulbul (*Pycnonotus cafer*) *etc.* were recorded throughout the study period at both the sites increasing similarity index. However the density of some species of birds like Bank myna, House crow, Cattle egret, Little egret, Comb duck, Rose ringed parakeet, *etc.* were high around SVP as compared to JIR. This indicates that these resident species of birds are highly habituated to the urban conditions. These few species are numerically dominant in the urban and suburban plots throughout the year as indicated by Lancaster and Rees (1979). Thus, the density of total birds was high during winter at SVP mainly due to the high density of terrestrial birds as well as residential water birds.

Similarity in community composition throughout the year has indicated that urban lakes do not just have relatively stable avian communities from one season to the next, but also from year to year (Hoyer and Canfield, 1994). Urban lakes can

sustain diverse water bird communities during both the breeding and winter seasons, and apparently provide functional habitat for a variety of seasonal needs (Traut, 2003). As a result of habituation, residential terrestrial species are high at urban ponds. Jawala Irrigation reservoir mainly supported more migratory species such as Grey lag geese, Pochards, Gadwall, Garganey and waders like Sandpipers, Little stint, Ringed plover and Wagtails.

The high Shannon-Wiener diversity index of total, terrestrial and water birds at SVP is clearly due to the residential species of birds. Significantly significant differences noted in the diversity indices of terrestrial birds between two water bodies during winter can be correlated with the open agricultural fields around JIR with monoculture type of vegetation. This habitat attracts a few terrestrial species whereas diverse habitats of SVP with urban influence provide additional food supply as well as shelter that attract more tolerant and hardy species, increasing density, diversity as well as evenness of birds. As said earlier, the high evenness throughout the year at SVP can be attributed to the residential species of birds present all throughout the years. The higher similarity index during summer is again because of terrestrial birds as JIR totally dries up during late summer and hence no water birds were present.

The birds are more sensitive towards the habitat changes. Quality of water affects the density and diversity of the bird species (Deshkar, 2008). However, in the present study the bird density and temperature were negatively correlated at both the water bodies. As the temperature of water increases the number of birds decreases due to unfavourable conditions of summer when migratory birds leave for their breeding grounds. Similar results are reported by Deshkar (2008) for two

village ponds out of the four water bodies studied. However, Deshkar's two other water bodies were irrigation reservoirs that are inundated with Narmada water whereas there is no Narmada inundation at JIR. At JIR, bicarbonate alkalinity and hydroxyl alkalinity are positively correlated with the density of birds whereas at SVP the density of birds is positively correlated with the oxygen level. As the O_2 level increases probably the primary productivity also increases inturn producing diverse prey base attracting more species of birds. Here, nitrite and nitrate were negatively correlated with the density of birds. The increase in nitrate and nitrite was probably due to the cattle shed run off from the cattle tied on the road running parallel to western boundary of SVP. In addition, the bird density also added the excreta to the water and increased the bicarbonate alkalinity. The influence of different human activities (sewage input, animal waste, *etc.*) should not be ignored as this lead to the degradation of the water that indirectly affects the density of water birds (Chapter VI).

CONCLUSION:

Because of terrestrial urban species like pigeons, crows, mynas and parakeets the density of birds is high around urban lakes influencing species richness all throughout the year except winter. During winter with the arrival of migratory birds, the density as well as species richness increases at JIR the undisturbed reservoir. This indicates that an urban pond supports more resident and terrestrial species of birds, whereas, an undisturbed irrigation reservoir is preferred by migratory species of birds.

Microhabitat around urban ponds like SVP provides diverse food (human leftover/stored food) and shelter in the form of buildings, houses and electric poles

as well as planted gardens compared to the open irrigation reservoir like JIR with few trees around and vast open agricultural land with monoculture type of crops. The organic productivity of Savli pond is probably high because of emergent and submergent vegetation as well as perennial conditions; presence of garbage dump, cattle shed runoff and domestic waste, which provide food directly or indirectly to birds almost all throughout the year.