CHAPTER III

THE PLANKTON DENSTIY AND DIVERSITY

INTRODUCTION:

The trophic structure as well as the dynamics of the wetland ecosystem depend upon the aquatic communities of the wetlands and is regulated by the array of biotic and abiotic components (Mitsch and Gosselink, 1993; Vakkilainen *et al.*, 2004). Plankton are the microscopic plants *i.e.* the phytoplankton and animals *i.e.* the zooplankton that drift freely through the water current and provide the basis for all food chains within aquatic ecosystem.

In this trophic structure of wetland ecosystem phytoplankton are responsible for the primary productivity thereby serve as the primary producers. Whereas, Zooplankton serve as primary consumers. Thus Plankton communities represent important elements of the biota in ponds (Soininen *et al.*, 2007). Being photo obligatory the phytoplankton occur on the surface of the water whereas the zooplankton are found on the vertical gradient of water and show vertical movements in water. Zooplankton feed upon the phytoplankton/ other smaller zooplankton/ detritus material.

Zooplankton are classified in two different ways, either they are categorized on the basis of their size or on the basis of duration of life spent as planktonic form. The organisms that live for the whole life as plankton, are known as *Holoplankton*, while those that spend only a part of their life (mainly the initial larval stages) as planktonic form are known as *Meroplankton*. On the basis of the size they are classified as follows: i. *Nanoplankton*: Plankton ranging in size between 0.005mm and 0.06 mm. ii. *Microplankton:* size between 0.06mm and 1mm and comprises usually eggs and larvae of invertebrates. Iii. *Macroplankton*: larger than 1mm and include Copepods, Amphipods, Rotifers and Crustaceans. Iv. *Megaplankton*: Other large organisms like large jellies. The plankton are given due importance in the aquatic ecosystem as they happen to be the vital food source for numerous other animals.

Plankton are of the central importance in the pelagic food web of Lakes and Oceans (Rothhaupt, 2000). The heterogeneity in the plankton distribution is because of the predation (Pinel-Alloul, 1995; Folt and Burns, 1999; Hulsmann *et al.*, 1999; Thackeray *et al.*, 2004; Castro *et al.,* 2007). The factors that may influence the dynamics of the assemblage of different types of plankton include variations in food, predation, physical and chemical quality of water (Coman *et al.*, 2006). Though the plankton community is considered as ecological health indicator of a wetland (Bary, 1959; Jones, 1968; Lindo, 1991; Webber & Webber, 1998; Webber *et al., 2005;* Padisak *et al.*, 2006) they are comparatively difficult to monitor. The waterbirds, the major predator of plankton, are easy to monitor. Plankton serve as food sources directly for several species of birds as well as other macro organisms. Bolduc and Afton (2004) explain that not only the birds but other organisms too feed upon plankton and in turn fall prey to the birds, serving as primary food resources for many wintering water birds. The prey size selection by several species of dabbling ducks is related to bill lamellae distance, varying between 0.43 mm and 1.06 mm (Nudds and Bowlby, 1984; Kooloos *et al.*, 1989). Thus for studying waterbirds, the evaluation of plankton communities become essential.

MATERIALS AND METHODS:

The plankton along the periphery of wetland were collected during each visit. At three station fixed volume of water (*i.e.* 10 Liters) was filtered through the net of mesh size 0.05mm (Michael, 1986). The net was then washed with the water by inverting it to collect the plankton attached to the net. The sample was fixed with 1 ml of 10 % Formalin and 1 ml of Lugol's Iodine at the collection site. 10 ml of sample from each station was further concentrated by centrifuging at 2000 RPM for 10 min. From each sample slides were prepared and observed under the low and high power microscope. The plankton observed were identified upto the genus/ species level using the standard key by Edmonson (1963). The number of plankton was considered for calculating density.

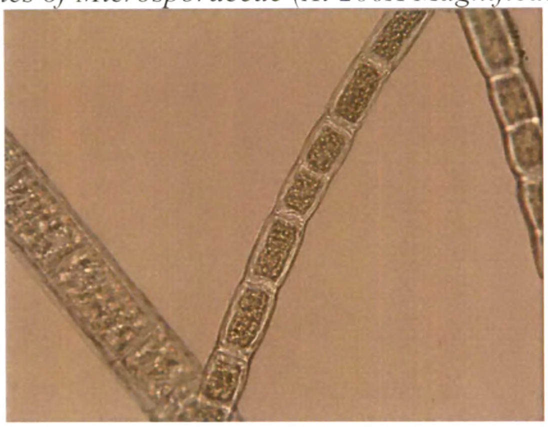
Three groups of plankton are studied. Group I Phytoplankton, Group II Rotifers and Group III Crustaceans.

The data for 3 months over 2 years was pooled and analyze for seasonal variations for winter (December, January, February), Summer (March, April, May), Monsoon (June, July, August) and Post monsoon (September, October, November). Further the Mean, standard error of mean (SEM) and One-way

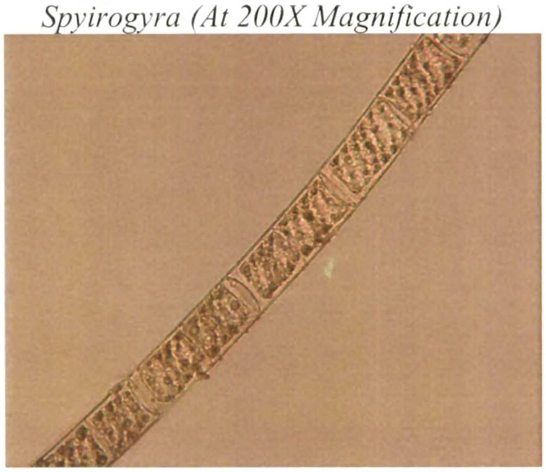
ANOVA with No post test for various parameters for four seasons was performed using GraphPad Prism version 3.00 for Windows, (GraphPad Software, San Diego California USA). The correlation between the abiotic factors and the plankton density and the percentage of dominance of each group is also calculated. The Pearson correlation is calculated by keeping plankton as dependent variable and other abiotic factors as independent variables with the help of SPSS 12.0 for windows. 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 $p < 0.0001$.

Plate XIII

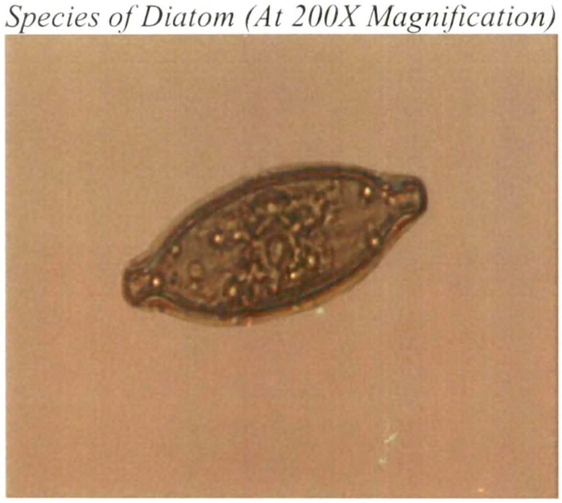
Species of Microsporaceae (At 200X Magnification)



Spyirogyra (At 200X Magnification)



Species of Diatom (At 200X Magnification)



RESULTS:

In the present study all about 22 species of plankton were collected. The distribution of these species in all the four study sites is given in Table: 3.1.

Table: 3.1 List of plankton observed at all the four study sites during the period of March 2005 to May 2007.

No.	Name of Plankton	WIR	TIR	MVP	HVP
	Phytoplankton				
1	*Navicula*				*
2	*Volvox*	*	*	*	*
3	*Spiyrogira*	*	*	*	*
4	*Chlamydomonas species*	*	*		
5	*Coccomyxa dispar*	*	*	*	*
6	*Ulothrix zonata*	*	*	*	*
7	*Coelastrum*	*	*	*	
8	*Rhizoclonium sp.*	*	*	*	*
	Protozoan				
1	*Paramecium caudatum*	*			
	Rotifer				
1	*Lecane lorica*	*	*	*	*
2	*Lecane luna*	*	*	*	*
3	*Brachionous havanaensis*	*	*	*	*
4	*Brachionous calyciflorus*	*	*	*	*
5	*Brachionus bidentata*	*	*	*	*
6	*Keratella Canadensis*	*	*	*	*
	Crustacean				
1	*Daphnia smiles*	*	*	*	*
2	*Latona sp.*	*			
3	*Cyclop sp .*	*	*	*	*
4	*Cyclop sp.*	*	*	*	*
5	*Argulus*	*	*	*	
6	*Mysis relicta*	*	*		
7	*Diaptomus stage I* (Nauplius larva)	*	*		
	Total species	21	19	16	15

*-Species of Plankton present

Figure: 3.1a: The variation in the plankton densities over the four seasons from March 2005 to May 2007 at Wadhwana Irrigation Reservoir.

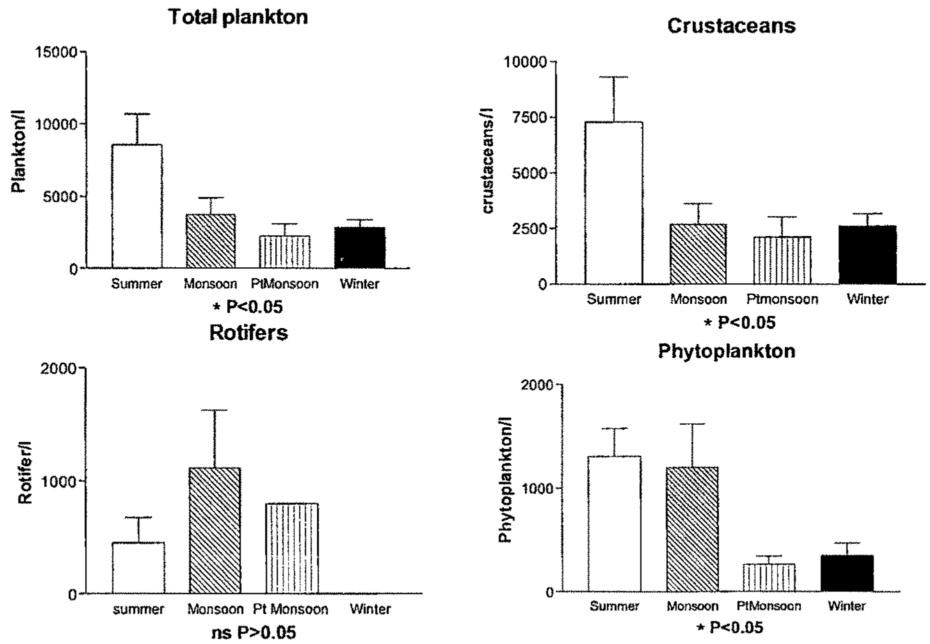
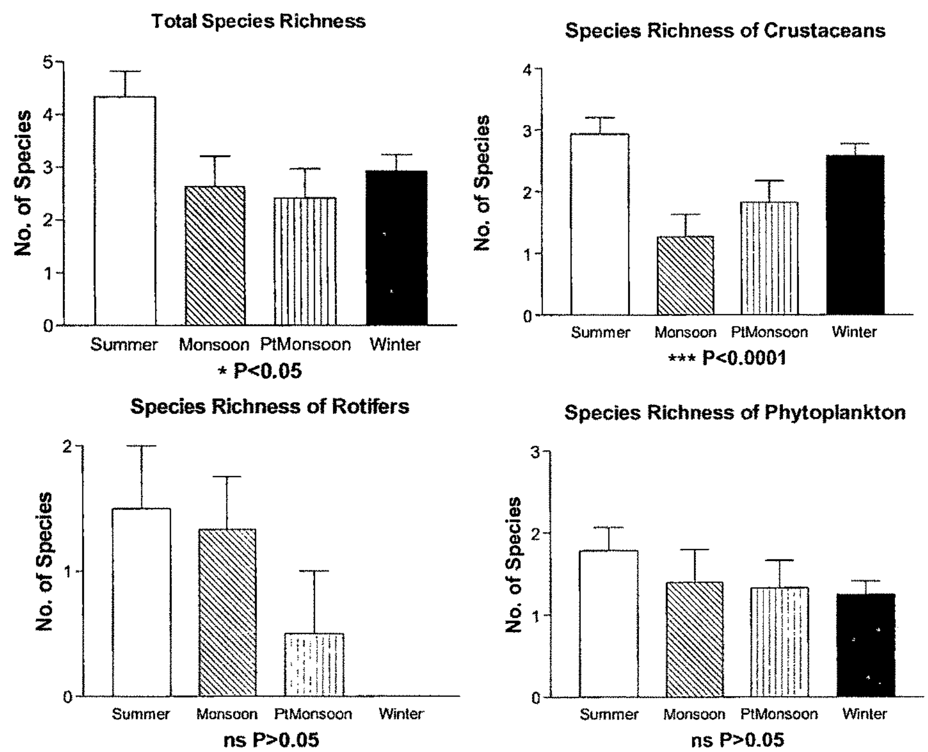


Figure: 3.1b: The variation in the plankton species richness over the four seasons from March 2005 to May 2007 at Wadhwana Irrigation Reservoir.



The plankton collected belong to 3 Groups. Group I Crustaceans, Group II Rotifers and the Group III Phytoplankton (Plate XIII).

Wadhwana Irrigation Reservoir (WIR):

When the over all seasonal comparison is carried out for total plankton at WIR, it is observed that the total plankton density ($P < 0.05$, $F_{3,\ 47}$ 4.13) with the Crustaceans ($P < 0.05$, $F_{3,\ 47,}$ 3.27) and the phytoplankton ($P < 0.05$, $F_{3,\ 26,}$ 3.10) densities, show significant variation between the seasons (Fig 3.1a). However, the Rotifers ($P > 0.05$, $F_{3,\ 13}$ 1.1) did not show a significant variation among the seasons. The detailed results shows that the highest density of plankton occurs during summer (8550.0 $\pm$ 2131.0/l), followed by monsoon (3733.0 $\pm$ 1142.0/l) and post monsoon (2244.0 $\pm$ 866.9/l). However, during winter the plankton density increased to 2833.0 $\pm$ 543.1/l (Fig 3.1a).

The group wise distribution indicates that the Crustaceans also followed the same pattern as that of the total plankton density being highest during summer (7266.0 $\pm$ 2025.0/l), followed monsoon (2679.0 $\pm$ 928.9/l) and post monsoon (2111.0 $\pm$ 885.9/l) and increased during winter 2600.0 $\pm$ 566.3/l. The Rotifers follow a completely different trend being highest during monsoon (1120.0 $\pm$ 507.0/l), followed by postmonsoon (800.0 $\pm$ 0.0/l) where they appeared only once (*i.e.* during the second visit of November). They completely disappeared during winter and reappeared during summer with density of 453.3$\pm$ 225.5/l (Fig. 3.1a).

When the phytoplankton density is considered it is observed that they also follow the similar pattern as that of the total plankton and the crustaceans densities. They

Table: 3a: The Plankton Density and Species richness at Wadhwana Irrigation Reservoir during March 2005 to May 2007.

	Total Plankton		Crustaceans		Rotifers		Phytoplankton	
SEASONS	Density#	Sp. Rich.	Density#	Sp. Rich.	Density#	Sp. Rich.	Density#	Sp. Rich.
Summer	8550±2131	4.33±0.49	7266±2025	2.93±0.26	453.3±225.5	1.5±0.5	1305±270	1.78±0.28
Monsoon	3733±1142	2.6±0.57	2679±928.9	1.27±0.35	1120±507	1.33±0.42	1200±421.6	1.4±0.4
Postmonsoon	2244±866.9	2.4±0.55	2111±885.9	1.83±0.34	800±0	0.5±0.5	266.7±76.98	1.33±0.33
Winter	2833±543.1	2.92±0.30	2600±566.3	2.58±0.19	0	0	350±20.71	1.25±0.16
Seasonal Variation	*	*	*	***	ns	ns	*	ns

Table: 3b: The Plankton Density and Species richness at Timbi Irrigation Reservoir during February 2005 to March 2007.

	Total Plankton		Crustaceans		Rotifers		Phytoplankton	
SEASONS	Density#	Sp. Rich.	Density#	Sp. Rich.	Density#	Sp .Rich.	Density#	Sp. Rich.
Summer	8761±1856	5.35±0.73	5937±1456	2.71±0.28	1962±701.1	2±0.4	2636±530.4	1.76±0.25
Monsoon	4111±1238	4.77±0.66	2933±855.9	2.44±0.17	1333±427.2	1.8±0.7	766.6±317.5	1.66±0.33
Postmonsoon	2900±1021	2.91±0.35	2611±1058	1.75±0.13	281.5±81.48	1.29±0.18	186.7±32.66	1±0
Winter	5167±326.3	3.75±0.65	4700±248.4	2.25±0.13	666.7±0	3±0	617.3±362.2	1.87±0.47
Seasonal Variation	*	*	ns	*	*	ns	**	ns

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

#Density- (Plankton/l)

Figure: 3.2a: The variations in the plankton densities over four seasons during March 2005- March 2007 at TIR.

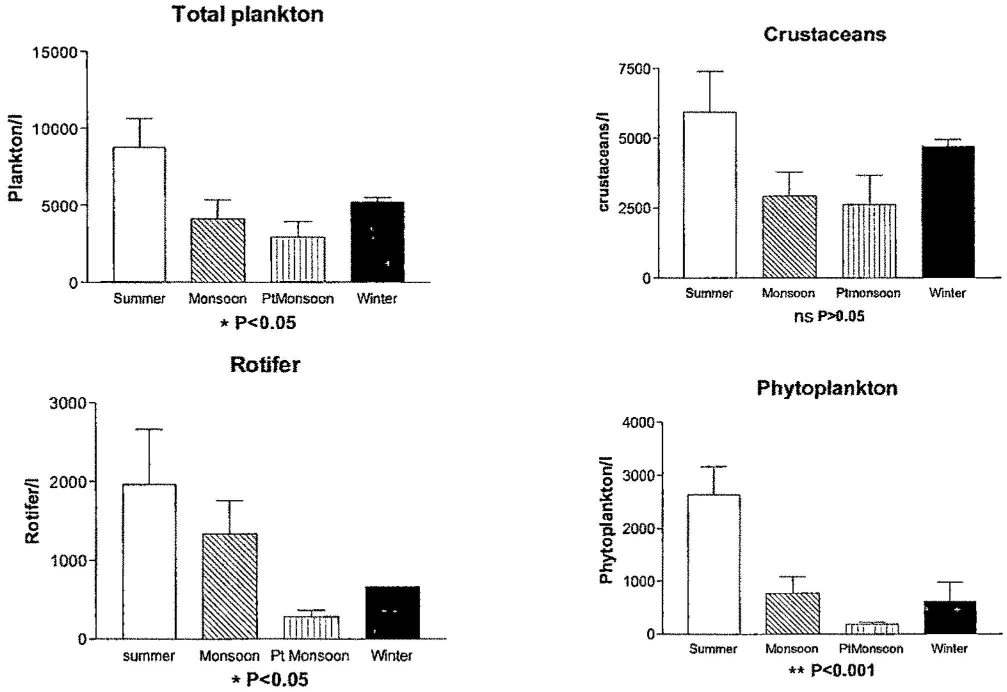
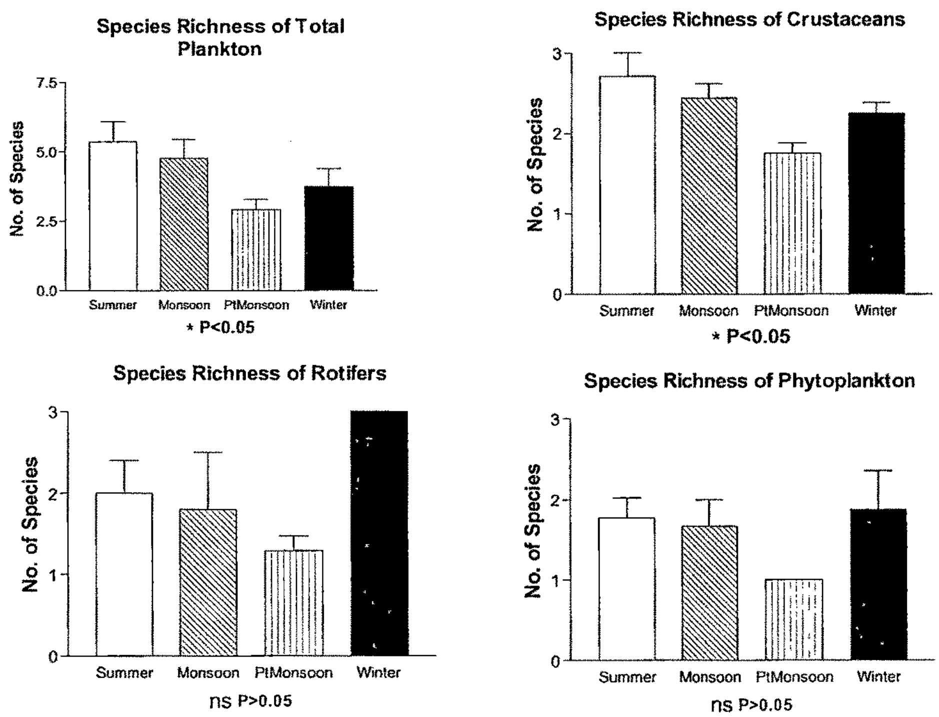


Figure: 3.2b: The variation in the plankton species richness over the four seasons from March 2005 to March 2007 at TIR.



monsoon it was 2933.0 ± 855.9 /l, for postmonsoon was 2611.0 ± 1058.0/l and for winter was 4700.0 ± 248.4 /l.

The highest Rotifer density 1962.0 ± 701.1/l of summer reduced to 1333.0 ± 427.2/l during monsoon and became lowest 281.5 ± 81.48 /l during postmonsoon. However, during winter the Rotifers were noted only once out of twelve visits in February 2005 with the density of 666.7. The phytoplankton density during summer was 2636.0 ± 530.4/l, monsoon was 766.6 ± 317.5/l, postmonsoon was 186.7 ± 32.66/l, and during winter was 617.3 ± 362.2/l (Fig.3.2a). The total species richness ($P < 0.05$, $F_{3,43}$ 3.1) and the Crustaceans ($P < 0.05$, $F_{3,43}$ 4.1) showed significant variation and the Rotifers ($P > 0.05$, $F_{3,18}$ 0.4) and the Phytoplankton ($P > 0.05$, $F_{3,28}$ 0.9) vary insignificantly across the seasons. The Total species richness was highest 5.50 ± 0.7 during summer, followed by 4.16 ± 0.6 during monsoon, 3.7 ± 0.6 during winter and minimum 2.9 ± 0.3 during postmonsoon (Fig.3.2b).

The crustaceans dominate in all the seasons with 67.7% during summer, 71.3% in monsoon 90.0% in postmonsoon and 90.8% in winter (Fig.3.5b).

Masar Village Pond (MVP):

The seasonal variations at MVP indicates that the total plankton vary highly significantly ($P < 0.0001$, $F_{3,47}$ 8.1), Crustaceans significantly significantly ($P < 0.001$, $F_{3,46}$ 5.5), Rotifers significantly ($P < 0.05$, $F_{3,38}$ 3.6) and Phytoplankton insignificantly ($P > 0.05$, $F_{3,10}$ 1.1) (Fig. 3.3a) throughout the year. The total plankton density was highest during summer (7146.0 ± 1363.0/l) and lowest during monsoon (911.1 ± 396.6/l) while during postmonsoon it was 3100.0 ± 759.4/l and during winter it was 3022.0 ± 632/l. The Crustacean density was highest during summer (4228.0 ± 1004.0/l) and lowest during monsoon (755.5 ± 414.3/l) while during postmonsoon and winter it was 1344.0 ± 329/l and 2722.0 ± 551.3/l respectively. At MVP Rotifer density was minimum during monsoon (22.22 ± 22.22/l) and maximum during postmonsoon with 1915.0 ± 632.9/l. The density declined during winter 476.2 ± 139.1/l and increased during summer (1578.0 ± 598.0/l). The phytoplankton has a different distribution pattern, where the maximum density was noted during summer (4844.0 ± 2630.0/l) followed by monsoon (400.0 ± 172.1 /l) and it was completely absent in postmonsoon and appeared only once during winter (133.3 ± 0.0 /l).

The total plankton species richness shows significantly significant variation ($P < 0.001$, $F_{3\ 43}$ 6.0) across the seasons. The Crustacean species richness varies significantly across the season ($P < 0.05$, $F_{3\ 39}$ 3.6) The Rotifers show insignificant variation ($P > 0.05$, $F_{3\ 22}$ 2.9) across the season and phytoplankton varied insignificantly ($P > 0.05$, $F_{3\ 9}$ 3.9). The species richness is highest during summer (4.9 ± 0.6) and minimum during monsoon 2.2 ± 0.6 while during postmonsoon and winter it was 2.75 ± 0.2 and 3.31 ± 0.3 respectively. Considering the percentile distribution it is observed that crustaceans dominate during summer with 55.2%, Monsoon with 82.97% and winter (90.0%) while during postmonsoon the rotifers dominate the Masar village pond with 56.6% (3.5c).

Figure: 3.3a: The variations in the plankton densities over the four seasons during March 2005 to March 2007 at MVP.

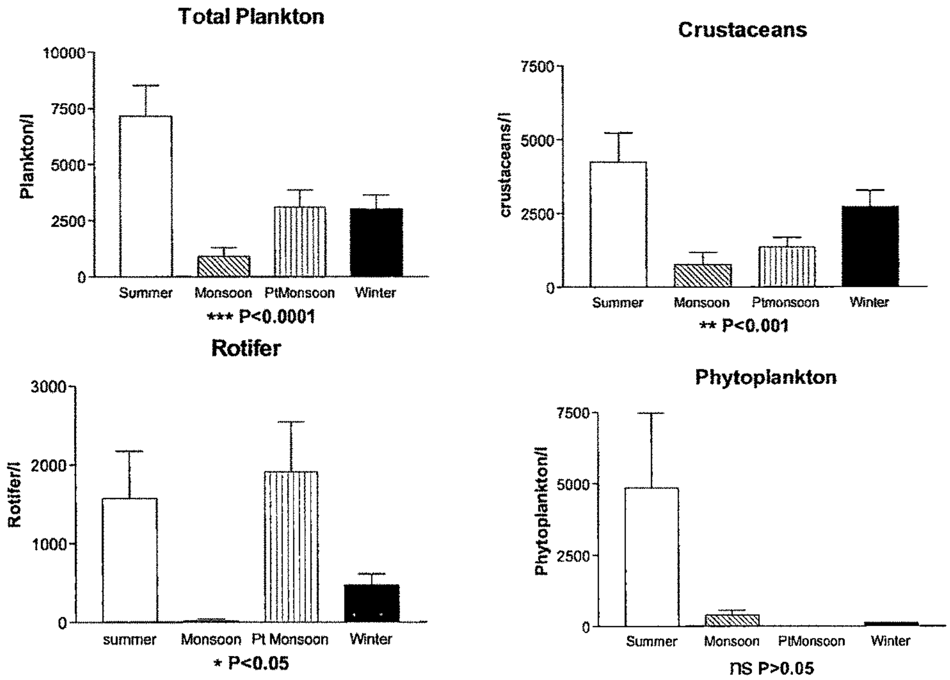


Figure: 3.3b: The variation in the plankton species richness over the four seasons from March 2005 to March 2007 at MVP.

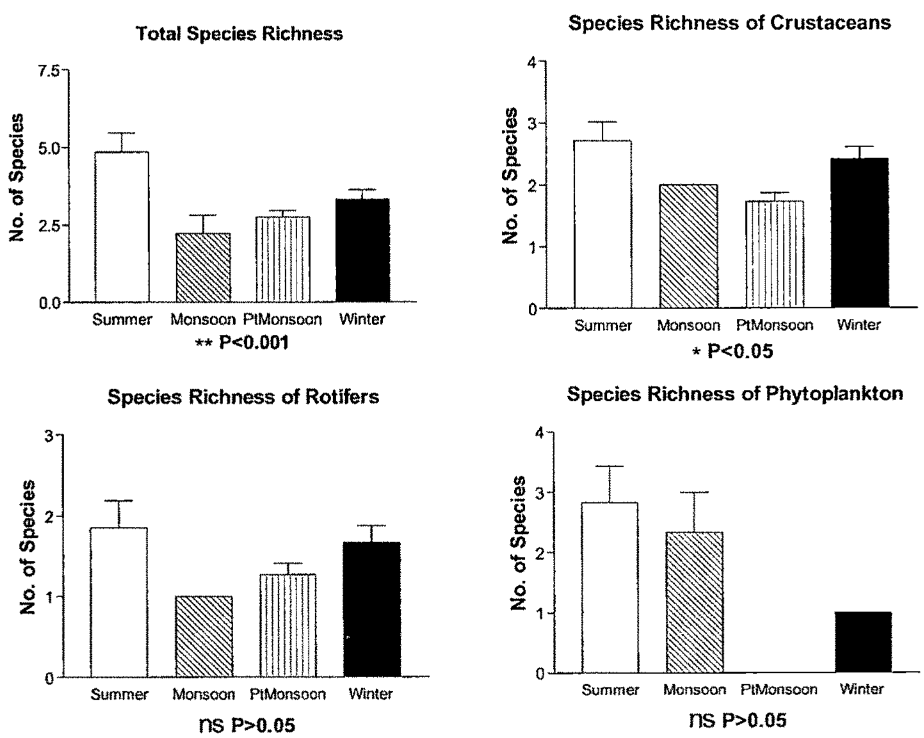


Figure: 3.4a: The variations in the plankton densities over the four seasons from March 2005 to March 2007 at HVP.

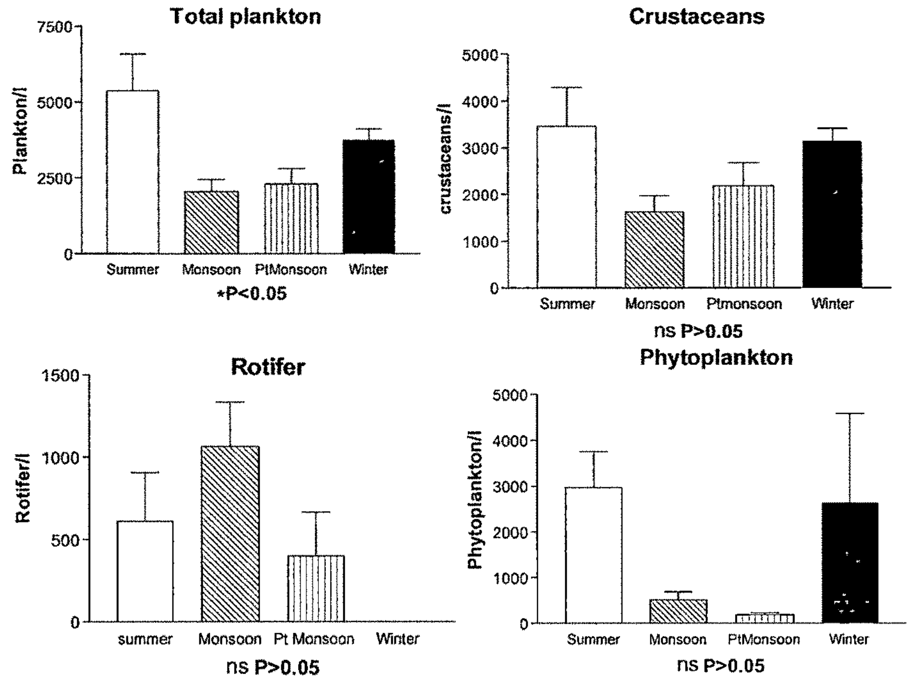


Figure: 3.4b: The variations in the plankton species richness over the four seasons from March 2005 to March 2007 at HVP.

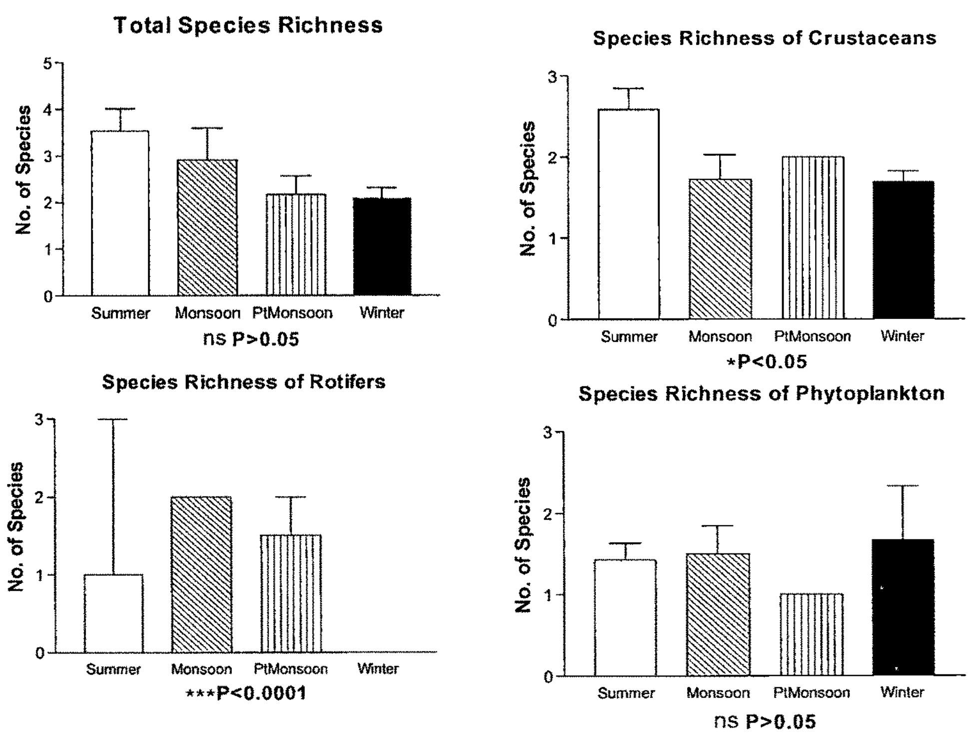


Figure: 3.5c: The group wise seasonal percentile distribution of Plankton at MVP.

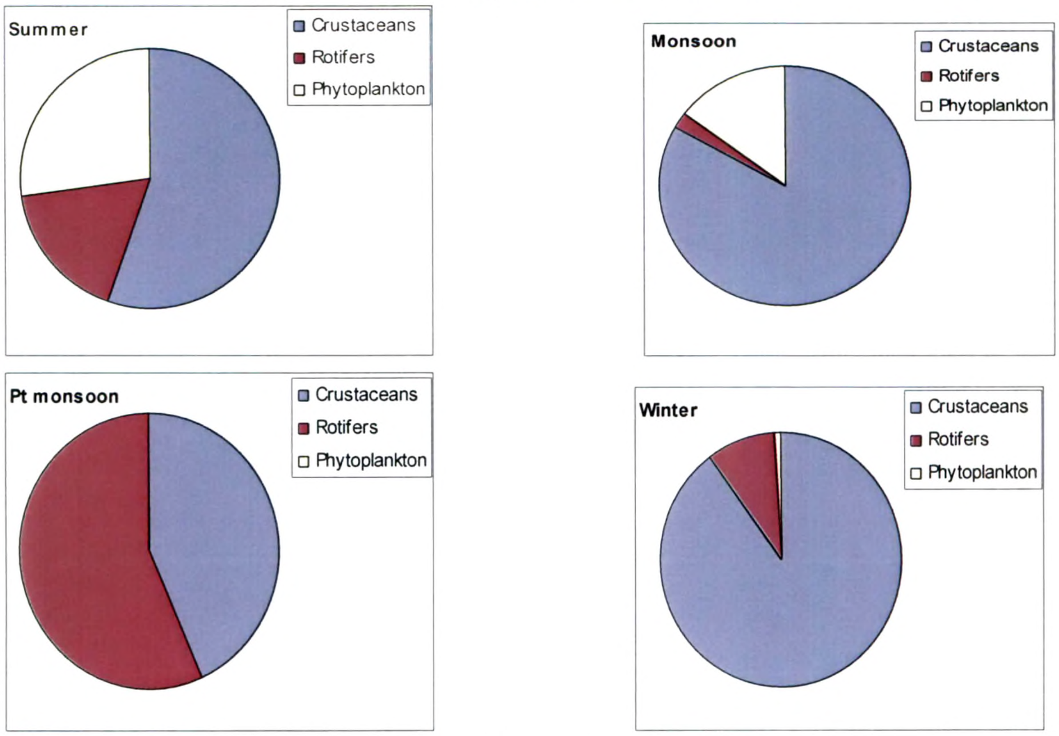
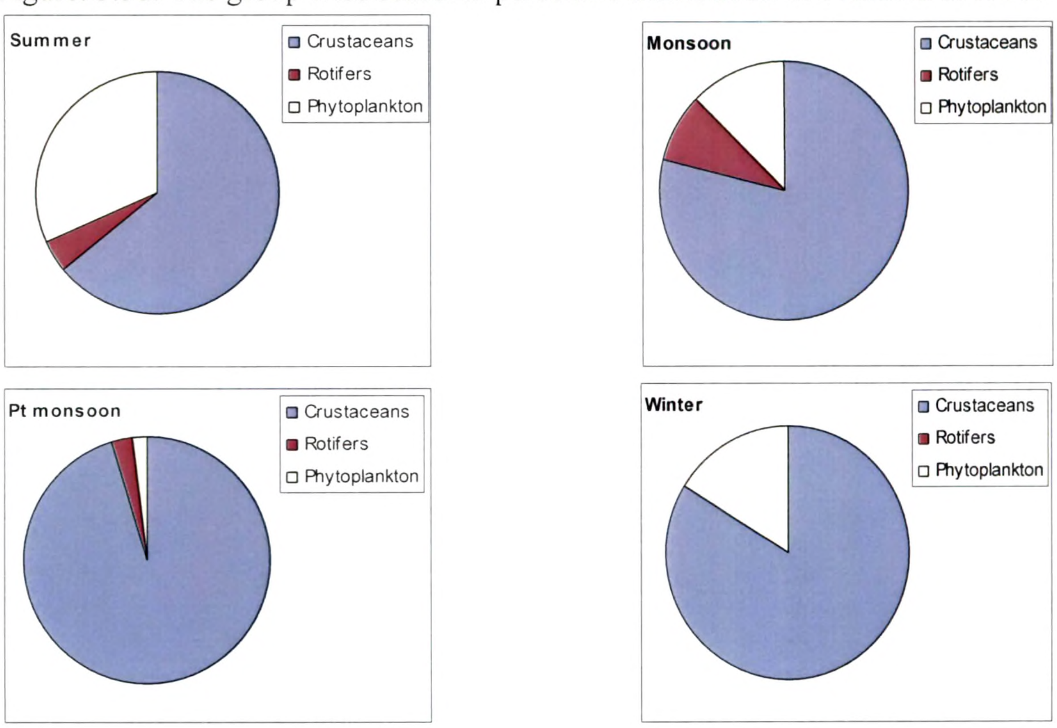


Figure: 3.5d: The group wise seasonal percentile distribution of Plankton at HVP.



Harni Village Pond HVP:

At HVP the total plankton density shows significant variation ($P<0.05$, $F_{3,47}$ 4.1) over all the seasons. The Crustaceans density ($P > 0.05$, $F_{3,47}$ 2.2), Rotifer density ($P > 0.05$, $F_{3,7}$ 1.3) and Phytoplankton density ($P > 0.05$, $F_{3,16}$ 1.8) varies insignificantly (Fig 3.4a). The total plankton and Crustaceans densities follow parallel trends with highest density during summer 5362.0 ± 1219.0/l and 3448.0 ± 836.6/l, and lowest during monsoon with 2056.0 ± 392.3/l and 1622.0 ± 346.9/l respectively. But during postmonsoon and winter the total plankton density was 2289.0 ± 514.3/l and 3733.0 ± 377.1/l and Crustacean density was 2178.0 ± 493.0/l and 3128.0 ± 280.7/l respectively. The Rotifers were highest during monsoon (1067.0 ± 266.7/l) while they were absent during winter. The density during summer and postmonsoon was 613.3 ± 293.9/l and 400.0 ± 266.7/l respectively. Phytoplankton density was also highest during summer (2967.0 ± 784.7/l), while minimum during postmonsoon (177.8 ± 44.44/l). During monsoon it was 511.1 ± 176.9/l and during winter (2622.0 ± 1957.0l/l).

The total plankton ($P > 0.05$, $F_{3,45}$ 2.2) and the phytoplankton ($P > 0.05$, $F_{3,15}$ 0.4) species richness show insignificant variations while Crustaceans show significant ($P < 0.05$, $F_{3,42}$ 3.9) and Rotifers ($P < 0.0001$, $F_{3,7}$ 20.5) show highly significant variations (Fig 3.4b). The total species richness is high during summer 3.5 ± 0.47 followed by monsoon 2.9 ± 0.6, postmonsoon 2.1 ± 0.4 and minimum during winter 2.0 ± 0.2.

At HVP also the Crustaceans dominate the percentile distribution with 64.2% during summer, 78.9% during monsoon, 95.1% and 83.7% during postmonsoon and winter respectively (Fig 3.5d).

When the Pearson correlation is carried out (Table 3.2) keeping the plankton as dependent factor and abiotic parameters as independent factors the parameters that are correlated vary according to the type of wetlands studied.

The correlation between the plankton density and various abiotic parameters at WIR (Fig.3.5a) showed significant positive correlation at the level of 0.01 with Temperature (0.49) and significant negative correlation with Dissolved Oxygen (-0.55) and Water cover (-0.62). Bicarbonate alkalinity (0.30), Calcium Hardness (0.39) and Total Hardness (0.32) were positively correlated with plankton density with 0.05 level significance at WIR. At TIR (3.5b) total plankton density was positively correlated with Total Hardness (0.39), Calcium Hardness (0.47), and TSS (0.76) at 0.01 level of significance and Temperature (0.36) at 0.05 level of significance. At MVP (Fig. 3.5c) the plankton density was negatively correlated with water cover (-0.60) at 0.01 level of significance and it was correlated positively at the 0.05 level of significance with Bicarbonate alkalinity (0.29) and Total solids (0.55). At HVP (Fig. 3.5d) the total plankton density was correlated with many factors. A positive correlation was established with Acidity (0.29), Bicarbonate alkalinity (0.46), Calcium Hardness (0.51), Chloride (0.38), Total Hardness (0.53), Hydroxyl alkalinity (0.53), Salinity (0.38) and Temperature (0.56) and negative correlation with pH (-0.49).

Table:3.2. Correlation of various abiotic factors and plankton density at four study wetlands.

	WIR	TIR	MVP	HVP
Acidity	0.14	0.00	-0.04	0.29*
Bicarbonate Alkalinity	0.30*	0.21	0.29*	0.46**
Calcium Hardness	0.39*	0.47**	0.20	0.51**
Chloride	0.12	0.15	-0.04	0.38**
Carbondioxide	-0.23	0.51	0.20	-0.10
Dissolved oxygen	-0.55**	-0.24	-0.19	0.00
Total Hardness	0.32*	0.39**	-0.06	0.53**
Nitrite	-0.03	0.24	-0.24	-0.33
Nitrate	-0.19	0.04	-0.41	-0.29
pH	-0.23	-0.01	-0.30	-0.49**
Hydroxyl Alkalinity	-0.20	0.11	0.11	0.53**
Phosphates	0.07	-0.13	-0.08	-0.11
Salinity	0.22	0.15	-0.04	0.38**
TDS	-0.15	-0.17	0.36	0.39
Temperature	0.49**	0.36*	0.23	0.56**
TS	-0.18	0.30	0.55*	-0.20
TSS	-0.12	0.76**	-0.02	-0.31
Water cover	-0.62**	-0.12	-0.60**	-0.11

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

Figure: 3.5a: Pearson Correlation of Plankton density and various abiotic parameters at Waadhwana Irrigation Reservoir.

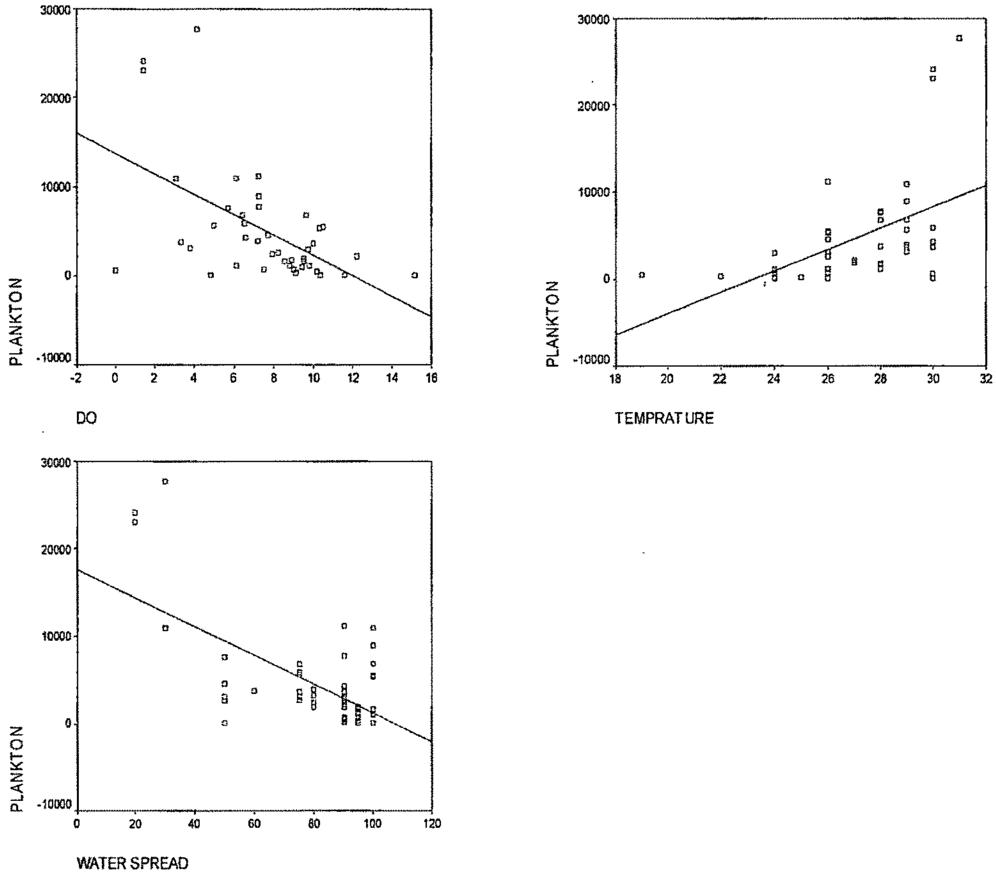


Figure: 3.5b Pearson Correlation of Plankton density and various abiotic parameters at Timbi Irigation Reservoir.

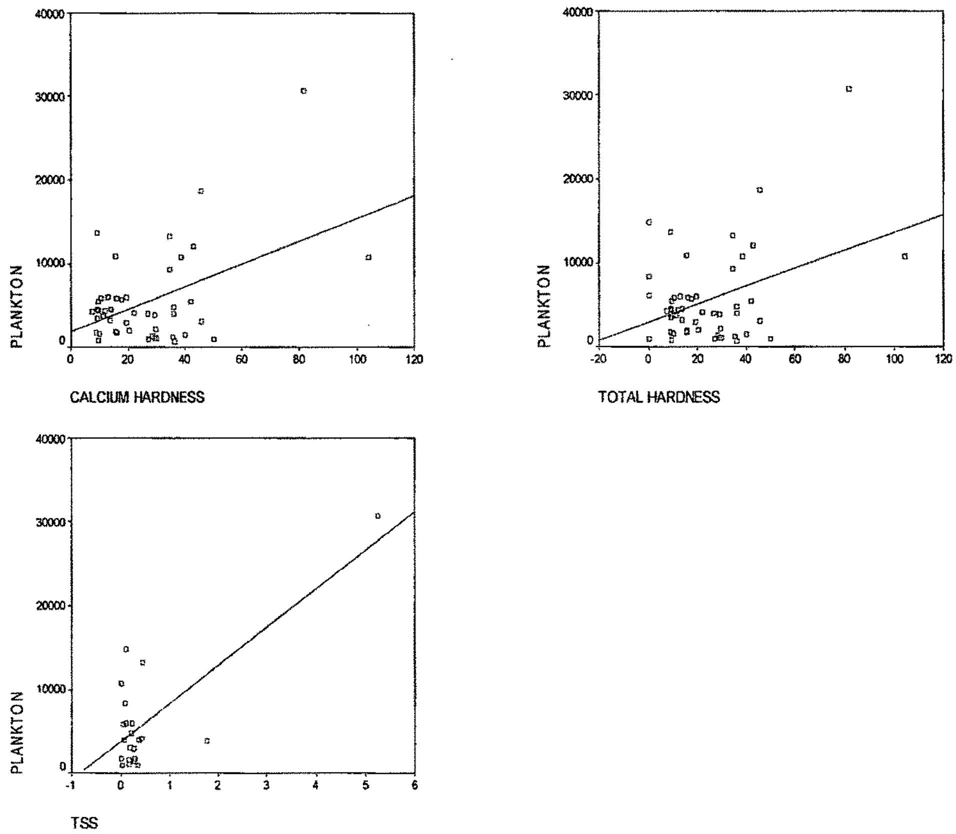


Figure: 3.5c Pearson Correlation of Plankton density and various abiotic parameters at Masar Village Pond.

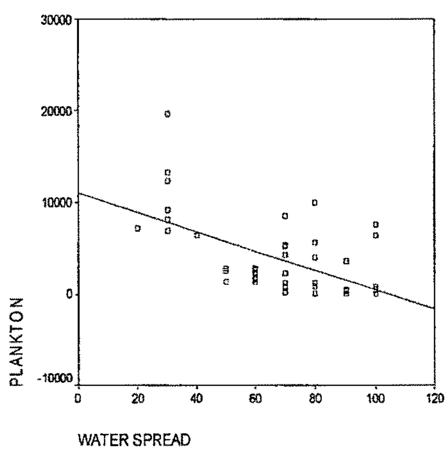
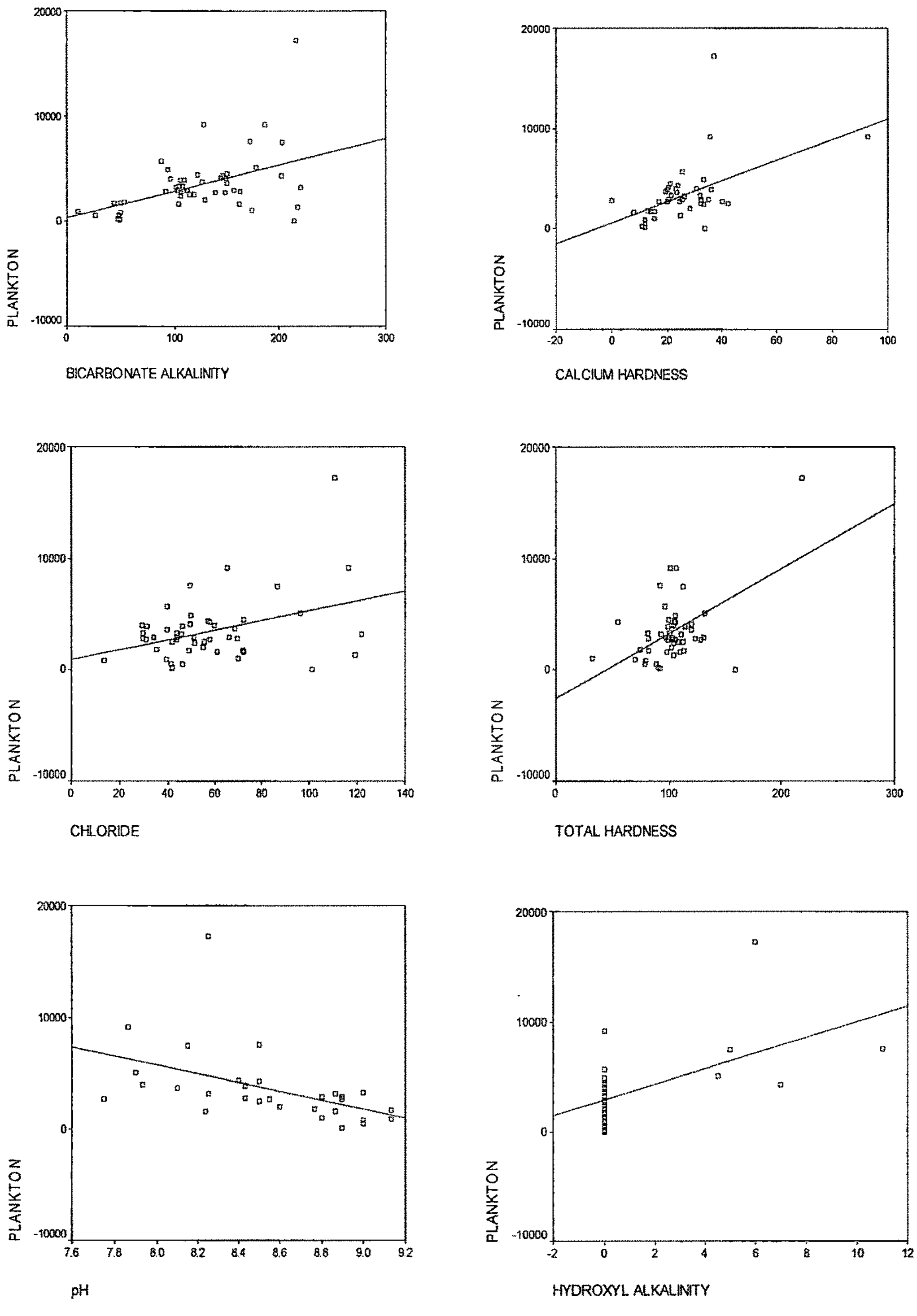
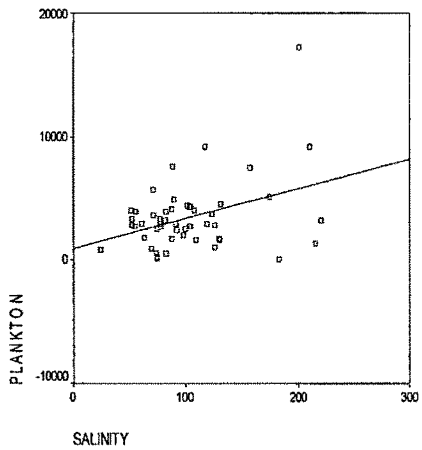


Figure: 3.5d Pearson Correlation of Plankton density and various abiotic parameters at Hrani Village Pond.

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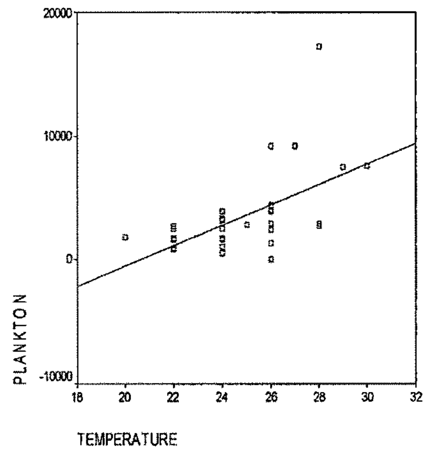
300
SALINITY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18
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26
28
30
32
TEMPERATURE

DISCUSSION:

The planktonic organisms are commonly employed to examine nutritional conditions and environmental perturbations of a wetland (Bianchi *et al.*, 2003; Beaugrand, 2005; Ternjej and Tomec, 2005; Yuhe Yu *et al.*, 2008). Many factors are affecting their distribution (Mayagoitia *et al.,* 2000). The physical factor hydroperiod and water cover are considered to be the major ones responsible for the formation of the ecological community (Shurin, 2000). According to Pennak, (1946) the plankton are abundant during the period of slow water current, and rise in water brings about a sharp decline in the plankton density. Studies carried by Bonecker and Lansac-Toha, (1996) support this result. In the present study of the semi arid zone of Gujarat, India, also the water level and the resultant water cover have proven to be the important factors for the density of the plankton. Highest plankton density is noted during summer, when the water level reduces and the plankton get concentrated and minimum during monsoon and postmonsoon when the water level is high and plankton get more distributed (Fig. 3.1a, 3.2a, 3.3a, 3.4a). Due to good rainfall during monsoon around the irrigation reservoirs, the water level and the resultant water cover were maximum during postmonsoon. This led to the decrease in density of the plankton. But, at both the village ponds being smaller in size compared to irrigation reservoir the density was minimum during monsoon. Both the ponds were either flooded or overflowing during monsoon (Plate IX.B and XI.B) of both the years and hence, the plankton drifted along with the water that was lost with the flood.

At all the four study areas the total density of plankton is mainly due to Crustacean during all seasons (Fig. 3.5a, 3.5b,3.5c and 3.5d). As expected the Crustacean density is high during summer as the water level was minimum in the semi arid region of India. As water level recedes, the resultant emergent macrophytes serve as hiding places for the planktonic microfauna, (Beklioglu and Moss, 1996). Further, at irrigation reservoirs water continues to arrive on one side through streams during postmonsoon and leave via canal for irrigation creating some what lotic condition. This condition is less preferred by the Crustaceans (Baranyi *et al.*, 2002) and thereby the Crustacean density is lowest during the postmonsoon. At village ponds the inflow of fresh water stops after monsoon and as these ponds are used for domestic work the waste with nutrients enter the pond. This results in increase in the Crustacean density. Minimum Crustacean density is observed at village ponds during monsoon but not during postmonsoon as noted for the irrigation reservoirs.

The other dominant group is Rotifer, one of the living fossils, which are also called as Rotatoria or wheel animalcules (Plate XIII). The Rotifers show a very different distribution at all the four wetlands. According to Pejler, (1995) the most cosmopolitan species of the aquatic ecosystem are the Rotifers. However, during present study they were absent in winter at WIR, HVP and appeared only once at TIR (Fig.3.1a, 3.2a, 3.4a). This is the season when the mercury goes down in the semi arid zone of Gujarat. Here mercury remains around 10° C, occasionally going further down during winters. During extreme environmental conditions the Rotifers are known to undergo diapause (Schroder, 2005). In summer increase in the density of Rotifers corresponds to decrease in water level hence rotifers are concentrated more densely in water. Moreover during summer the littoral vegetation exposes creating the best habitat for Rotifers (Pejler, 1995).

At both the village ponds rotifer densities were higher either during monsoon (HVP) or post monsoon (MVP). The overflowing of the village ponds probably created effect of a lotic ecosystem resulting in a favourable habitat for rotifers (Baranyi *et al.*, 2002). Rotifers are more successful in the lotic ecosystem due to their short embryonic development, fast growth rate (Townsend *et al.*, 1997). At MVP, the Rotifer density dominated among other plankton groups during postmonsoon (Fig.3.3a and 3.4a). This is the period when predators (Birds) density is low at MVP. It is known that the Rotifer density is often influenced by the abundance of the food and the predation pressure (Urabe, 1992). At MVP during both the years of study (Monsoon 2005, 2006) the rains were heavy and peripheral boundaries were washed away due to floods (Plate IX.B). The effect of overflowing can not be ignored and an attempt to correlate rotifers at MVP during normal conditions needs to be evaluated.

The use of phytoplankton, the principal component of a wetland ecosystem or higher taxa for water quality assessment has a long history (Willén, E. 2001; Padisak *et al.*, 2006). Phytoplankton are known to undergo annual periodicity in lakes (Barbiero *et al.*, 1999). During the present study also seasonal variations in phytoplankton densities, following similar trend as those observed by Munawar (1974) in the freshwater ponds of Hyderabad are noted, with highest density during summer, followed by monsoon and winter. The study sites in semi arid zone of Gujarat fall in subtropics which receives maximum photoperiod during summer invigorating growth of the aquatic autotrophs. The algal blooms are also known to be maximum during the warmer periods of the year (Pennak, 1946). Further, as the water level decreases due to evaporation, plankton get aggregated too, resulting in further increase in the density. Various physical components are known to determine the composition of phytoplankton assemblages in lakes (Mischke, 2003, Madwick *et al.*, 2006) and rather than the chemical factors (Pennak, 1946) the predation by the planktonic Crustaceans (the biotic component) have a major impact on the phytoplankton density as the former feeds on the latter one (Hann and Zrum, 1997).

Highest species richness is noted during summer when the water level is minimum. According to Mayagoitia *et al.* (2000) the rise in water level leads to loss of macrophytes and hence loss of species richness in semi arid zone of temperate region (Spain). Moreover, in Alaska the species richness increases with the increase in the lake area (Dodson, 1992; Dodson *et al.*, 2000). In the present study also high species richness is noted when the water level is minimum during summer and low species richness during monsoon with the rise in water level (Fig. 3.1b, 3.2b, 3.3b and 3.4b).

Though only seven species of Crustaceans were noted their density was always high. Compared to Rotifers the Crustaceans are known to be more dominating in the lentic conditions (Baranyi *et al.*, 2002). The Crustacean density is high during summer, when the availability of food is also high reducing the competition. The predation and competition are more predictable factors for the zooplankton density (Mayagoitia *et al.,* 2000; Serrano and Fahd 2005).

According to Sladecek (1983) the alkaline ponds support low Rotifer species richness. At all the four sites the water is more alkaline and hence supports few species of rotifers. Only six species of Rotifers were identified during the present study. The patchy distribution of Rotifers probably suggests that the species distribution is not controlled by any single biotic or abiotic factor. Rotifers are known to acclimatize themselves or modify their position in the water column (King and Serra, 1998). This needs further investigations with reference to Rotifers alone. Eight phytoplankton species identified during the present study also showed seasonal variations. Seasonality in phytoplankton density and species composition have been the subject of many studies (Padisak, 1992).

As mentioned earlier the abiotic factors also have an impact on the distribution of the plankton population. The correlation of several abiotic factors with the total plankton density is presented in Table: 3.2.

The plankton population are determined by temperature (Pennak, 1946), especially the Rotifer (Mikschi, 1989). This is true for WIR, TIR and HVP (Figs. 3.5a, 3.5b and 3.5d), where the temperature is correlated either at the significance level of

0.01 (WIR, HVP) or at 0.05 (TIR). The bicarbonate alkalinity is correlated positively only at HVP with the significance at the level of 0.01. The Total Hardness with Calcium Hardness is correlated with plankton density at WIR, TIR, and HVP, the fresh water wetlands. However at MVP (Fig. 3.5c), the wetland having brackish water influence it is correlated with bicarbonates. Further, Salinity is known affect the Rotifer density (Hutchinson, 1967; Gama-Flores *et al.*, 2005) and at HVP the positive correlation of salinity with plankton density is noted. As none of the wetlands studied are facing extensive eutrophication, the nutrients like the Nitrates, Nitrites and Phosphate are not correlated at any of the study area. The water cover is negatively correlated with the Plankton density. The high flood levels at all the wetlands during study period (Plate IV.A,IV.B,VII.B,VIII.A, IX.B and XI.B) had resulted into either over flowing of the reservoir or washing of their boundaries. The overflowing water must have taken the plankton along with it resulting into decrease in the density, thus a negative correlation gets established. Further a negative correlation is established with Plankton density and the dissolved oxygen. The water samples were collected during morning hours when the photosynthetic activity is low. The plankton come to the surface of water during early hours of the day and are known to feed there further reducing the dissolved oxygen content. Mikschi (1989) has correlated Rotifers and oxygen concentration. However, the correlation of Plankton density with dissolved oxygen needs further evaluation. In the present study a negative correlation between pH and the plankton density is observed, similar results have been reported by Sladecek (1983).

CONCLUSION:

The plankton being primary producers and primary consumers are at the base of aquatic ecosystem the plankton get concentrated in shallow waters during summer when water cover decreases due to evaporation resulting in rise in plankton density.

The lowest density of Plankton is noted at irrigation reservoir during postmonsoon and at village pond during monsoon. Among three groups studied the Crustaceans dominate the area with respect to density but the lotic effect created during monsoon favours rotifer. All the wetlands being highly alkaline have low Rotifer species richness. The Phytoplankton density is affected by temperature. No single abiotic factor was correlated with plankton density in wetlands of semi arid zone of Gujarat. As all the wetlands are obligatory no correlation with nutrients was established.