CHAPTER I

BIRD SPECIES DIVERSITY AND DENSITY

INTRODUCTION:

More than 9,600 species of birds occur all over the world. Of these, about 2,100 species and their subspecies occur in the Indian subcontinent and about 1200 species of birds are found in various habitats of India (Ali & Ripley 1983). One of the major habitats that support congregation of large number of migratory and resident species of birds is wetland. These birds are either waterfowls or water dependent birds. The term "Waterfowl" is widely accepted and described in different ways by different people. The Ramsar Convention refers to water-fowl as birds belonging to the Orders Gaviiformes, Podicipediformes, Pelecaniformes, Ciconiiformes, Anseriformes, Gruiformes, Ralliformes and Charadriiformes (Annonymous, 1971). While according to Fog and Lampio (1982) the birds that are dependent on wetland are waterfowls. The recent definition given by Campbell and Lack (1985) states that waterfowls are all aquatic birds of wild species which are ecologically dependent on water, especially the Anatidae (ducks). In the present study the definition given by Ramsar convention is followed and birds belonging to the said orders are taken into consideration. About 273 species of birds from the list of birds of Indian subcontinent (Ali and Ripley, 1983) belong to these groups and may be considered as waterfowl.

Being ecologically important, because of their high nutritional value and productivity, the wetlands support good diversity of birds (Whittaker and Likens, 1973; Gibbs, 1993; Paracuellos, 2006). The wide varieties of birds use wetland habitats either throughout their life or during certain part of their life (Weller, 1981). This explains the different modes of life possible for birds in a wetland. Water birds exploit a range of different parts of wetland, *i.e.* microhabitats. Each of these microhabitats can supply a variety of different food sources which includes microscopic plankton to higher plants and animals. Many larger predatory birds like Marsh Harrier and Osprey are observed feeding on Coots and ducks (Personal observation). Thus wetlands are the habitats which support different species of organism of which some like birds are conspicuous. Many of these birds are globally threatened (Green, 1996) and needs conservation.

The conservation of water birds is a century old concept wherein the man realized the importance of these species. This is evident by the establishment of several National and International level organizations, starting from the Royal Society for the Protection of Birds (RSPB) in the United Kingdom followed by the Bird Life International, International Council for Bird Preservation (ICBP), International Union for the conservation of Nature and Natural Resources (IUCN), International Wildfowl Research Bureau (IWRB also known as Wetland International), World Wide Fund for Nature (WWF) and many others eventually taking the lead with the declaration of series of conservation acts and finally the master piece, the Ramsar Convention which is the first modern Global Environment Treaty passed during the conference held in the Caspian coastal town of Ramsar, Iran, in early 1971(Boere *et al.*, 2006). Thus it is evident that waterbirds are important for conservation of wetland.

As early as 3rd century B.C. King Ashoka gave importance to preservation of wildlife and environment (Panjawani, 1994).

The international counts of water birds have been a key activity of Wetland International for almost two decades. The Mid Winter Waterfowl Census 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). Compared to the bird conservation, the realization of the immense importance of environmental, economic and social values of wetlands is quiet recent. In most of the 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 has started partially to offset loss and degradation of natural wetlands (Belanger and Couture, 1988). The bird population parameters such as species richness, relative density and diversity of birds are frequently used as indicators of habitat quality (Nilsson and Nilsson, 1978; Weller, 1978; Sampath and Krishnamoorthy, 1990; Nagarajan and Thiyagesan, 1996).

In the present study an attempt is made to evaluate the role of some wetlands in semiarid zone of Gujarat, as an important habitat with respect to the birds, and further, categorize them either as Sanctuary/ Internationally Important wetland/ Important Bird area/ Nationally Important Wetland/ Education and Ecotourism site/ Community Reservoir, or as Recreation area. The Mid Winter Waterfowl Census, carried out, in Vadodara since 1995 revealed the fact that several waterbodies around Vadodara serve as a good habitat for birds (Padate *et al.*, 2001). Further, positive influence of Narmada water inundation on Anatidae population is also noted around Vadodara (Padate *et al.*, 2008). On the basis of this, four wetlands are selected and the seasonal variations and the dependency of different species of birds on them is evaluated here.

MATERIALS AND METHODS:

The four study sites selected are two irrigation reservoir Wadhwana Irrigation Reservoir (WIR) and Timbi Irrigation Reservoir (TIR) and two village ponds Masar Village Pond (MVP) and Harni Village Pond (HVP), each under varied anthropogenic pressure nil to high. Observations were conducted twice in a month. During each visit the water level and the hydrological conditions were noted down. The census was conducted 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; censuses should be conducted at times when there is little change in the conspicuousness of birds (Dawson, 1981) To count the waterfowl, either transects method (at WIR), or the total count method (at TIR, MVP and HVP) were used. These methods provide an overall estimate of the population in the ponds and are proved to be the most appropriate methods for the density and diversity estimation of water birds (Rodgers, 1991; Javed and Kaul, 2002; Paracuellos, 2006). The waterfowl present on both the side of transect were counted while walking on the edge of the wetland. At WIR the length and the width of transect were 1.7 kms. and 0.5 km. respectively. While at TIR, MVP and HVP, the entire area of the pond was covered due to their smaller size. At the smaller wetlands the visibility of birds upto the opposite bank was clear and the total area was considered for calculation of density. A direct count was carried out with the help of binoculars having the magnification of 10 X 50 or 7 X 35. The study was carried out from February 2005 to May 2007 for 24-27 months. The birds were identified on the basis of field guides by Ali and Ripley, (1983); Sonobe and Usui, (1993); Kazemirack, (2000) and Grimmett *et al.,* (2001).

The diversity indices, Species Richness- No. of species; Species diversity, Shannon wiener index (H') and Equitability (E) and the density of waterbirds were calculated for each visit. The birds observed in the pond as well as those present in the agricultural fields and observed to move in and out of ponds (Waders *Charadriidae, Threskiornithidae, Gruidae, Scolopacidae, Ardeidae* and some of the duck species like the Grey Lag Geese *Anser anser*) were also counted.

To make the analysis simpler the birds that are observed are categoried into four groups depending on their feeding habits. These are group 1: Divers- Grebe (*Podicipedidae);* Cormorants *(Phalacrocoracidae)*; marsh birds Moorhens and Coots (*Rallidae)* and Jacanas *(Jacanidae);* Group 2- Ducks *(Anatidae)*, Group 3: Waders- Herons and Egrets *(Ardeidae);* Storks *(Ciconiida*e); Ibisies *(Threskiornithidae)*; Flamingos *(Phoenicopteridae)*; Cranes *(Gruidae);* Stilts *(Recurvirostrida*e); Lapwing and Plovers *(Charadriidae);* Curlew, Godwits and Sandpipers *(Scolopacidae)* and the Group 4 Kingfishers *(Alcedinidae)* and Terns *(Laridae)*. The density is calculated as per km^2 for the block count method or the transect method (Rodgers, 1991). Total No. 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 is information content of sample (bits/individuals) = index of species diversity (Krebs, 1985;

Javed and Rahul, 2002). For the statistical analysis the data for 3 months is pooled according to the seasons as Summer: March, April, May; Monsoon: June, July, August; Postmonsoon (Pt Monsoon): September, October, November and Winter: December, January, February. Further the Mean, standard mean of error (SEM) and One-way ANOVA as described by Floler and Cohen with No post test for various parameters for four seasons was performed using GraphPad Prism version 3.00 for Windows, (GraphPad Software, San Diego California USA). The correlation is carried out using SPSS software. The percentile distribution for the density and species richness is calculated as summation of the density of Resident/ Migratory birds/summation of Total bird density (Migratory + Resident) X 100. This was calculated for each season.

The p value for ANOVA is non significant if $P > 0.05$ (ns), significant if $P < 0.05$ (*), significantly significant (**) if P is < 0.001 and highly significant (***) if $p < 0.0001$.

RESULTS:

During present study 61 species of birds were noted at WIR, 53 at MVP, 56 at TIR and 31 at HVP from February 2005 to May 2007 (Annexure I). The variations in the bird density and the species richness are observed according to the seasonal changes as well as various other factors. The results are considered site wise over here.

Wadhwana Irrigation Reservoir (WIR):

At WIR highly significant variation ($F_{3, 48}$ 11.57, $P < 0.0001$) in the density was noted across the seasons. The maximum density of WIR as recorded for birds was 4364 $\pm$ 985.5 birds/km^2 and species richness was 31$\pm$ 3.2 during winter and minimum density (66.2 $\pm$ 25.9 birds/km^2) and species richness (7.2 $\pm$ 1.92) during monsoon with highly significant variation of $F_{3, 47}$ 22.5, $P < 0.0001$ (Fig. 1.1a).

When the four different seasons are considered separately for each group it can be seen from Fig. 1.1b that the summer and post monsoon support mainly birds categorized in Group 1- Divers and Marsh birds- the Cormorants, Coots and Jacanas with 707.2 $\pm$ 228.9 birds/km^2 and 542.6 $\pm$ 283.1 birds/km^2 density respectively. While the Group 2, the ducks (1996 $\pm$1027 birds/km^2) with higher fluctuation and Group 1 (1964 $\pm$ 493.6) with lower fluctuation inhabit WIR almost equally during winter. The Group 3- waders though with very low density maximally utilize the habitat during monsoon with 11.57 $\pm$ 5.54 birds/km^2 (Fig. 1.1b). However, when the species richness is compared it is seen that the waders dominate all the four seasons starting with maximum in winter (12.5 $\pm$ 1.5), followed by summer (10.9 $\pm$ 0.74). In monsoon it was minimum (3.6 $\pm$ 1.2) and in postmonsoon it was 5.0 $\pm$ 0.4 (Fig. 1.1c).

Group 4 always occurred in minority.

When a comparison of resident and migratory species of birds is carried out for WIR (Fig.1.1d), it can be seen that the Resident birds dominate in terms of density during summer (51.74%) and monsoon (93.4%) while the migratory birds dominate the area during postmonsoon (91.9%) and winter (85.9%). However, when percentile distribution of species richness is considered it is the resident species of Birds that dominate the area during all the seasons with highest during monsoon (94.3%) followed by postmonsoon (81.8%), summer (73.75%) and lowest during winter (56.7%).

The Bird diversity, Shannon wiener index (H'), at WIR is noted to be maximum during summer (1.5 $\pm$ 0.15), while during monsoon it was 1.1 $\pm$ 0.18 and minimum during postmonsoon (1.0 $\pm$ 0.15) and it started increasing during winter (1.2 $\pm$ 0.11). The birds are more evenly distributed during monsoon (with E = 0.56 $\pm$ 0.09), postmonsoon (0.51 $\pm$ 0.08) and summer (0.5 $\pm$ 0.05) and less evenly distributed during winter (0.37 $\pm$ 0.02). The diversity ($F_{3, 41}$ 1.9, $P > 0.05$) and evenness ($F_{3, 41}$ 1.7, $P > 0.05$) varied non significantly across the season.

Wadhwana Irrigation Reservoir (WIR):

Figure: 1.1a: Total Bird Density and Total Species richness of birds in 4 seasons from March 2005 to May 2007 at Wadhwana Irrigation Reservoir.

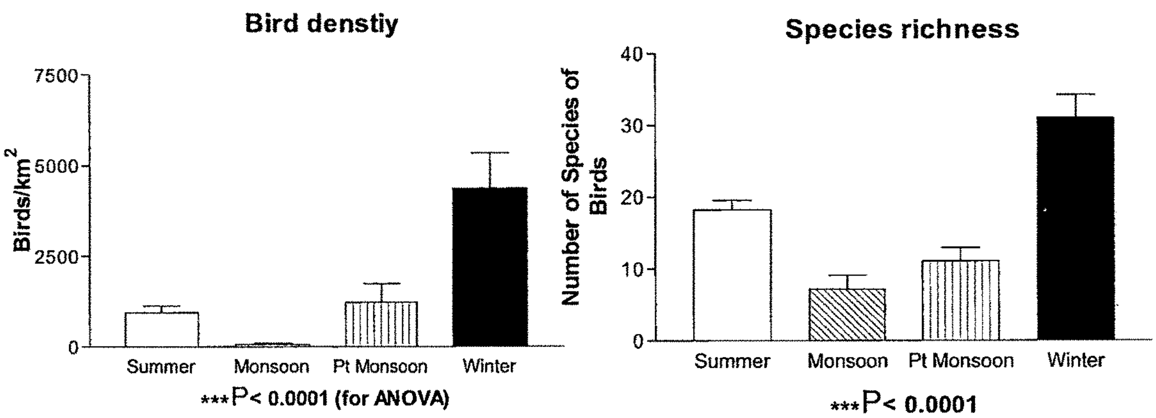


Figure: 1.1b: Bird Density of different groups in 4 seasons from March 2005 to May 2007 at Wadhwana Irrigation Reservoir.

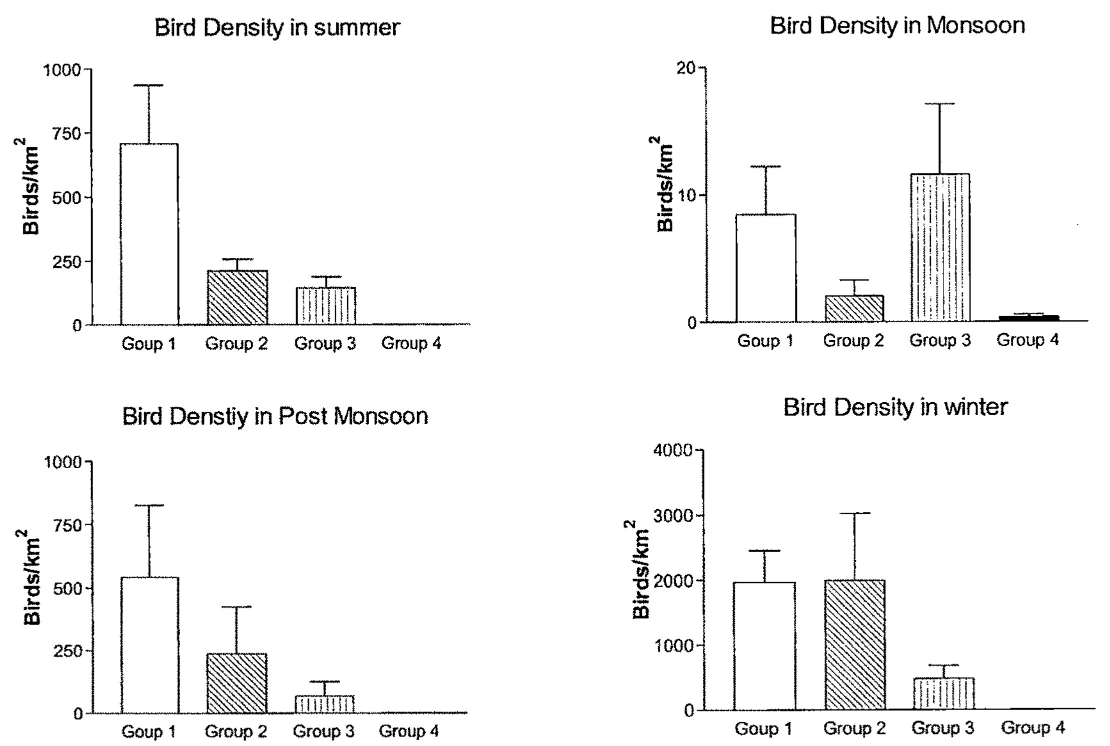


Figure1.1c: Species richness of different groups in 4 seasons during March 2005 to May 2007 at Wadhwana Irrigation Reservoir.

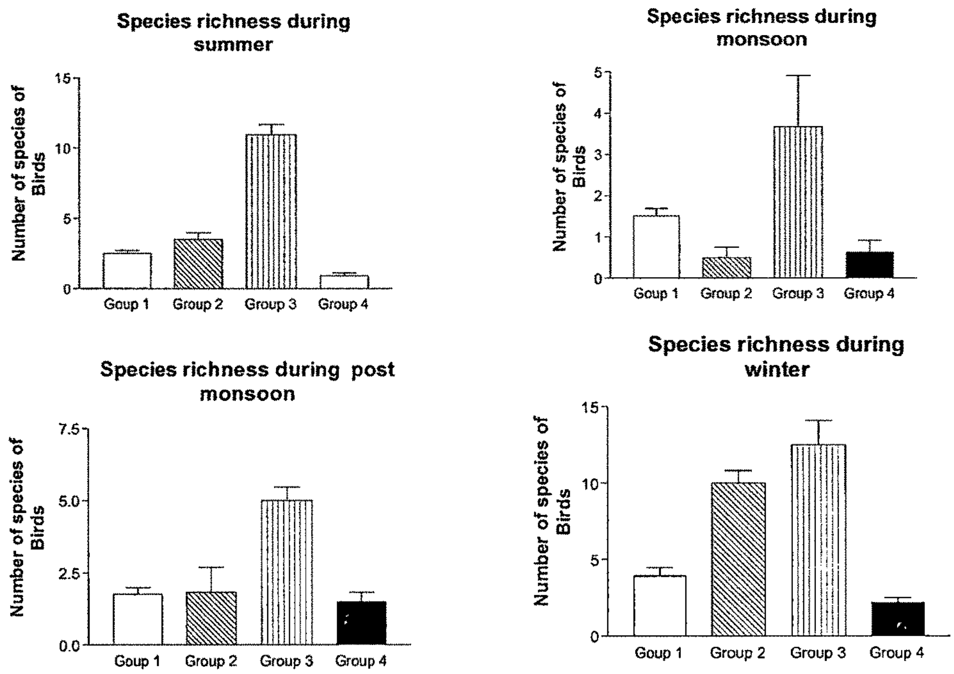


Figure1.1d: The percentile distribution of resident and migratory Birds in all the four seasons at Wadhwana Irrigation Reservoir.

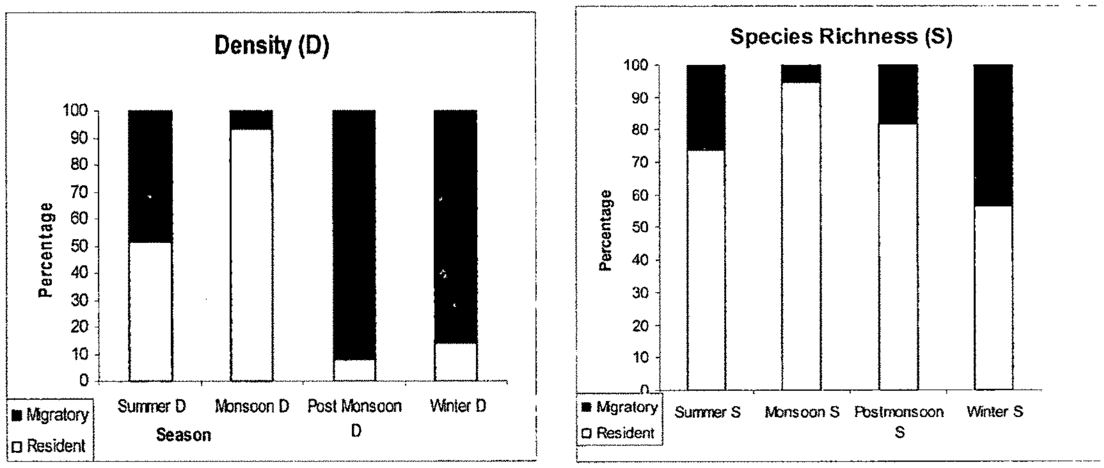


Figure: 1.1e: Seasonal variations in the Shannon- Weiner index (H′) and the Evenness (E) of Birds at Wadhwana Irrigation Reservoir.

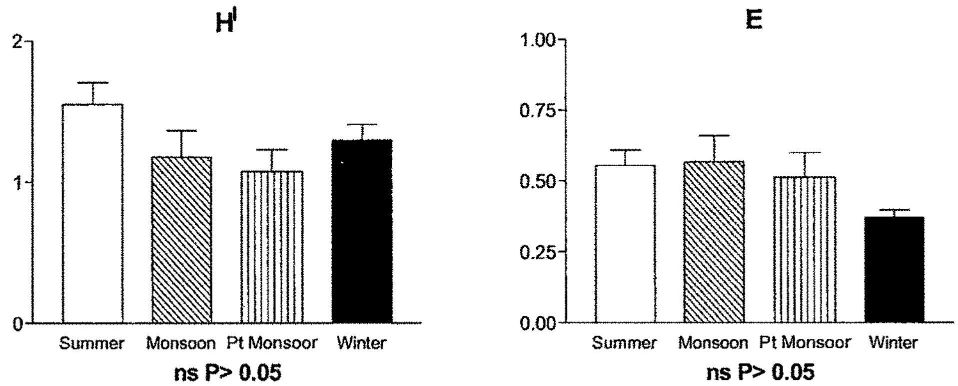


Table 1a: The Bird density, Species richness, Diversity and Evenness at Wadhwana Irrigation Reservoir during March 2005 to May 2007.

	Total Birds				Group I		Group II		Group III		Group IV	
SEASONS	Density#	Sp.Rich.	Diversity	Evenness	Density#	Sp.Rich.	Density#	Sp.Rich.	Density#	Sp.Rich.	Density#	Sp.Rich.
Summer	943.2 ±176.10	18.24 ±1.30	1.55 ±0.15	0.55 ±0.05	0.71 ±0.21	0.88 ±0.24	212.4 ±45.48	3.5 ±0.40	144.9 ±41.69	10.94 ±0.74	0.71 ±0.21	0.88 ±0.24
Monsoon	55.25 ±22.71	7.2 ±1.92	1.18 ±0.18	0.56 ±0.09	0.39 ±0.16	0.63 ±0.27	2.05 ±1.22	0.5 ±0.26	11.57 ±5.54	3.66 ±1.25	0.39 ±0.16	0.63 ±0.27
Postmonsoon	1221 ±512.5	11.08 ±1.88	1.07 ±0.15	0.51 ±0.08	1.12 ±0.23	1.5 ±0.313	235.2 ±190.6	1.83 ±0.86	66.72 ±57.53	5 ±0.47	1.12 ±0.23	1.5 ±0.313
Winter	4364 ±985.5	31.08 ±3.2	1.2 ±0.11	0.37 ±0.02	2.37 ±0.90	2.16 ±0.34	1996 ±1027.0	10 ±0.80	479.5 ±207.80	12.5 ±1.59	2.37 ±0.90	2.16 ±0.34
Seasonal Variation	***	***	ns	ns								

Table 1b: The Bird density, Species richness, Diversity and Evenness at Timbi Irrigation Reservoir during February 2005 to March 2007

	Total Birds				Group I		Group II		Group III		Group IV	
SEASONS	Density#	Sp. Rich	Diversity	Evenness	Density#	Sp. Rich	Density#	Sp. Rich	Density#	Sp. Rich	Density#	Sp. Rich
Summer	608 ±241.4	14.87 ±1.47	1.99 ± 0.18	0.81 ±0.11	289.3 ±183.7	2.4 ±0.27	148.2 ±80.37	2.93 ±0.39	167.7 ±71.59	9.33 ±0.80	2.78 ±2.44	0.53 ±0.40
Monsoon	82.1 ±19.17	7.91 ±1.11	1.66 ±0.15	0.75 ±0.070	9.62 ±2.93	1.3 ±0.28	11.26 ±6.03	0.83 ±0.32	57.74 ±13.8	5.41 ±0.71	1.6 ±1.22	0.33 ±0.18
Postmonsoon	254.5 ±125.8	9.25 ±1.20	1.67 ±0.15	0.76 ±0.06	160.3 ±102.5	1.25 ±0.17	22.32 ±12.17	1.16 ±0.51	53.85 ±11.4	6.33 ±0.65	1.2 ±0.47	0.5 ±0.19
Winter	4186 ±1200	16.54 ±1.33	1.49 ±0.24	0.65 ±0.11	3061 ±1062	2.07 ±0.30	1012 ±497.6	5.76 ±0.57	106 ±50.96	7.46 ±0.91	4.1 ±0.97	1.23 ±0.28
Seasonal Variation	***	***	ns	ns								

ns – P> 0.05, * -P< 0.01, **-P<0.001, ***-P<0.0001

- Density- (Birds/sqkm)

Timbi Irrigation Reservoir: (TIR)

Figure 1.2a: Total Bird Density and Total Species richness of birds in 4 seasons from February 2005 to March 2007 at Timbi Irrigation Reservoir.

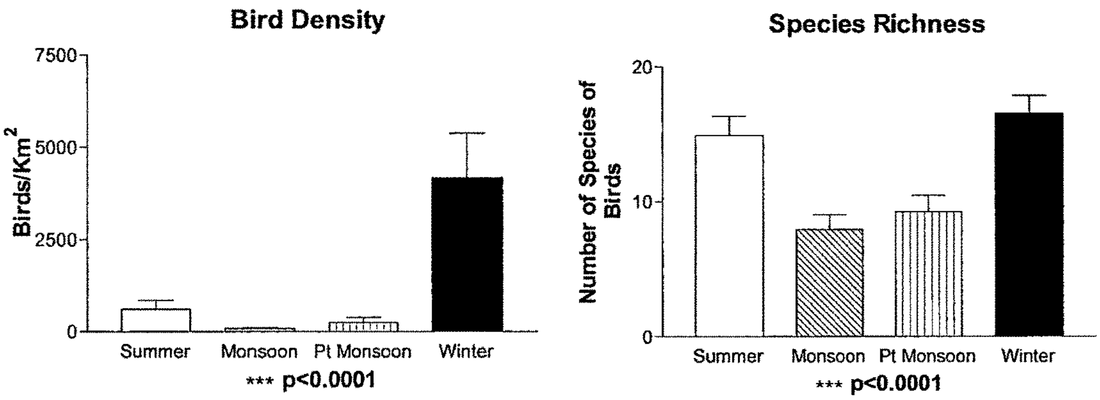


Figure 1.2b: Bird Density of different groups in 4 seasons from February 2005 to March 2007 at Timbi Irrigation Reservoir.

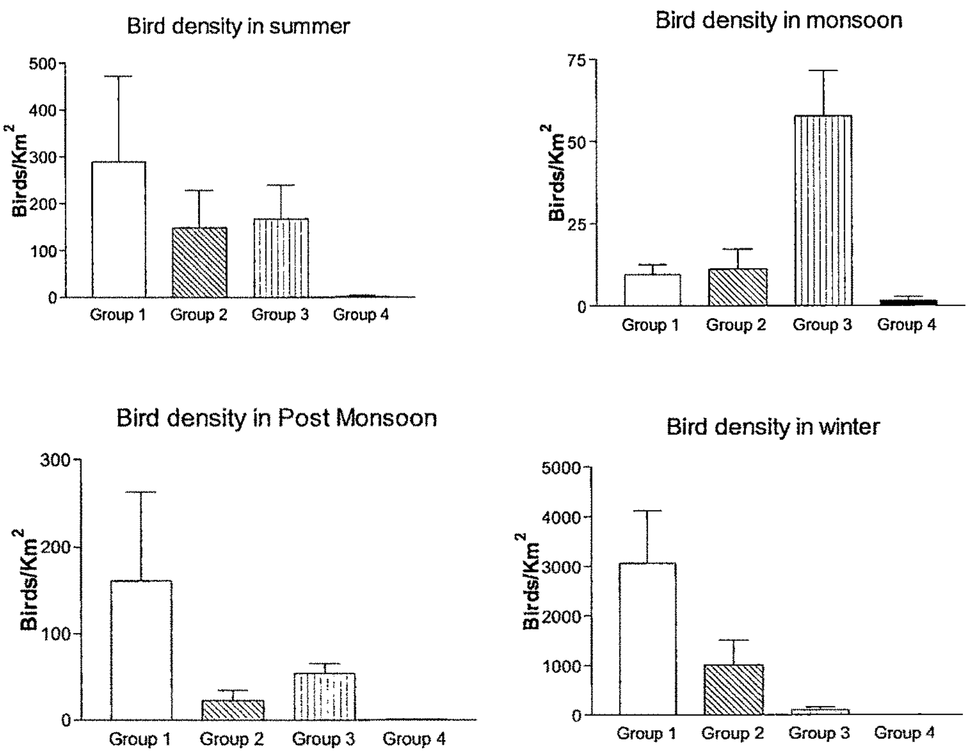


Figure1.2c: Species Richness of different groups in 4 seasons during February 2005 to March 2007 at Timbi Irrigation Reservoir.

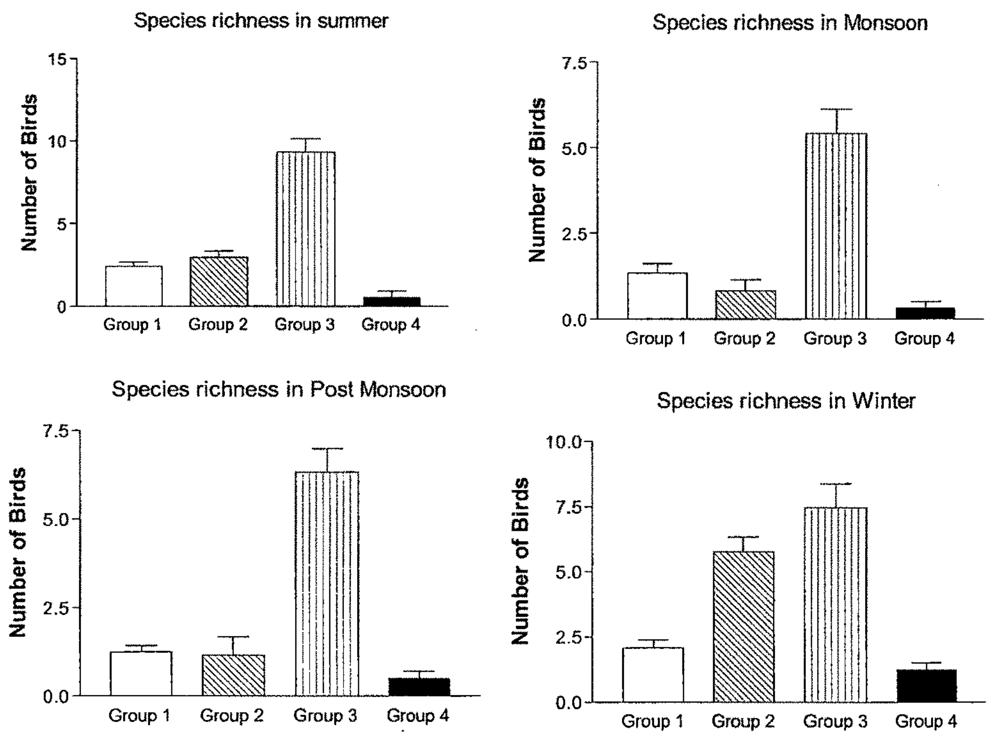


Figure 1.2d: The percentile distribution of Migratory and resident species of Birds in all the four seasons during February 2005 to March 2007 at Timbi Irrigation Reservoir.

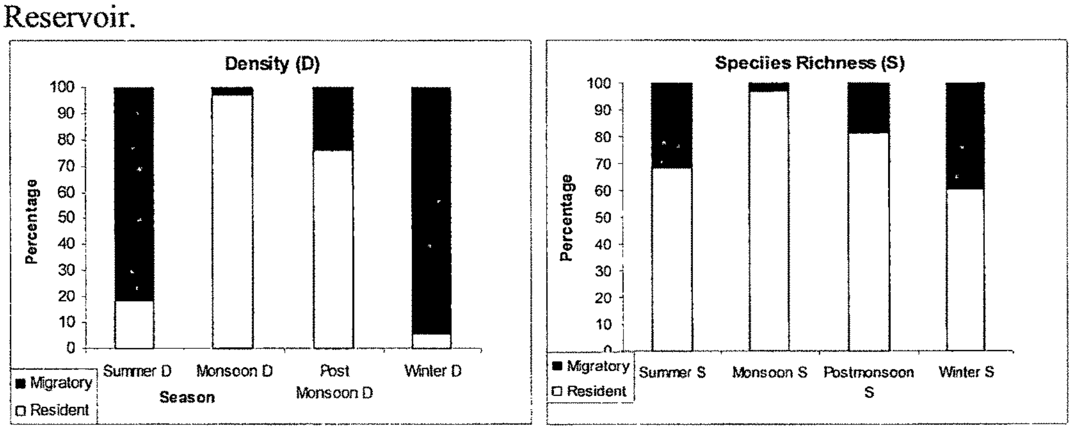
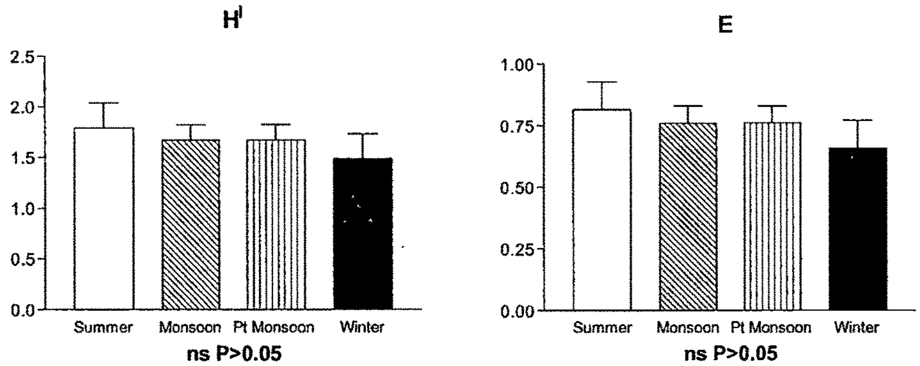


Figure: 1.2e: The Shannon- Weiner index ($H^{/}$) and the Evenness (E) of Birds at Timbi Irrigation Reservoir.



When the percentage of the Resident and Migratory birds is considered it is noted that TIR is always dominated by the resident species of birds with maximum 96.84 % during monsoon and minimum 60.46 % during winter. During postmonsoon the resident species dominate by 81.39 % and 68.75 % in summer (Fig.1.2d). However, when the density is compared, the density of migratory birds is high during winter (94.4%) and summer (81.3%) while other two seasons are dominated by the density of resident birds with 97.25 % during monsoon and 76.13 % during Post monsoon.

The Shannon wiener diversity index H' at TIR during summer was 1.7 ± 0.24, and during monsoon it was 1.6 ± 0.15 and it remained constant during postmonsoon at 1.6 ± 0.15 and was minimum during winter at 1.4 ± 0.24. TIR is always having higher H' values than WIR. The birds are more evenly distributed during summer (0.8 ± 0.11) followed by monsoon (0.7 ± 0.07) and the equitability is maintained during postmonsoon (0.7 ± 0.06) and was minimum during winter (0.6 ± 0.11) (Fig.1.2e). Like WIR at TIR also the variations are statistically non-significant with $F_{3,48}$, 0.83, $P > 0.05$ in diversity and $F_{3,48}$, 0.99, $P > 0.05$ in equitability.

Masar Village Pond: (MVP)

As noted for the reservoirs (WIR and TIR) at the Masar village pond also the density is maximum during winter, with 23450 ± 3963 birds/km^2 and minimum during monsoon with 2928 ± 1420 birds/km^2 (Fig. 1.3a). The species richness is also maximum during winter (23.2 ± 1.14) and minimum during monsoon ($7.58 \pm$

1.36) with highly significant variations in the means of density ($F_{3, 47}$ 13.1, $P < 0.0001$) and species richness ($F_{3, 47}$ 25.2, $P < 0.0001$), across the four seasons. At MVP it is evident from Fig. 1.3b that as far as the density is concerned, the Group 2 (ducks) dominates the wetland all throughout the year with 16930 $\pm$ 3175 birds/km^2 during winter followed by 7949 $\pm$ 1444 birds/km^2 during summer, 2184 $\pm$ 641 birds/km^2 during monsoon and 2767$\pm$ 1139 birds/km^2 during postmonsoon. However, when the species richness is considered (Fig. 1.3c), though Group 3 dominates all throughout the year as noted for WIR and TIR, the trend is similar to that observed at TIR. At MVP maximum species richness is noted during summer (10.5 $\pm$ 1.6) and minimum during monsoon (4.0 $\pm$ 0.79).

Masar Village Pond:(MVP)

Figure 1.3a: Total Bird Density and total Species richness of birds in 4 seasons from February 2005 to March 2007 at Masar Village Pond.

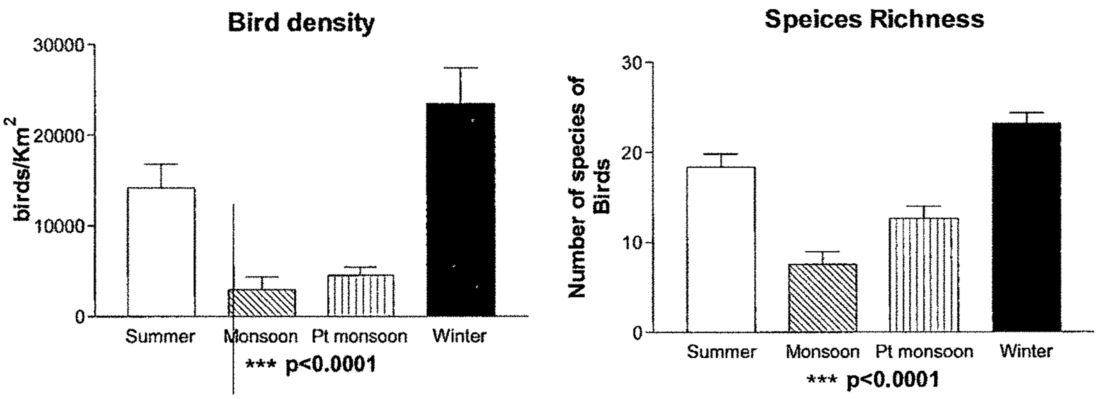
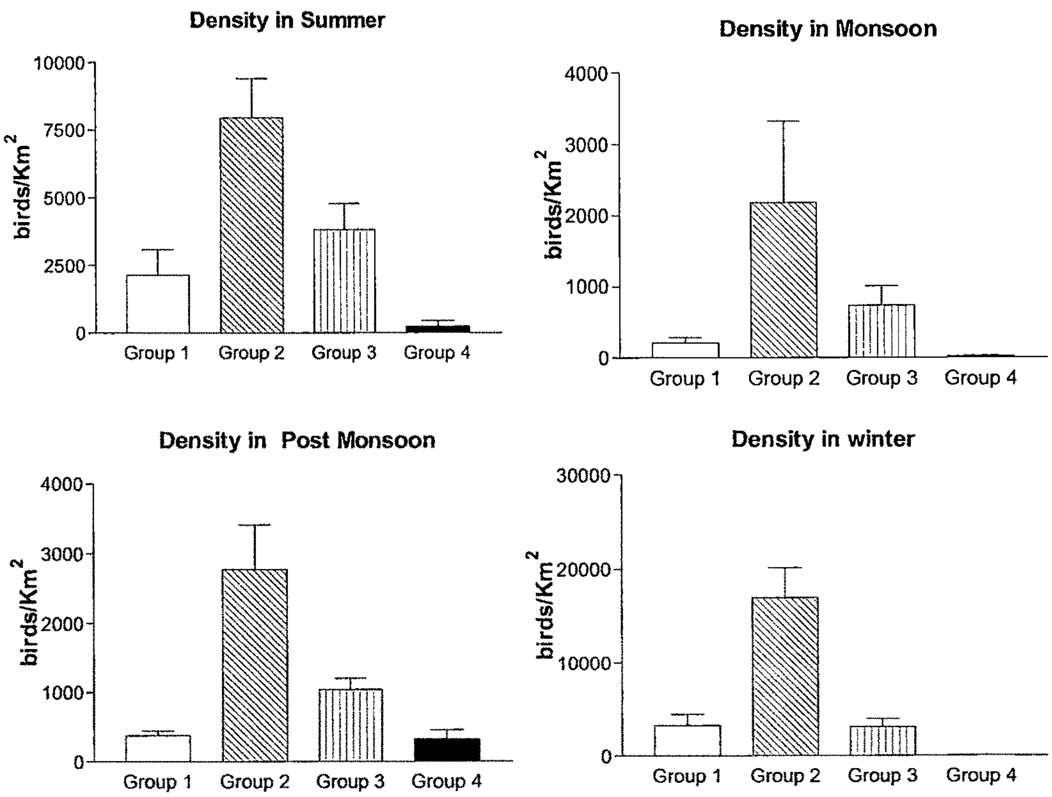
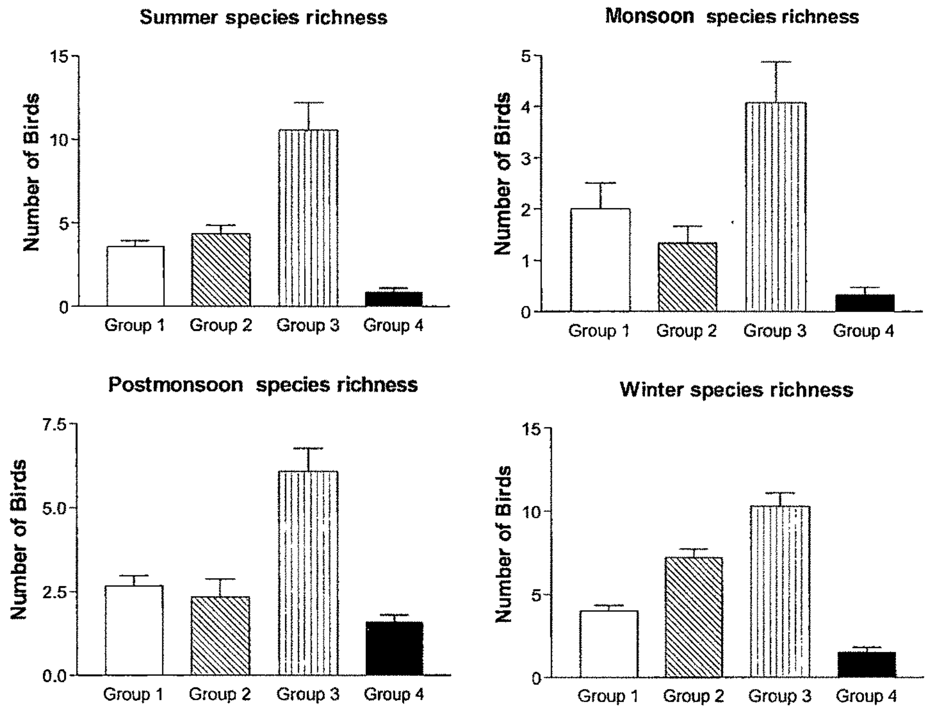


Figure1.3b: Bird Density of different groups in 4 seasons from February 2005 to March 2007.at Masar Village Pond.



Figurel.3c: Species Richness of different groups in 4 seasons from February 2005 to March 2007 at Masar Village Pond.



Figurel.3d: The percentile distribution of Migratory and resident species of Birds in all the four seasons from February 2005 to March 2007 at Masar Village Pond.

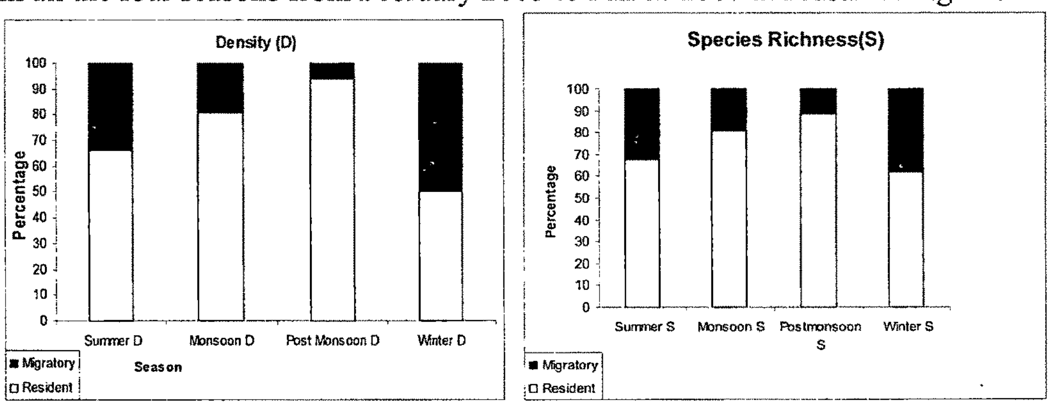
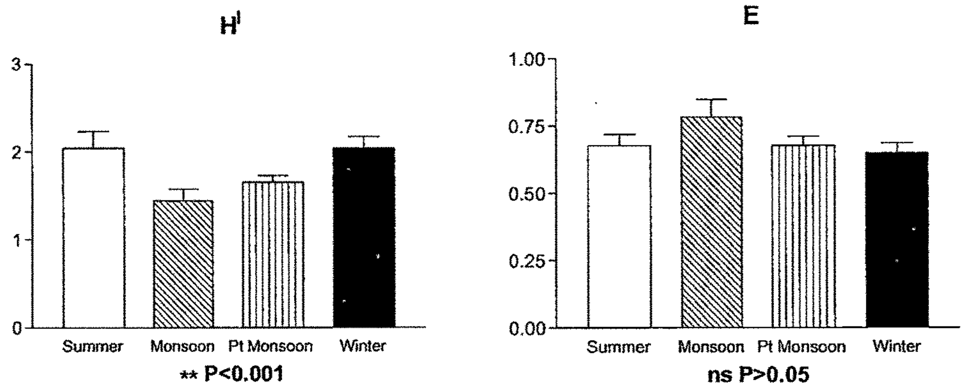


Figure: 1.3.e: The Shannon- Weiner index (H') and the Evenness (E) of Birds at Masar Village Pond.



The percentile distribution of bird density at MVP indicates (Fig. 1.3d), that the resident birds are dominating the area during three seasons summer, monsoon and postmonsoon with respect to density with 94.02 % during postmonsoon, 80.45% during monsoon and 66.14% during summer. During winter the resident and migratory birds equally inhabit the pond and hence their occurrence at pond is about 50% each. The percentile distribution of species richness shows the dominance of the resident species of birds (Fig. 1.3d) in the area throughout the year with maximum 88.7 % during postmonsoon and minimum 61.83% during winter. However, the resident species dominated with 80.47 % during monsoon and 67.5% during summer.

The species diversity (H') at MVP is noted to be same during summer (2.0 ± 0.18) and winter (2.0 ± 0.12) while during monsoon it was minimum (1.4 ± 0.13) and during postmonsoon it was almost retained (1.6 ± 0.07). Seasonal variations in the equitability E of MVP are more comparable to TIR. At MVP the birds are most evenly distributed during monsoon (0.7 ± 0.06). The equitability (E) is same during postmonsoon (0.67 ± 0.03) and summer (0.67 ± 0.04) and winter (0.65 ± 0.03). Significantly significant variations ($F_{3, 44}$ 4.6 $P < 0.001$) are noted in the diversity, across the season while evenness varies non significantly ($F_{3, 44}$ 1.615, $P > 0.05$) (Fig1.3e).

Table 1c: The Bird density, Species richness, Diversity and Evenness at Masar Village Pond during February 2005 to March 2007

	Total Birds				Group I		Group II		Group III		Group IV	
SEASONS	Density#	Sp. Rich	Diversity	Evenness	Density#	Sp. Rich	Density#	Sp. Rich	Density#	Sp. Rich	Density#	Sp. Rich
Summer	14160 ±2623	18.36 ±1.47	2.04 ±0.18	0.67 ±0.04	2135 ±939	3.571 ±0.34	7949 ±1444	4.35 ±0.50	3804 ±985.5	10.57 ±1.64	244.5 ±199.7	0.85 ±0.25
Monsoon	2928 ±1420	7.58 ±1.36	1.44 ±0.13	0.78 ±0.06	209.4 ±79.3	2± 0.50	2184 ±1139	1.33 ±0.33	735.3 ±272.4	4.08 ±0.79	22.28 ±10.32	0.33 ±0.14
Postmonsoon	4510 ±891.8	12.67 ±1.32	1.65 ±0.07	0.67 ±0.03	374.3 ±67.1	2.66 ±0.30	2767 ±641	2.33 ± 0.54	1043 ±160.5	6.0 ±0.67	325.3 ±131.4	1.58 ±0.22
Winter	23450 ±3963	23.23 ±1.14	2.04 ±0.12	0.65 ±0.03	3324 ±1105	4 ±0.35	16930 ±3175	7.23 ±0.49	3102 ±834.7	10.31 ±0.78	90.5 ±17.5	1.53 ±0.29
Seasonal Variation	***	***	**	ns								

Table 1d: The Bird density, species richness, diversity and Evenness at Harni Village Pond during February 2005 to March 2007

	Total Birds				Group I		Group II		Group III		Group IV	
SEASONS	Density#	Sp. Rich	Diversity	Evenness	Density#	Sp. Rich	Density#	Sp. Rich	Density#	Sp. Rich	Density#	Sp. Rich
Summer	1063± 116.3	14.57 ±0.73	2.09 ±0.12	0.75 ±0.03	1228 ±726.4	6.07 ±0.26	285.7 ±39	2.5 ±0.22	173.9 ±16.72	5.21 ±0.29	7.7 ±2.7	0.64 ±0.22
Monsoon	568.3 ±100.2	11.08 ±1.12	2.18 ±0.08	0.77 ±0.02	258 ±43.4	5.83 ±0.58	81.33 ±30.9	1 ±0.21	221.9 ±56.4	3.75 ±0.50	7.02 ±2.7	0.58 ±0.22
Postmonsoon	1229 ±24.3	13.67 ±0.99	2.24 ±0.07	0.79 ±0.02	564.3 ±87.3	6.41 ±0.28	380.5 ±139.8	1.91 ±0.28	242 ±71.5	4.08 ±0.45	13 ±4	1.08 ±0.33
Winter	1890 ±235.8	17 ±0.60	2.47 ±0.02	0.79 ±0.06	924.9 ±92.4	6.92 ±0.23	633 ±122.6	3.23 ±0.16	317.9 ±4.5	5.53 ±0.36	13.9 ±4	1.15 ±0.33
Seasonal Variation	***	***	*	ns								

ns – P> 0.05, * -P< 0.01, **-P<0.001, ***-P<0.0001

Density- (Birds/sqkm)

Harni Village Pond (HVP):

At HVP also the birds occupy the pond maximally during winter (Fig.1.4a) with highest density of 1890 $\pm$ 235.8 birds/km^2 and species richness of 17 $\pm$ 0.6 while the minimum birds are observed during monsoon with density of 568.3 $\pm$ 100.2 birds/km^2 and species richness of 11.0 $\pm$ 0.1. The mean species richness ($F_{3,47}$ 7.7, $P < 0.0001$) and density ($F_{3,47}$ 7.8, $P < 0.0001$) of birds vary highly significantly across the four seasons.

At HVP that the Group 1(Coots, Cormorants and Jacanas) dominates the area all-throughout the year without any exception with respect to both, the bird density and the species richness. However, seasonal variations in the density (Fig. 1.4b) of these birds is maximum during summer (1228 $\pm$ 726.4 birds/km^2), followed by winter (924.9 $\pm$ 92.4 birds/km^2), postmonsoon (564.3 $\pm$ 87.3birds/km^2) and monsoon (258 $\pm$ 43.4 birds/km^2). The Species richness (Fig. 1.4c) varies with 6.9 $\pm$ 0.23 during winter, 6.0 $\pm$ 0.2 during summer, 5.8 $\pm$ 0.58 during monsoon and 6.4 $\pm$ 0.2 during postmonsoon.

The dominance of the resident species at HVP can be seen throughout the year (Fig. 1.4d). The resident bird density dominates with maximum of 93.98 % during monsoon, 86.36 % during summer, 86.1 % during postmonsoon and 78.51 % during winter. The resident species also dominate with respect to the species richness with maximum 92.53 % during monsoon, 90.05 % during summer, 86.66% during postmonsoon and 80% during winter.

Harni Village Pond: (HVP)

Figure1.4a: Total Bird density and total Species richness in 4 seasons from February 2005 to March 2007 at Harni Village Pond.

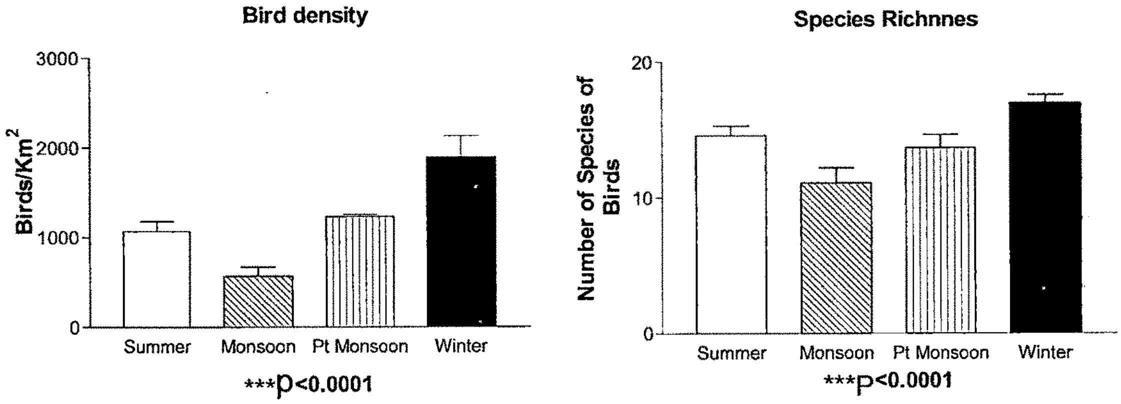


Figure1.4b: Bird Density of different groups in 4 seasons from February 2005 to March 2007 at Harni Village Pond.

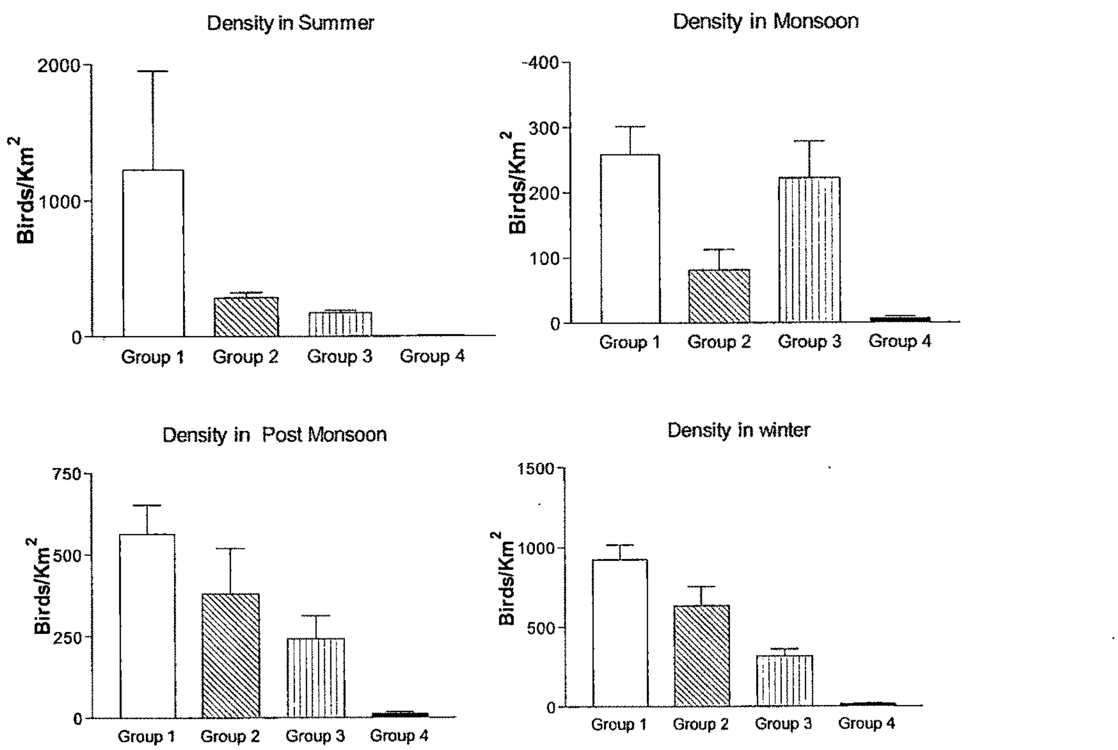


Figure1.4c: Species Richness of different groups in 4 seasons from February 2005 to March 2007 at Harni Village Pond.

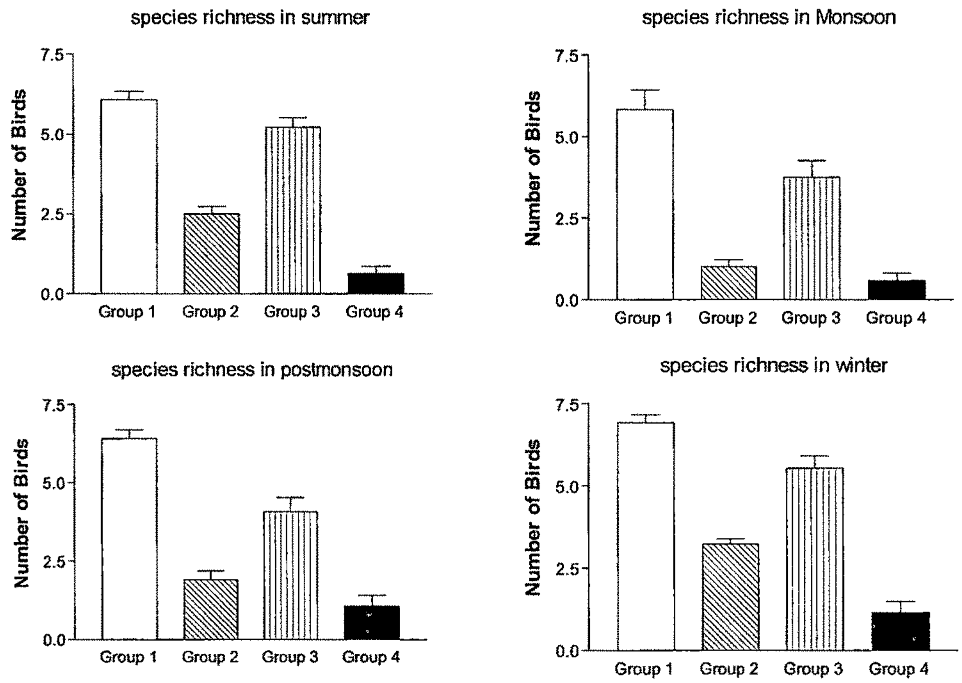


Figure1.4d: The percentile distribution of Migratory and resident species of Birds in all the four seasons from February 2005 to March 2007 at Harni Village pond.

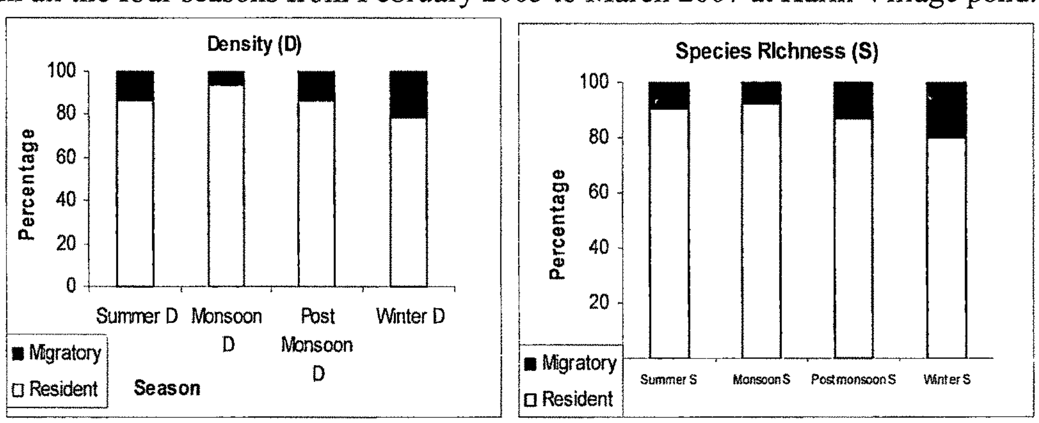
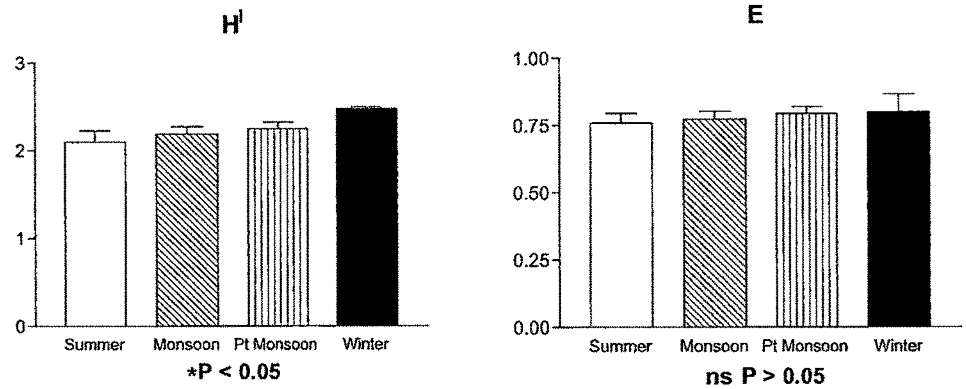


Figure: 1.4.e: The Shannon- Weiner index (H') and the Evenness (E) of Birds at Harni Village Pond.



The diversity index H' was maximum at HVP among all the four wetlands studied. It was maximum during winter (2.4 ± 0.02) and was minimum during summer (2.0 ± 0.12) that was higher than the diversity indices (H') of other wetland during any season. During monsoon it was 2.1 ± 0.08 and during postmonsoon it was 2.2 ± 0.07. The equitability of birds at HVP was almost constant all throughout the year with 0.75 ± 0.03 during summer, 0.7 ± 0.02 during monsoon, 0.7 ± 0.02 during postmonsoon and 0.7 ± 0.06 during winter. The variation in the diversity was significant at HVP ($F_{3, 46}$ 3.4, $P < 0.05$) while the evenness was varying insignificantly ($F_{3, 46}$ 0.19, $P > 0.05$).

The list of various species observed during present study at the four wetlands is given in Annexure: I.

When only summer congregation of birds at WIR and TIR during 3 years (2005, 2006 and 2007), are considered (Table 1.1), it is observed that at WIR the density of birds was 943.2 ± 176.1 birds/km^2 and at TIR it was 608.0 ± 241.4 birds/km^2. At WIR during summer 2005, 163 and during 2006 summer 150 comb Ducks *(Sarkidiornis melanotos)* were observed which increased to 820 individuals during summer 2007. The Lesser Whistling Teal *(Dendrocygna javanica)* population was also continuously increasing with 150 during summer 2005, 300 during summer 2006 and 325 during 2007. (In 2008 summer when this thesis is being written visit the number increased to 750 individuals).

Table: 1.1 Waterfowl density at WIR and TIR during summer of 2005, 2006 and 2007.

	2005	**2006**	**2007**
WIR birds/km²	701 ± 299.9	1036 ± 450.0	1092 ± 206.2
TIR birds/km²	511.4 ± 381.5	197.8 ± 28.27	2037 ± 702.7

Table: 1.2 Correlation of Birds with various abiotic factors at all the four sites during February 2005 to May 2007.

	WIR	TIR	MVP	HVP
Acidity	0.11	-0.25	0.24	-0.06
Bicarbonate Alkalinity	0.05	-0.27	0.30*	-0.12
Calcium Hardness	-0.21	-0.03	0.21	0.03
Chloride	0.11	-0.09	0.04	-0.25
Carbondioxide	0.75**	0.48	0.42**	-0.08
Dissolved oxygen	-0.04	-0.02	-0.42**	-0.37**
Total Hardness	-0.03	0.00	-0.01	0.05
Mollusc	-0.22	0.35*	0.11	0.24
Nitrite	-0.15	-0.03	-0.22	-0.31
Nitrate	-0.37	-0.10	-0.27	0.14
pH	-0.06	-0.04	0.20	0.08
Hydroxyl Alkalinity	-0.16	0.50**	-0.10	-0.07
Plankton	-0.06	0.25	0.34*	-0.04
Phosphates	0.26	-0.14	-0.04	-0.37*
Salinity	-0.02	-0.09	0.04	-0.25
TDS	-0.21	-0.20	-0.31	-0.28
Temperature	0.22	0.23	0.50**	0.35*
TS	-0.11	-0.15	-0.02	-0.05
TSS	0.58**	0.88**	-0.20	-0.07
Water cover	0.16	0.06	-0.48**	-0.11

***- Significance at the level of 0.05**
****-Significance at the level of 0.01**

The correlation between the birds and various abiotic, as well as biotic factors at all the four study sites have also been studied. As shown in Table 1.2. the factors that are correlated at 0.01 level of significance are considered over here. At WIR the positive correlation of bird density is obtained with carbondioxide and TSS with the correlation coefficient of 0.75 and 0.58 respectively (Fig.1.5a). At TIR the hydroxyl alkalinity (0.50) and the TSS (0.88) are positively correlated with bird density (Fig.1.5b). At MVP four factors of which Carbondioxide (0.42) and Temperature (0.50) are positively correlated and Dissolved Oxygen (-0.42) and Water cover (-0.48) are negatively correlated with the bird density (Fig.1.5c). However, at HVP, the bird density is negatively correlated with Dissolved Oxygen (-0.37) and positively correlated with Temperature (0.35) (Fig.1.5d). The details are considered in Chapter IV.

Figure 1.5a: Correlation between carbondioxide and Bird density at Wadhwana Irrigation Reservoir.

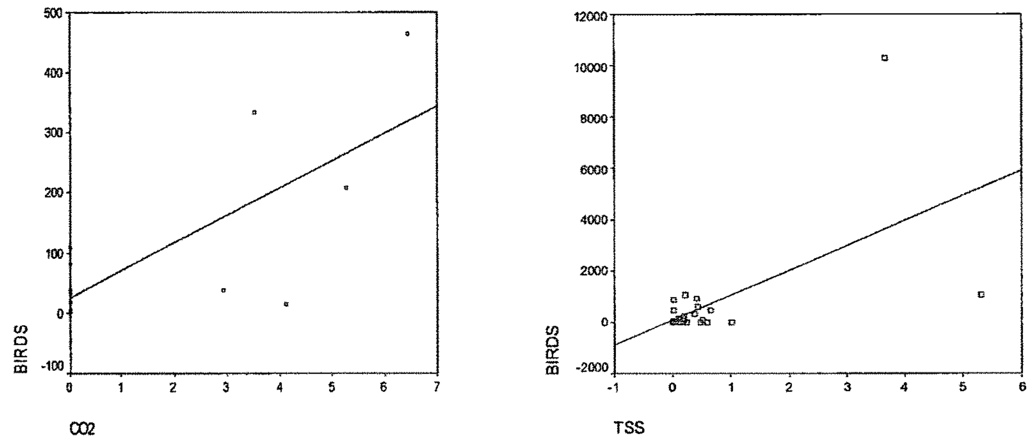


Figure 1.5b: Correlation between Bird density and TSS at Timbi Irrigation Reservoir.

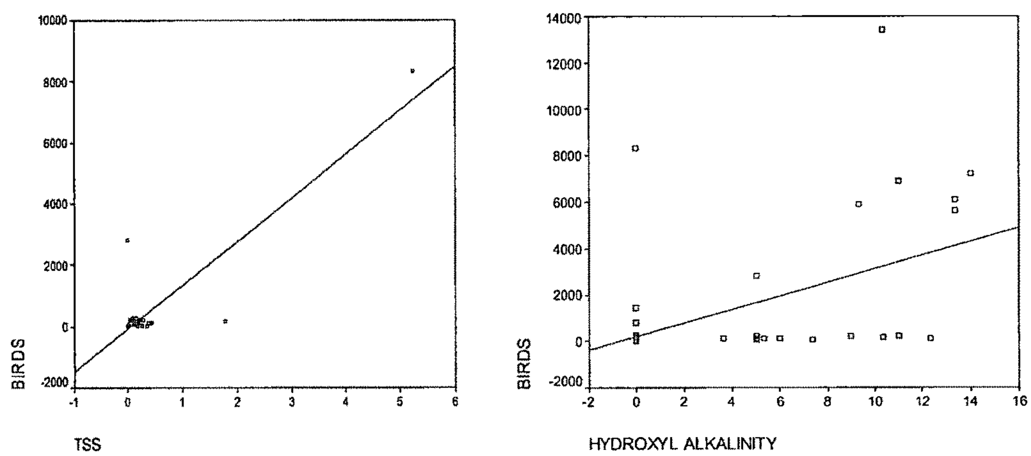


Figure 1.5c: Correlation between Bird density and Temperature at Masar Village Pond.

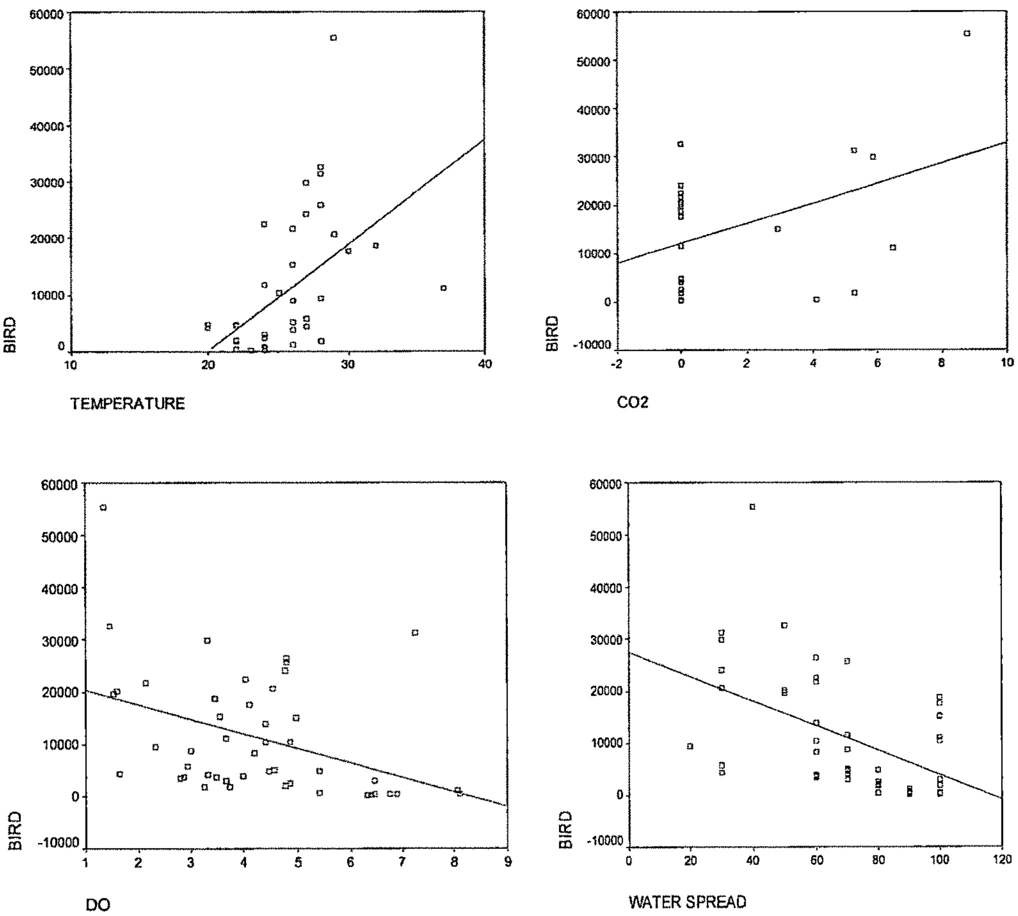
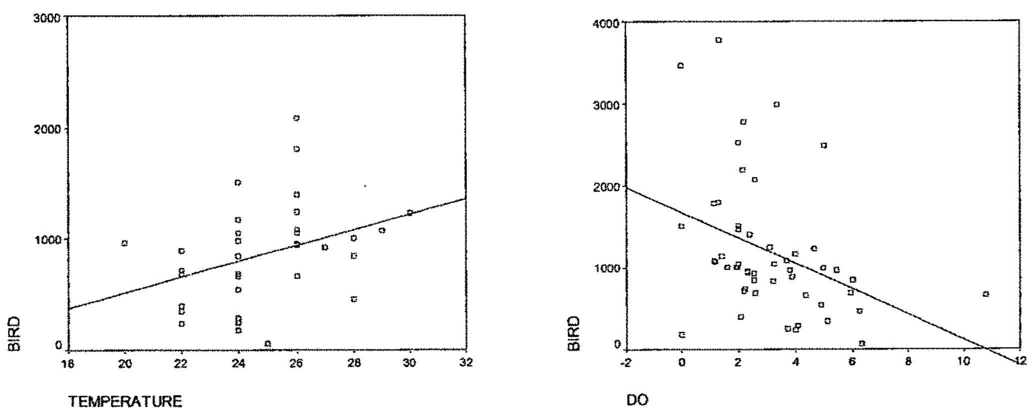


Figure 1.5d: Correlation between Bird density and Phosphate at Harni Village Pond.



DISCUSSION:

Density and Species richness:

To overcome the scarcity of water prevailing in the semi-arid zone of central Gujarat, several artificial water bodies were constructed. Apart from being used by the human being, these water bodies also form important habitats for several avian species. The management of such habitats irrespective of their sizes, for conservation of nature, is necessary (Kushlan, 1986b). To study any ecosystem the birds serve as important bio-indicators as they have the ability to fly and avoid any obnoxious condition. Hence, they are considered as important health indicators of the ecological condition and productivity of an ecosystem (Newton, 1995; Desai and Shanbhag, 2007; Li and Mundkur, 2007). The most important parameters of the bird study are the species richness (Nilsson and Nilsson, 1978; Weller, 1978; Murphy *et al.*, 1984), their density (Patterson, 1976; Nilsson and Nilsson, 1978) and diversity (Krebs, 1989). 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 MacMahon, 1981; Nudds, 1983; Powell, 1987; Bethke *et al.*, 1993). Present study also confirms these results (Figs. 1.1a, 1.2a, 1.3a, 1.4a). It is noted that, the density and species richness are maximum during winter (the peak migratory season) and minimum during monsoon (when the migratory populations of birds leave the area and the resident species are engaged in the nesting activities).

Considering the group wise distribution it is observed that during the peak migratory season the winter (December, January and February) Group 2 birds dominate in density at WIR (Fig. 1.1b) and MVP (Fig 1.3b), mainly due to migratory duck population that are utilizing the wetlands. The ducks with different feeding habits *i.e.* the dabbling ducks (Gadwall: *Anas streper* and Garganey : *Anas querquedula*), the diving ducks (Pochards) and the Marsh ducks (Showeller: *Anas clypeata)*, (Grimette, 1998) inhabit different microhabitats of the wetlands. This proves that both the sites are potent enough to sustain the load of large population of ducks. This reduces the competition for the food resources which is known to be the limiting factor for the distribution of ducks (Tramer, 1969, Green, 1998). At WIR, with ducks (Group 2) large number of Coots and Cormorants (Group 1) equally utilize the wetlands during winters (Fig. 1.1b) (Plate V. B and Vi. B). Here, 1430 acre water cover with its adjoining agricultural fields supports more than 50, 000 birds during winter. At TIR (Fig. 1.2b) and HVP (Fig. 1.4b) the Group I birds dominate the area with high density during winter which is mainly because of the migratory population of Common Coot (*Fulica atra*) at TIR and resident species like Jacanas at HVP. HVP is subjected to a certain level of eutrophication with floating and submerged vegetation that creates a favourable habitat for Jacanas and Moorhens (Plate XI.A). Moreover, during this time the presence of juveniles of these birds are also observed increasing the overall density of the Group 1 birds.

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 is noted during summer at WIR (Fig.1.1b) where the algae starts drying and the dead algae float over the water creating not only the suitable habitat for walking for the birds like Jacana but also hosts several microorganisms making it one of the best feeding habitat. Further, at TIR and HVP (Plate XI A) the exposure of vegetation due to decline in water level during summer creates suitable hiding places in and around the wetland. Group 1 birds Cormorants (*Phalacrocorax niger*) are the dominant species at TIR (Fig.1.2b) while both the species of Moorhens (*Gallinula chloropus and Porphyrio porphyrio*) are abundant at HVP (Fig.1.4b). However at MVP (Fig 1.3b) the dominating Group during summer is Group 2 (Ducks). The congregation of birds is observed during early summer when the surrounding water bodies start drying and few late migrants congregate at MVP. This is the period when the food intake needs to be high to enable the birds to build up nutrient reserves in advance for high energy demand during their return journey (Owen and Cook, 1977; Pienkowski *et al.*, 1984; Ebbinge, 1989; Fox *et al.*, 1992; Own *et al.*, 1992 and Madsen, 1994.). Hence the habitat of MVP with good food availability is favourable. Moreover the resident species of ducks also congregate to such water bodies as they have to build up nutrients for the forthcoming breeding period.

During study period both the monsoons were heavy and thereby all the study sites were found flooded (Plate IV.A, B, VII.B, VIIIA, IX.B, XI.B). This has clearly indicated its impact on the density of the water birds, by being extremely low. The dominating group at both the irrigation reservoirs during monsoon is Group 3 waders. It is known that the waders do prefer shallow water with marshes, where food can be easily accessed (Bancroft *et al.,* 2002). However, the dominance in the density of Group 3 is mainly because of the Egrets, Herons and Storks that were observed in the agricultural fields surrounding the reservoirs. Agricultural fields provide a wide variety of avian habitats that vary seasonally (Sundar, 2006). Some of the birds were observed at the outlet point of the reservoir in shallow water. At MVP the Group 2 birds (ducks) dominate the reservoir during monsoon, when the resident species of ducks such as the Comb duck (*Sarkidiornis melanotos*) and the Lesser whilstling Teal *(Dendrocygna javanica)* are benefited. However, at HVP the group 1 dominates with the species like Cormorants and Grebes *(Tachybaptus ruficollis).*

During post monsoon the water levels are high at all the wetlands and hence the Group 1 birds especially the Cormorants are found in abundance. Cormorants are known to fish at greater depth (Lea *et al.*, 1996). Moreover in the month of October and November the migratory population of Coots start arriving at the wetlands increasing in their dominance. Among other species from Group 2 and 3 resident species are still engaged in their nesting activity while migratory species just start arriving and their occurrence at the wetland is in minority.

With respect to the species richness the Group 3 (Waders), being the largest group dominates all the wetlands (Fig. 1.1c, 1.2c, 1.3c) except HVP (Fig.1.4c). Seasonal fluctuations in water levels in natural habitats are known to cause cyclic variations in abundance of birds (Powell, 1987; Bancroft *et al.*,, 2002). These fluctuations also changes the availability of food resources for large adding water birds in turn changing their foraging behaviour (Kushlan, 1979; González, 1997). The seasonal variations in the dominance of Group 3 are noted in the present study too. During winter, the productivity of waterbody is stabilized and the food is easily accessible. This attracts the migratory species of wading birds and also increases the species richness. During summer though the water level is low, food is aggregated in small ponds where it becomes easy to obtain. This again creates a favourable foraging habitat for the birds. During monsoon and postmonsoon although the water level is high the waders are seen to be dominating as the nestlings of Egrets and the Storks leave the nest and start visiting water logged fields around the wetland.

The higher percentile density of migratory birds, compared to resident species at WIR (Fig. 1.1d) during postmonsoon indicates early arrival of the migratory species at WIR. Similar situation occurs at TIR during early summer (Fig.1.2d), here it is related to the late departure of migratory birds. The migratory ducks like Garganey (*Anas querquedula*) waders like Sandpipers are observed till late April. At the village ponds the migratory population is not observed to exceed the resident bird population. 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 (Rathod *et al.*, 2008, Traut, 2003).

Many human decisions bring about the changes in the natural habitat. Some of these human actions like inundation from larger reservoir, protection, ecotourism, *etc.*, have positive effects at global scale, whereas some others like urbanization, sewage disposal, draining wetland *etc.* cause negative effect. These negative effects leads to the loss of habitat, such as create patchiness, reduce the area and may result in disappearance of (Finlayson, 1992; Paracuellos., 2006). This in turn affects negatively the fauna, specially the waterfowl (Owen and Black, 1990). Padate *et al.* (2008) have reported positive influence of human decisions at WIR. Wherein, the highly significant increase on the diversity and species richness is noted. Further, the awareness among the local people, regarding pollution and the sustainable use of water has led to the conservation of the MVP. Although the number of studies that describe avian responses to urbanization are immense and growing through out the world (Marzluff, 2001) such studies are meager in India and creates lacunae in the knowledge. No such awareness is observed at HVP where the immense pressure of urbanization has led to the degradation of the wetland. This is indeed considered the main factor responsible for the degradation (Boyer and Polasky, 2004). According to Hoyer and Canfield (1994), at urban lakes there is similarity in community composition throughout the year which indicates that there is not only relatively stable avian community from one season to the next, but also from year to year. This is very well observed at HVP with the

Group 1 dominating the wetland throughout the year in both the aspects of density and species richness. According to Paracuellos (2006) generalized species get adapted to any kind of habitat. This is also observed at HVP. Many of the migratory species observed a decade ago (Padate and Sapna, 1996) are completely lacking at HVP or if present only few were observed during present study. An interesting observation is noted with reference to bird density when density is calculated per km^2 area the density is high at rural undisturbed village pond at Masar as compared to the large irrigation dam at Wadhwana (Fig. 1.2a and 1.3a). This indicates that though WIR supports large congregations of birds the Masar village Pond supports good diversity and density of birds.

Diversity indices: Shannon wiener (H') and Evenness (Equitability) (E).

When the four wetland studied are compared, the $H'$and E are always high at HVP and low at WIR. The smaller wetland with low species richness shows higher diversity than the larger wetland with higher species richness. Heterogeneity is known to be higher in a community when there are more species and also when the species are equally abundant (Krebs, 1985). In the smaller pond like HVP the number of species is low leading to higher evenness however at larger wetland species richness is high, in proportion resulting into low evenness.

A large number of species increases the species diversity and a more even or equitable distribution among species will also increase the species diversity H', measured by Shannon Wiener index. The lower species diversity H' at Wadhwana could be because of the fluctuating bird population due to unplanned inundation of

Narmada water. As far as ducks are concerned, at WIR, influence of Narmada water inundation with higher water level supporting diving ducks like Pochards and shallow water supporting Marsh ducks has been reported (Padate *et al.*, 2008). The fluctuating water levels probably resulted in low seasonal H' with higher SEM. H' ranges from 0.7 to 2.0 during three months of winter where on one side Narmada water is brought to the reservoir and on other side water is given for irrigation of Rabi crop disturbing the water level. E equitability depends on H' as $E = H' / H$ max. Among the four wetlands studied the larger wetland (WIR) has low equitability (evenness) whereas smaller wetland (HVP) has higher equitability. Low and variable E perhaps appears to be general characteristics either of early succession or of ecosystem containing opportunistic species (Krisher, 1997). This could be the situation at WIR as the reservoir of WIR which used to dry up completely during summer (Plate III.A) now retains water all throughout the year because of inundation from Narmada (Plate III.B). The inundation from Narmada has started recently in the beginning of 21^{st} century and hence the ecosystem is under succession and many opportunistic species are visiting the area and have not yet settled down. The influence of Narmada water inundation timings and bird population needs to be evaluated.

The diversity is highest during summer at both the irrigation reservoirs, of the semi arid zone. These two reservoirs have become perennial because of Narmada water inundation. During this period the smaller waterbodies in the area dries off forcing birds to move towards larger. Moreover the migratory birds before returning to their breeding grounds congregate at larger water bodies at the start of summer, further adding to the diversity. MVP, though being in the semi arid zone, is a larger pond that retains water till mid of summer (Plate IX.A), while the other smaller water bodies of the same area dries off, providing some of the few habitats for waterbirds and sustaining diversity. HVP also retains water during summer as it receives sewage from the neighbouring residential areas (Plate XII) adding to the organic matter that resulted in increase in eutrophication. The H' at HVP is high all throughout the year but still higher during winter when few migratory birds visit the area. However as the migratory birds leave the area the diversity becomes minimum during summer.

The diversity at WIR was minimum during postmonsoon as this is the season when no migratory birds are present and the resident birds are busy with their breeding activities. The diversity at TIR is minimum during winter when the higher water level of wetland is utilized by the Pochards, while the marsh ducks prefers utilizing surrounding smaller water bodies. During monsoon the MVP was washed off due to heavy rainfall and flood (Plate IX.B) and hence there was loss of fishes, plankton and other biota which are among the main prey species for the birds, influencing the bird population. As the diversity increases the birds are not much evenly distributed in this area, which has been noted during present study. The birds are less evenly distributed during winter at WIR, TIR and MVP. At HVP (Plate XI.A) the birds are less evenly distributed during summer. At HVP the resident bird species dominate the area and as vegetation is high and exposed (Plate XI.A) the visibility of birds is poor.

Correlation with biotic and abiotic factors:

Birds being affected by various factors are not correlated with a single common abiotic factor at all the four wetlands studied in the Semi arid zone of Gujarat. The correlation with abiotic factors is different at each study site (Table 1.2). At WIR carbondioxide (Fig. 1.5a) is correlated with the bird density however, this is not the only factor that influences the bird density. At WIR and TIR (Fig. 1.5a, 1.5b), TSS is also positively correlated with the bird density, as these irrigation reservoirs receives the water from the Narmada river during early summer the agitation caused by the inflow of water increase the TSS and probably also disturbs the prey base by forcing it to come out of soil. The bird density during this time is, though not maximum, is high as this is the season when the migratory birds before leaving the area congregate at large water bodies. At TIR the high concentration of TSS, though statistically very well correlated with birds, is not the only abiotic factor affecting the congregation of birds. Another factor that is correlated with bird congregation is mollusc density. The birds are known to depend on the mollusc, to meet their calcium demand (Eeva and Lehikoinen, 1995; Nisbet, 1997; Brenninkmeijer *et al.*, 1997). However, the birds and mollusc are positively correlated only at TIR.

The temperature and bird density are positively correlated at MVP (Fig. 1.5c) and to some extent at HVP. Though the highest water temperature was noted during monsoon, difference is noted only of 1^{o} between monsoon and summer temperature. Early summer is the period when the water bodies surrounding Masar dry off and the migratory birds before leaving the area congregate at MVP, as this still retains water. The bird density at MVP is negatively correlated with water cover, mainly because during monsoon and postmonsoon when the water level/spread is maximum no birds are present. As said earlier the resident species are busy with the breeding activity and migratory birds are still to arrive. Here (at MVP) the birds are negatively correlated with the dissolved oxygen and positively correlated with carbondioxide. This indicates that in water where the rate of decomposition is high the bird density decreases. When decomposition is high decrease in the microscopic prey base may take place as animals of this trophic levels are affected by the dissolved oxygen content in the water.

At HVP it is observed that there is negative correlation between phosphate and the bird density (Fig.1.5d), this could be due to pressure of domestic sewage. The high phosphate content known to fluctuate during summer, lead to monotypic vegetation, which neither supports the diverse group of birds nor, the high number of same species. Further, at HVP also the concentration of dissolved oxygen is negatively related with the bird density. The high vegetation cover at HVP (Plate XI.A) is responsible for high dissolved oxygen. The negative correlation could be because of high vegetation which decrease the visibility and hence decrease in bird density. The floating type of vegetation favours only the species of birds of Group I that can thrive in such floating vegetation. The density and diversity of group 4, though increase during winter was always in minority as this group includes fe species of birds.

When total congregation of birds is noted, (mainly during midwinter waterfowl census) WIR supports more than 50,000 waterfowl and TIR supports more than 25,000 birds. As a result of Narmada water inundation these reservoir have become perennial. This has influenced summer bird congregations (mainly at WIR, Plate VI.A).

Wetland need not be an Internationally important wetland on the basis of waterbirds alone but an Important Bird Area is declared on the basis of bird species as well as bird population only. At WIR, it has been noted that the congregation of comb duck exceeds 1 % global population and hence satisfies one of the criteria of Ramsar Convention and IBA. Further, more than 700 individuals of Lesser Whistling Teal *(Dendrocygna javanica)* have been observed during summer 2008. The reservoir which use to dry up during summer is now almost perennial. This suggests the importance of WIR to the resident birds.

In addition among, the migratory species, Glossy Ibis, Ruff, Black Tailed Godwit and Grey Lag Geese are also recorded during winter at WIR in high numbers which are higher than their 1% global populations. Further, Brahmininy duck, Painted stork and Spoonbill also utilize the pond in large number (few short of 1 % global population). This wetland satisfies the criteria of regularly supporting more than 20,000 birds the criteria for declaring it as Important Bird Area. Further the wetland also supports waterfowl based criteria put forward by the Ramsar Convention (Khan and Zafar, 2007).

Hence WIR fulfills many of the criteria for declaration as IBA and also Ramsar site.

CONCLUSION:

The four sites selected are having presence of the representatives of all the different groups of resident and migratory species of birds. Depending on the type of the wetland the density, species richness, diversity and evenness differ. During summer too high density is in the larger wetlands of the area, as the surrounding smaller wetland dries off. The wader being the largest group, dominate the wetlands of semi arid zone of central Gujarat.

From the present study it is evident that the water inundation at the larger wetlands (WIR) and (TIR) has made the wetlands perennial, supporting huge congregations of waterfowls especially the birds of family Anatidae. The congregation is so high that WIR satisfy the Ramsar convention criteria of supporting more than 20,000 birds as well as that of supporting the 1% of Global population of several species.

Wadhwana Irrigation Reservoir supporting huge congregation of birds satisfies the criteria for the *Important Bird Area* and hence should to be declared as IBA. Timbi Irrigation Reservoir, supporting good density and diversity of bird species can be declared as *Nationally Important Wetland.* Masar Village Pond as *Community Reservoir* and Harni Village Pond supporting migratory as well as the resident species of birds can be declared as *Recreation Site.*