CHAPTER V

INFLUENCE OF URBAN PRESSURES ON PLANKTON DIVERSITY

INTRODUCTION:

Plankton communities represent important elements of the biota of the ponds (Soininen *et al.*, 2007). These communities are divided into two major types Phytoplankton and Zooplankton, the microscopic plants and animals respectively. Phytoplankton, the primary producers being photo obligatory, occur on the surface of the aquatic ecosystem and react rapidly to changes in water quality (Willen, 2001). Zooplankton are the primary consumers that occur in a vertical gradient and change their movements according to the fluctuations in the temperature. Both the groups of Plankton are used to assess the ecological status of surface water (Padisak *et al.*, 2006). Changes in the quality of water can directly or indirectly affect the composition and abundance of plankton communities. Density of Phytoplankton are related to many factors; such as hydrochemistry, season, lake morphology, presence of macrophytes, predators *etc*. Phytoplankton are particularly important for the productivity of the lake (Wetzel 2001; Coman *et al.*, 2006). Hence, the plankton communities are considered as ecological health indicators of a wetland ecosystem (Bary, 1959; Jones, 1968; Lindo, 1991; Webber & Webber, 1998; Webber *et al.*, 2005; Padisak *et al.*, 2006). Besides they also serve as direct food source for several organisms. A relationship between plankton and birds has been explained by Bolduc and Afton (2003). Plankton form prey base

not only for water birds but also for many other organisms, many of which in turn serve as primary food resources for water birds.

Urbanization is known to influence water bodies in adverse way. Under the process of urbanization large quantity of organic and inorganic nutrients are added in the water that can lead to eutrophication and in turn result in degradation of water bodies. In urban area water bodies are drained off by adding garbage in them and later on converted to land covered with concrete jungle. This degradation of water bodies can be measured by direct or indirect methods. Direct methods involve assessment of physico-chemical parameters whereas indirect methods involve measuring of the diversity and density of biota supported by it. Plankton are the base line biota of an aquatic ecosystem that are comparatively difficult to monitor. Urbanization is also known to lead to eutrophication of water bodies, further affecting the specific composition of zooplankton through physical and chemical alterations of the environment (Tallberg *et al.*, 1999). The Species richness and diversity of different organisms are influenced by the physico-chemical properties. This effect is worse under anthropogenic salinization (Alcocer and Hammer, 1998; Mirabdullayev *et al.*, 2003; Blinn *et al.*, 2004). In addition, the seasonal changes also alter the physical and chemical properties of the water. The seasonal changes are more pronounced as one moves away from the equator and are expected to be more evident in the semiarid zone of India where hydrochemistry depends upon monsoon type of climate. With the changes

caused by the different activities of the human being these seasonal changes are expected to alter the biota of water bodies.

Thus, urbanization leads to the changes in the quality of water which in turn affect the micro- and macrofauna. In the present study, influence of urbanization and seasonal changes on the species richness, density and percentage distribution of plankton are studied in two water bodies the same water bodies in which bird diversity is studied (Chapter IV). These are Savli Pond (SVP), under pressures of human development and Jawala Irrigation Reservoir (JIR), located a kilometer away from SVP without such pressures. They face same climatic conditions but are under varied anthropogenic pressures. In the present chapter variations in Phytoplankton and Zooplankton are considered.

MATERIALS AND METHODS:

The plankton were collected twice in a month from three selected points of both the water bodies by filtering 10 liters of water through a net of mesh size 0.05 mm as described by Michael (1986). The net was then washed by inverting it to collect the plankton attached to the net. The samples were fixed with 1 ml of 10 % formalin and 1 ml of Lugol's Iodine at the collection site and brought to the laboratory. About 10 ml of sample from each station was further concentrated by centrifuging at 1500 RPM for 10 min. From each sample 5 slides were prepared and observed under low and high powers of microscope. The plankton observed were identified up to the species level whenever possible using the standard key by Edmonson (1963). The number of plankton observed was considered for calculating density (D = n × 1000/ 0.75 × 10, Where, n = total number of plankton,

0.75 = amount of sample and 10 = amount of water filter). The plankton were classified into four groups Group I Phytoplankton; Group II and group III the crustaceans: further categorized as Brachiopod and Copepod respectively and Group IV Rotifers.

The data for the three months over the two years were pooled to analyze the seasonal variations as Pre-winter (September, October, November), Winter (December, January, February), Summer (March, April, May) and Monsoon (June, July, August). For comparisons, Similarity index (Jacquard's = C/(A+B)-C) was calculated in two different ways that is twice in a month comparison pooled together for seasonal comparison and overall similarity with all species observed during study period. For the statistical analysis of the two water bodies t-test was performed while to find out seasonal variations one-way ANOVA was performed. Both the statistical analysis were carried out using GraphPad Prism version 3.00 for windows, (GraphPad Software, San Diego California USA). The correlation between the plankton density and the abiotic factors is also carried out. Further, the percentage of dominance of each group are calculated. The Pearson correlation is calculated by keeping plankton density as dependent variable and other abiotic factors as independent variables with the help of SPSS 7.0 for windows. Chapter VI includes the details of the comparison and seasonal variations of physico-chemical parameters at the two water bodies studied.

The p values for ANOVA and t-test are insignificant if $P > 0.05$ (ns), significant if $P < 0.05$ (+/*), significantly significant (++/**) if $P < 0.001$ and highly significant $P < 0.0001$ (+++/***).

RESULTS

Comparisons of phytoplankton at two water bodies:

Table 5.1 shows lists of plankton identified at two water bodies. The plankton

density and diversity of two water bodies were compared seasonally (n= 12) as

well as annually (n = 48) using student t-test (Fig 5.1a). It was noted that 46%

species were common to both the ponds when Jaccard's similarity index was

calculated (Table 5.2). However, when seasonal data was considered, 42% (23

$\pm$ 5%, n = 12) were common during pre-winter, 25% (20 $\pm$ 4%) for winter,

50% (22 $\pm$ 6%) for summer and only 14% (16 $\pm$ 1%) for monsoon.

During winter and summer the densities of total plankton were significantly

different (P < 0.05) whereas the differences were insignificant during other two

seasons. When individual groups were compared only the density of copepod

showed significant difference in summer whereas Phytoplankton,

Branchiopods and Rotifers densities showed insignificant (P > 0.05)

differences during all the seasons. However, when species richness was

considered, significant differences (P < 0.05) in total species richness were

noted only in summer and insignificant differences (P > 0.05) in other three

seasons. Among the four groups rotifers showed significantly significant

differences (P < 0.001) in summer and significant differences (P < 0.05) in

monsoon. Insignificant differences (P > 0.05) were noted in the species

richness of other three groups Phytoplankton, Branchiopods and Copepods.

Savli Pond (SVP)

The minimum density (Fig 5.1a) of **total plankton** occurred during pre-winter

(1238.0 $\pm$ 445:7/l) that increased gradually from winter (4178 $\pm$ 751.0/l) to

summer (8800 $\pm$ 2491.0/l) and reached to maximum level in monsoon (10150.0

$\pm$ 3831.0/l) with insignificant (P > 0.05, $F_{3, 23}$ 3.004) seasonal variations. The

density of **phytoplankton** were low in pre-winter (323.80 $\pm$ 205.40),

increasing in winter (1311.00 $\pm$ 448.1/l) reached to highest level in summer

(1867.00 $\pm$ 825/l) and decreased in monsoon (1352.00 $\pm$ 418/l). The seasonal

variations were insignificant (P > 0.05, $F_{3, 23}$ 1.529).

The two groups of Crustaceans the brachiopods and copepods did not followed

the same pattern as that of total plankton density. The density of **Brachiopod**

was lowest in pre-winter (38.09 $\pm$ 24.59/l) and higher in winter (66.67 $\pm$ 0.0/l)

when, it appeared only once (i.e. during February, *Daphnia longiremis*). The

brachiopod density was maximum in summer (476.20 $\pm$ 234.30/l) but dropped

during monsoon to 57.14 $\pm$ 26.94/l. The seasonal variations were significant (P

< 0.05, $F_{3, 23}$ 3.047). The density of **Copepod** was also minimum in pre-winter

(723.80 $\pm$ 344.10/l), increased in winter (2422.0 $\pm$ 951.80/l) and reached to

maximum level during summer (4819.0 $\pm$ 1747/l) but decreased during

monsoon (1733.0 $\pm$ 782.90/l) with insignificant seasonal variations (P > 0.05,

$F_{3, 23}$ 2.626). The **Rotifers,** the third group of zooplankton, followed similar

trend to that of total plankton density. The rotifer density was minimum during

pre-winter (152.40 $\pm$ 93.96/l), gradually increased from winter (377.80 $\pm$

159.30/l) and summer (1638.00 $\pm$ 822.80/l) reaching to maximum level in

monsoon (7009.0 $\pm$ 3194.0/l) with significant seasonal variations (P < 0.05, $F_{3,}$

$_{23}$ 3.56).

The species richness (Fig 5.1b) of total plankton varied insignificantly (P >

0.05, $F_{3, 24}$ 1.383). It was minimum during pre-winter with 3.1 $\pm$ 0.59, increased

in winter (4.4 $\pm$ 0.7) and reached to its highest level 5.3 $\pm$ 0.9 during summer but dropped to 4.1 $\pm$ 0.7 during monsoon. Only 5 species of phytoplankton were identified (Table 5.1). The **Phytoplankton** species richness was stable in monsoon (0.86 $\pm$ 0.14) and pre-winter (0.86 $\pm$ 0.40) it increased in winter (1.83 $\pm$ 0.31) but decreased insignificantly in summer (1.29 $\pm$ 0.47). The seasonal variations in phytoplankton species richness were insignificant (P > 0.05, $F_{3,\,23}$ 1.573).

Only two species of **Brachiopods** were identified. They were observed only once during winter (February) and twice in pre-winter (0.28 $\pm$ 0.18, September). In summer the Brachiopod species richness increased to 0.57 $\pm$ 0.20 but declined again during monsoon to 0.28 $\pm$ 0.18 with insignificant seasonal variations (P > 0.05, $F_{3,\,23}$ 0.844). Among the zooplankton only the **Copepods** species richness showed significant variations (P < 0.05, $F_{3,\,23}$ 3.958) over the seasons. Higher species richness of copepods was noted during winter 2.0 $\pm$ 0 and summer 1.57 $\pm$ 0.20 that decreased in monsoon to 0.85 $\pm$ 0.34 but once again increased in pre-winter 1.14 $\pm$ 0.2.

Four species of **Rotifer**, the aqua pollution indicators, appeared at SVP during study period. The minimum species richness were noted during pre-winter 0.85 $\pm$ 0.34 and winter 1.00 $\pm$ 0.36 that gradually increased in summer 1.85 $\pm$ 0.40 and reached to maximum level in monsoon 2.14 $\pm$ 0.40 with insignificant seasonal variations (P > 0.05, $F_{3,\,23}$ 2.775).

When the percentile distribution of plankton was (Fig 5.2a) considered, the maximum **phytoplankton** were noted during winter (31.38%) minimum in, monsoon (13.32%) while higher in summer (21.21%) and in pre-winter

(26.15%). Compared to other groups the percentage of **brachiopod** was low in all the seasons 4.16% during pre-winter, 2.32% in winter, 6.86% in summer and 0.64% in monsoon. The **copepod** dominated the pond during pre-winter (79.16%), winter (84.49 %) and summer (69.5%), however in monsoon pond was dominated by rotifers (79.65%). During monsoon copepods were only 19.69% in minority (Fig 5.2a). The percentage of **Rotifer** was 16.66% in pre-winter, 13.17% during winter, 23.62% in summer and maximum 79.65% in monsoon as reported earlier.

Jawala Irrigation Reservoir (JIR):

Maximum density of **total plankton** at JIR was observed during summer (1867 $\pm$ 463.8/l), that decreased in monsoon (711.1 $\pm$ 379.70/l) and was maintained in pre-winter (716.6 $\pm$ 128.3/l) and was minimum in winter (466.7 $\pm$ 200/l) with significant seasonal variations (P < 0.05, $F_{3, 14}$ 3.945). In JIR water only three species of **phytoplankton** were observed during the study period. The highest phytoplankton density was 266.7 $\pm$ 75.59/l during pre-winter and that dropped in winter (66.67 $\pm$ 66.67/l) when only once in January *Chlamydomonas* was visible. In the summer and monsoon this species were visible again only once in each season 133.30 $\pm$ 133.30/l (March and July). Here the seasonal variations in phytoplankton density were insignificant (P > 0.05, $F_{3, 14}$ 0.604) during the present study period.

Among the crustaceans **Brachiopods** were not observed during monsoon and winter (n=12 each). However, their density was low in pre-winter (50.0 $\pm$ 24.40/l) and high in summer 346.7 $\pm$ 221.5/l. Also the seasonal variations were insignificant (P > 0.05, $F_{3, 20}$ 2.834) as Brachiopod density fluctuated during

both these seasons (high SEM). Highest **copepod** density was observed in summer (1360.30 $\pm$ 382.7/l) and lowest during monsoon (266.7 $\pm$ 154.0/l). During pre-winter the density was 333.30 $\pm$ 115.5/l but in winter when Cyclops were observed only once (in December) giving the average density to 333.30 $\pm$ 333.30/l. The seasonal variations were significant with P < 0.05, $F_{3, 14}$ 4.540.

In later part of year during pre-winter, the density of **Rotifers** was 66.67 $\pm$ 35.63/l. Moreover, the rotifers were also observed only once per season out of twelve visits per seasons with densities 66.67 $\pm$ 66.67/l in winter, 26.67 $\pm$ 26.67/l during summer and 311.10 $\pm$ 311.10/l in monsoon, with insignificant seasonal variations (P > 0.05, $F_{3, 14}$ 1.185). During study period minimum 2 species (monsoon) and maximum 5 (Pre-winter) species of rotifers were observed.

When total species richness was considered only 9 species of plankton were observed at JIR during study period. Maximum total species richness 2.5 $\pm$ 0.4 was noted in pre-winter and minimum in winter (1.5 $\pm$ 0.5). It increased in summer (2.0 $\pm$ 0.3) but again decreased in monsoon (1.7 $\pm$ 0.7) with insignificant seasonal variations (P > 0.05, $F_{3, 14}$ 0.709). The **phytoplankton** species richness was 0.58 $\pm$ 0.23 (1 to 2 species) during pre-winter and only one species *Chlamydomonas* was observed during winter (December), summer (March) and monsoon (June) with insignificant seasonal variations (P > 0.05, $F_{3, 14}$ 1.545). Two species of **Brachiopods** were observed mainly during pre-winter (September, October and November) and summer (March). Brachiopod could not be detected in monsoon and winter. Hence the seasonal variations were insignificant (P > 0.05, $F_{3, 14}$ 0.813). For **copepods** only 2 species were

noted during study period (Table 5.1) with 0.87 $\pm$ 0.12 species richness in pre-winter and only one species that also once (0.5 $\pm$ 0.5) during winter (December). It increased in summer to 1.20 $\pm$ 0.20 and was also found in monsoon (1.00 $\pm$ 0.57) with insignificant seasonal variations (P > 0.05, $F_{3, 14}$ 0.860). For **rotifers** also only 2 species were observed at JIR (Table 5.1). These are *Lecane luna* in pre-winter (October and November) and *Collurella obtuse* observed only once each in winter (December), summer (March) and monsoon (May). Insignificant seasonal variations (P > 0.05, $F_{3, 14}$ 0.192) were noted.

As noted for SVP, at JIR also copepods dominated the percentile distribution of the plankton during all the seasons except monsoon with 74.07% during pre-winter, maximum 83.33% in winter, 78.46% in summer but only 46.15% in monsoon (Fig 5.2a and b). The percentile distribution of brachiopod was minimum as compared to other groups of plankton with 11.11% in pre-winter, 0% in monsoon as well as in winter and 20% in summer. The rotifer occurred with 14.81% in pre-winter, 16.66% during winter, 1.53% in summer and 53.84% during monsoon. The percentile distribution of phytoplankton was 37.2% in pre-winter, 14.28% in winter, 7.14% in summer and 18.75% in monsoon (Fig 5.2).

The Pearson correlation (Table 5.3 and Fig 5.3a and b), carried out keeping the plankton density as dependent factor and abiotic parameters as independent factors (Table 5.3), showed that correlation vary probably according to the type of wetland. The Pearson correlation between the plankton density and temperature (-0.503) and nitrite (-0.598) showed significant negative correlation at the level of 0.01 at SVP. But at JIR the density of plankton
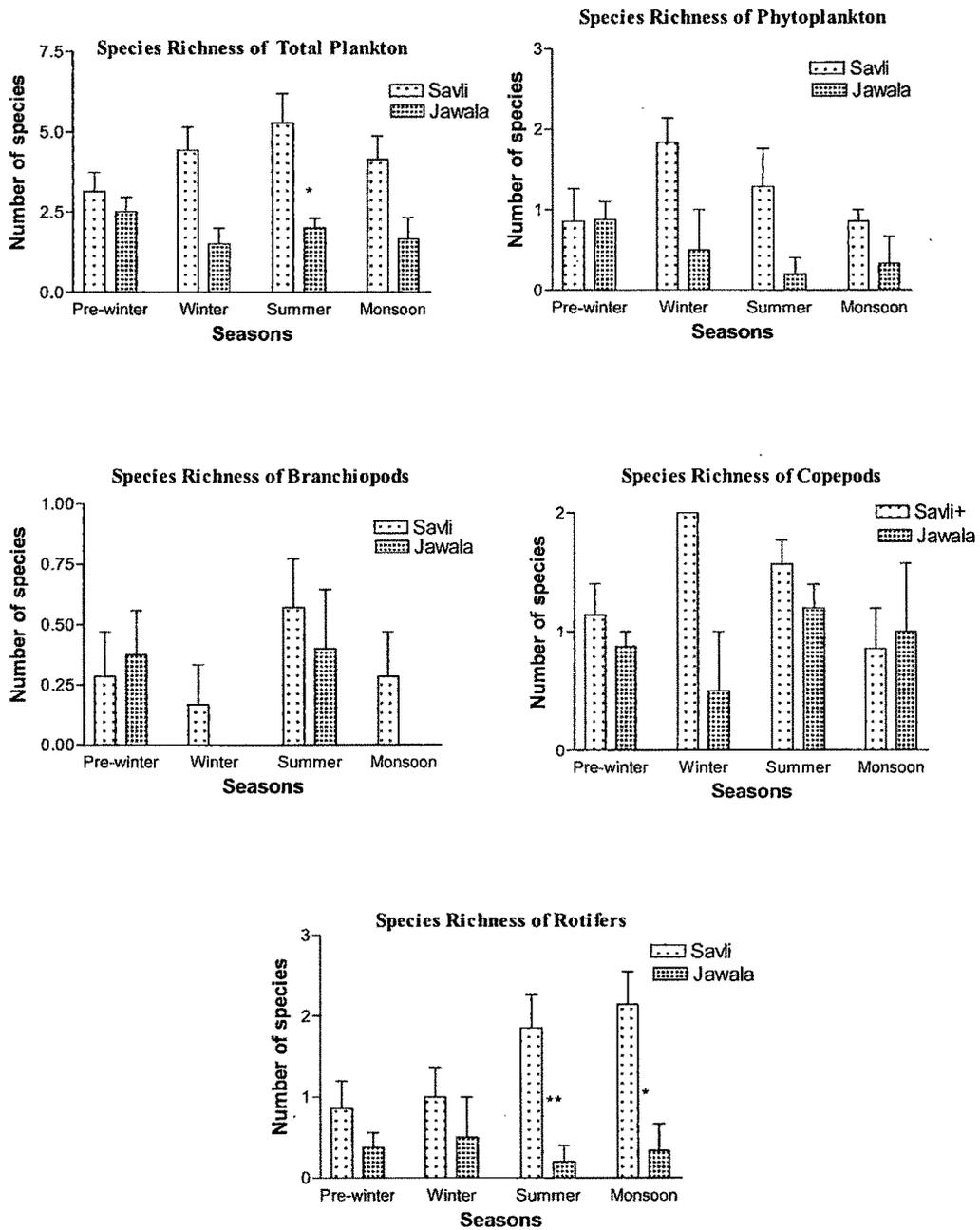
showed positive correlation at the level of 0.05 with oxygen only (0.492) as per

details given in chapter VI.

Fig. 5.1a Comparison and seasonal variations of densities of plankton at Savli Pond (SVP) and Jawala Irrigation Reservoir (JIR).
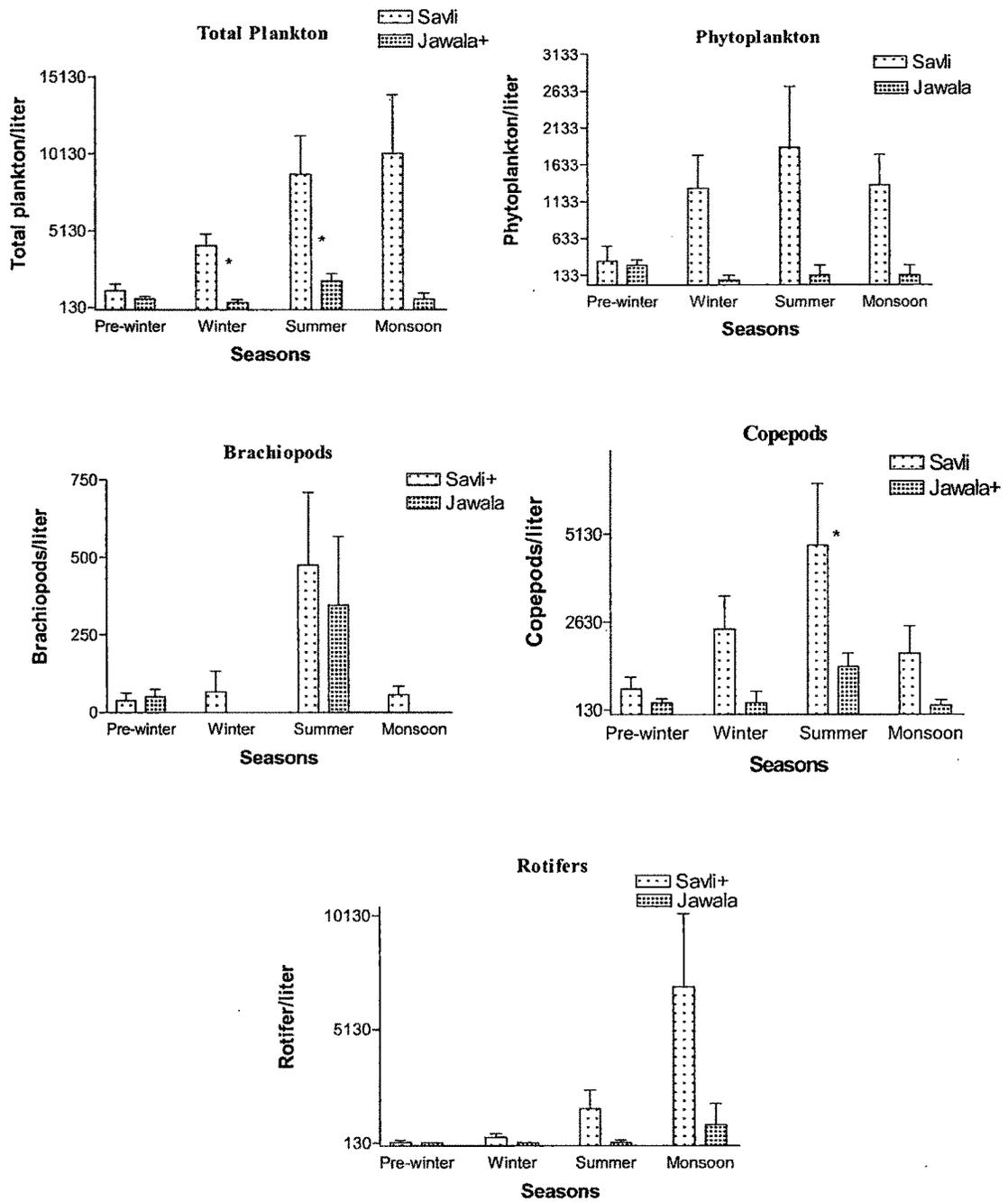
*/ + P< 0.05, ** /++ P< 0.001, *** / +++ P<0.0001
*For T-test, + For ANOVA

Fig. 5.1b Comparison and seasonal variations of species richness of plankton at Savli Pond (SVP) and Jawala Irrigation Reservoir (JIR).

Species Richness of Total Plankton

Species Richness of Phytoplankton

Species Richness of Branchiopods

Species Richness of Copepods

Species Richness of Rotifers

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

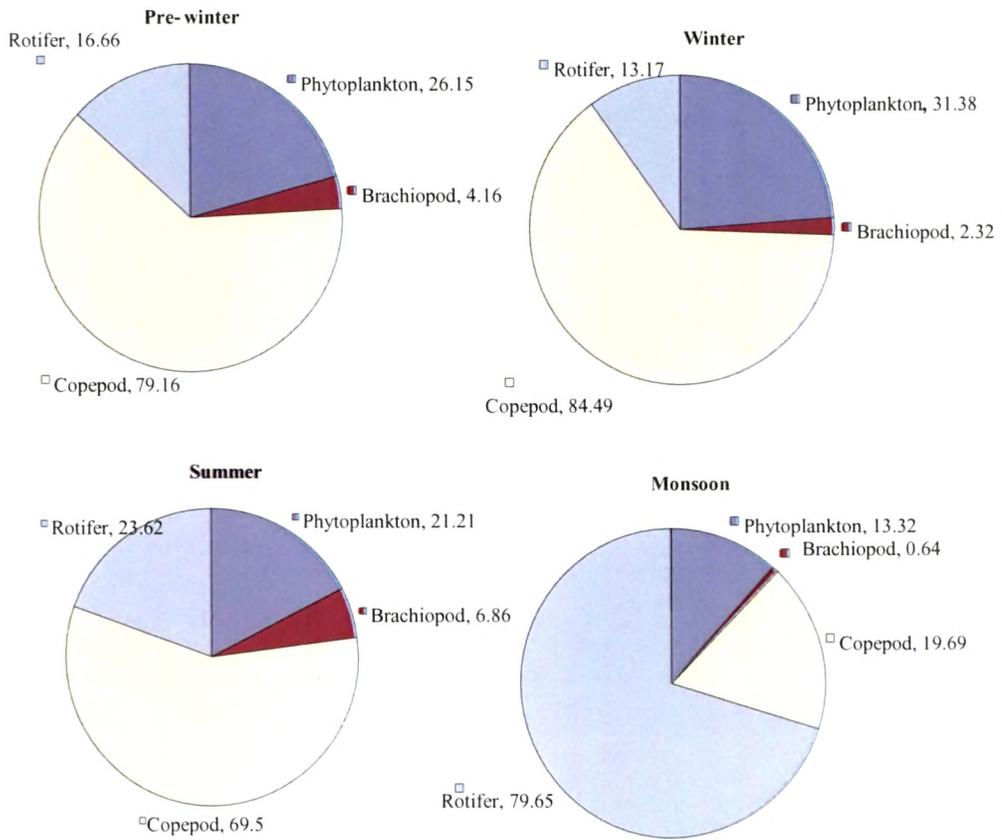Fig 5.2a. Seasonal variations in percentile Distribution of Plankton at Savli Pond.

Pre-winter

Rotifer, 16.66
Phytoplankton, 26.15
Brachiopod, 4.16
Copepod, 79.16

Winter

Rotifer, 13.17
Phytoplankton, 31.38
Brachiopod, 2.32
Copepod, 84.49

Summer

Rotifer, 23.62
Phytoplankton, 21.21
Brachiopod, 6.86
Copepod, 69.5

Monsoon

Phytoplankton, 13.32
Brachiopod, 0.64
Copepod, 19.69
Rotifer, 79.65

Fig 5.2b. Seasonal variations in percentile distribution of Plankton at Jawala Irrigation Reservoir.

Pre-Winter

Rotifer, 14.81
Phytoplankton, 37.2
Brachiopod, 11.11
Copepod, 74.07

Winter

Rotifer, 16.66
Phytoplankton, 14.28
Brachiopod, 0
Copepod, 83.33

Summer

Rotifer, 1.53
Phytoplankton, 7.14
Brachiopod, 20
Rotifer, 53.84
Copepod, 78.46

Monsoon

Phytoplankton, 18.75
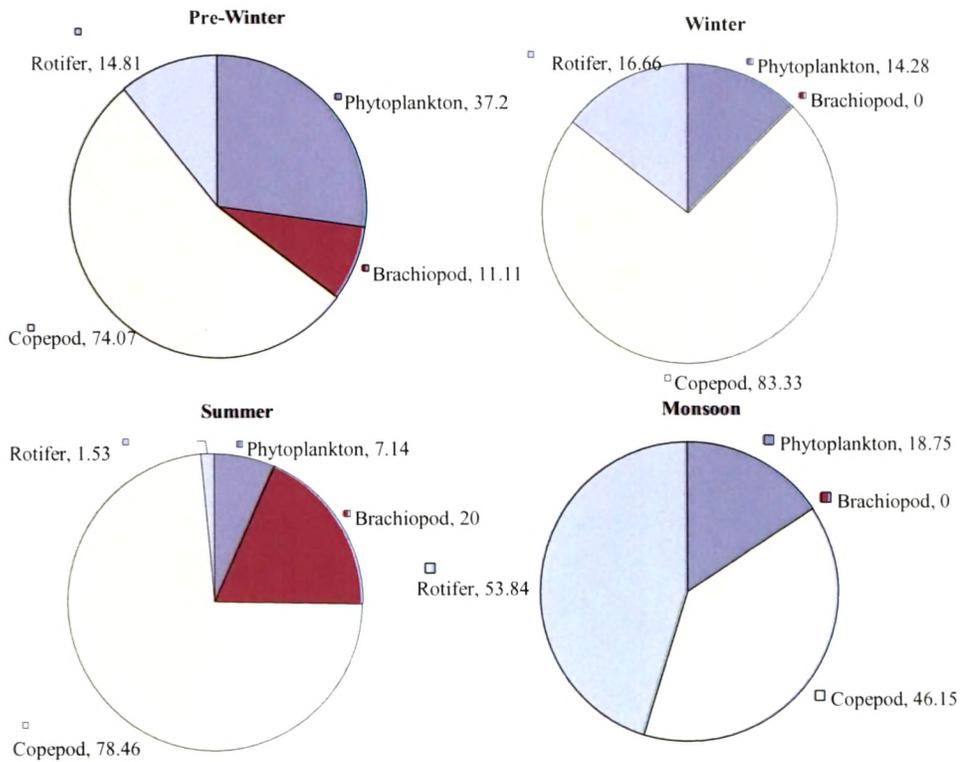Brachiopod, 0
Copepod, 46.15

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Fig 5.3a Pearson Correlation between plankton density and temperature and nitrite at Savli Pond (SVP):
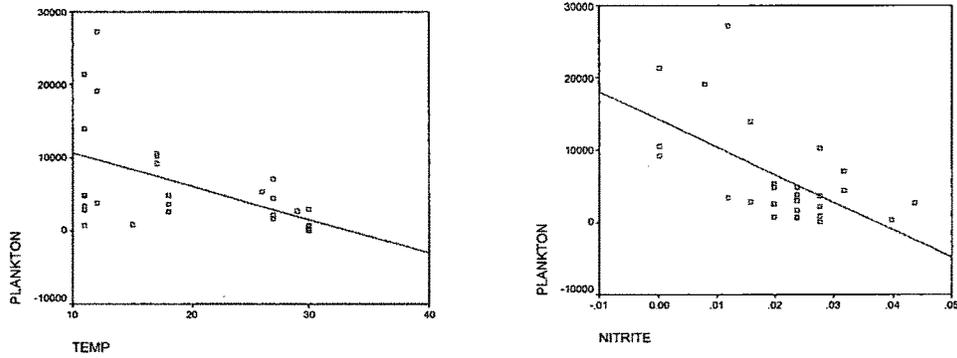

Fig 5.3b Pearson Correlation between plankton density and dissolved oxygen at Jawala Irrigation Reservoir (JIR).
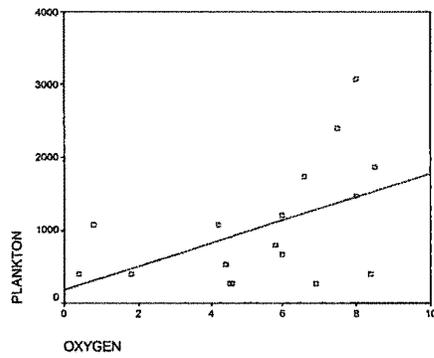
Table 5.1 List of plankton observed at two water bodies over the period.

No	Names of Plankton	SVP	JIR
	Phytoplankton		
1	*Navicula*	*	
2	*Spiyrogira*	*	*
3	*Chlamydomonas species*	*	*
4	*Chlamydomonas species*	*	*
5	Diatoms	*	
	Branchiopods		
1	*Daphnia smile*	*	*
2	*Daphnia longiremis*	*	*
	Copepods		
1	*Cyclops species*	*	*
2	*Cyclops species*	*	*
	Rotifers		
1	*Collurella obtusa*		*
2	*Brachionus havanaensis*	*	
3	*Brachionus calyciflorus*	*	
4	*Brachionus plicatilis*	*	
5	*Lecane loricae*	*	
6	*Lecane luna*		*

Table 5.2 Jaccard's similarity index between the two water bodies.

	Total	Pre-winter	Winter	Summer	Monsoon
For Whole season	0.46	0.42	0.25	0.5	0.14
Mean to each visit n=12		0.23 ± 0.05	0.2 ± 0.04	0.22 ± 0.06	0.16 ± 0.01

Table 5.3 Correlation of various abiotic factors and total plankton density at two water bodies.

Abiotic Factors	SVP	JIR
Acidity	0.361	0.025
Bicarbonate Alkalinity	-0.329	-0.132
Calcium Hardness	-0.015	-0.191
Chloride	-0.044	-0.073
Carbon dioxide	-0.161	
Hydroxyl alkalinity	-	-0.092
Magnesium Hardness	0.155	0.278
Nitrate	-0.022	-0.097
Nitrite	-0.598**	-0.330
Oxygen	0.217	0.492*
pH	-0.242	0.052
Phosphate	0.100	0.432
Salinity	-0.044	-0.073
TDS	-0.268	0.060
Temperature	-0.503**	0.309
Total Hardness	0.112	-0.084
TS	-0.044	0.081
TSS	0.119	0.030

DISCUSSION

Plankton are known to occupy lowest trophic levels in the aquatic ecosystem. Due to their short life cycle they respond more strongly to any small variations in the environment (Paszowski and Tonn, 2000; Gillooly *et al.*, 2002) and are commonly used to examine nutritional conditions and environmental perturbations of the water bodies (Bianchi *et al.*, 2003; Beaugrand, 2005; Ternjej and Tomec, 2005; Yuhe Yu *et al.*, 2008). Annual environmental changes influence the physico-chemical and community structure of an ecosystem, several other changes also occur due to different anthropogenic pressures. These anthropogenic influences are considered as one of the major threat responsible for influencing community structure of an aquatic ecosystem (Shurin, 2000). In present study, at JIR, maximum density of plankton was noted in summer when the water level was minimum thereby plankton were concentrated. The plankton density was associated with declining water level resulting in their concentration (Pennak, 1946). It was minimum in monsoon and pre-winter as the water level was high and plankton got more distributed. However, at SVP the plankton density was high during monsoon. This could be correlated with higher density of rotifers during the same period. Among the zooplankton, the Rotifers, the microscopic wheel animalcules, that are known to be aqua pollution indicators, play significant role in the food chain (Pontin, 1978; Sladecek, 1983). Out of six species of rotifers observed, the pollution indicator *Brachionus calyciflorus* was found only at SVP. It is a common cosmopolitan species of alkaline pond (Sladecek, 1983) with high tolerance to

pollution (Wilkens, 1972; Dhanapathi, 1977). In SVP water the bicarbonate alkalinity was also highest during monsoon (Rathod *et al.*, 2008). At SVP cattle are tied on the road towards the western side of the pond. Thus, during monsoon cattle shed runoff as well as storm water runoff over the concrete covered urban surfaces, result in accumulating organic matter as well as pollutants respectively in the pond. The rotifers prefer lotic ecosystem (Townsend *et al.*, 1997). Because of monsoon type of climate in India a percolation was high in July- August- September period that results in to temporary lotic system probably favouring rotifers. At SVP this continuously added organic and inorganic matter to the ponds for said period favouring rise in rotifer density. The influence of partial lotic system on rotifer density was reported by Townsend *et al.* (1997) and Deshkar (2008).

When the two water bodies were compared the influence of natural environmental conditions at JIR and anthropogenic pressures at SVP were prominent. Further, it has been reported that the plankton were abundant during the period of slow water current but rise in water quality resulted in a sharp decline in the plankton density (Pennak 1946; Bonecker and Lansac-Toha, 1996). Though the differences in the mean plankton density between the two water bodies were high, the fluctuations (SEM) at each water body were also equally high decreasing the statistical significance (Fig 5.1a). This could be attributed to difference in the percolation during two monsoons of this study period. Long term data are required to set threshold limits of various factors that can help to monitor, conserve and protect ecology (Hellawell, 1991).

The use of phytoplankton, the principal component of a wetland ecosystem, for assessment of the quality of water has a long history (Willen, 2001; Padisak *et al.*, 2006). Phytoplankton undergo annual periodicity in lake (Barbiero *et al.*, 1999) with maximum algal blooms during the warmer periods of the year (Pennak, 1946). During present study, the seasonal variations in phytoplankton density, followed similar trend as those observed by Munawar (1974) in the fresh water ponds of Hyderabad and by Deshkar (2008) in the fresh water bodies of semiarid zone of Gujarat, India. However, highest density during summer, followed by monsoon and winter were noted but only at SVP. As JIR is totally monsoon dependent water body, when water was used for irrigating surrounding agricultural land, it totally dried up under the scorching heat of semiarid zone of India in later part of summer. Hence, phytoplankton density was low at JIR in summer. Out of the four wetlands studied by Deshkar (2008) two wetlands received Narmada water, one is postulated to be under the under ground influence of estuarine tide and the fourth one receives sewage input. No such input occured at JIR. Further, it is also known that various other physico-chemical components are involved in determining the composition of phytoplankton assemblages in lakes (Mischke, 2003; Madwick *et al.*, 2006). However, according to Pennak (1946) rather than the chemical factors, predation by the planktonic Crustaceans, play a major role on the phytoplankton density as the former feeds on the latter one (Hann and Zrum, 1997). The densities of crustaceans such as Brachiopods and Copepods were highest at JIR during Summer.

Water birds get disturbed due to different human activities (Traut, 2003). The zooplankton are surmised to disperse relatively efficiently via water birds (Figuerola and Green, 2002). The two species each of copepods and Brachiopods noted during study period were common at both the water bodies. This may indicate that movement of birds between the two water bodies were involved in their dispersal. The density of Crustaceans (Copepods and Brachiopods) seems to be inversely correlated with water level in the monsoon dependent water body (JIR) located in semi arid zone of India where high density was noted during summer but low in pre-winter. Except during pre-winter the densities of both the groups were always higher at Savli pond, the pond that is under anthropogenic pressures. The influence of anthropogenic activities on the quality of water (Chapter VI and Rathod *et al.*, 2008) has also been reported by Deshkar (2008). The receding water level results in the emergence of macrophytes that serves as hiding places for the planktonic microfauna (Beklioglu and Moss, 1996). During pre-winter these two groups of Crustaceans showed opposite trend at the two water bodies. At the irrigation reservoir though plankton density was low the brachiopod density was higher compared to the pond under urban influence, where copepod density was high. Very low copepod density occurred in a temple tank enclosed with four walls and sediments at the bottom (Dadhich and Saxena, 1999). At irrigation reservoirs during pre-winter, water arriving from one side through streams and leaving from other side via canals for irrigation, created a temporary lotic condition, a condition less preferred by the Crustaceans (Baranyi *et al.*, 2002). The copepod density was highest at both the ponds during summer as is also

reported by Saxena and Bhargava (1981). Among the two water bodies SVP having high organic input had higher rate of decomposition and hence higher water temperature during winter favouring phytoplankton growth.

With the density, total species richness of plankton was also high at SVP in summer when the water level was minimum. Out of 6 species of rotifers 4 species were found only at SVP and rest 2 species at JIR. In temperate zone rotifers were regarded as bioindicators of water quality (Sladecek, 1983; Saksena, 1987) and high rotifer density has been reported to be a characteristic of eutrophic lakes (Sendacz, 1984). Among the two water bodies organic matter was added to SVP which was a perennial water body. However, at the irrigation reservoir, totally dependent on rain water, the total species richness was high as the water level was maximum during pre-winter. At the end of pre-winter irrigation started in neighbouring fields probably draining plankton with the water. By the end of summer JIR totally dried up.

Maximum species richness of phytoplankton was noted during winter at SVP and pre-winter at JIR. In Spain phytoplankton have been correlated with moderate temperatures of subtropical semiarid zone. In India winters are comparatively less pronounced and SVP being nearer to concrete jungle has higher environmental temperature. During moderate weathers of northern hemisphere highest plankton species richness was reported in August-September (Mayagoitia et al., 2000). Similar condition was noted at JIR that was under natural climatic influence, with highest phytoplankton species richness in pre-winter i.e. September-October period.

Though only four species of crustaceans (2 brachiopods and 2 copepods) were recorded during the present study they dominated in percentile distribution. In pre-winter, winter and summer the percentile distribution of Copepods were high at both the water bodies. At JIR the density and the species richness of the Brachiopod were high during summer when the oxygen level was low (Chapter VI). Saxena and Bhargava (1981) have reported higher number of *Daphnia* sp. (Brachiopod) in a pond which had negligible or zero level of oxygen. Further, Cyclopoid copepods are also known to thrive in eutropic lakes (Gannon and Stremberger 1978) as well as lakes with low transparency and lower algal biomass (Ceirans 2007).

Of the six species of rotifers observed during the present study, *Brachionus calyciflorus,* the indicator of the water pollution is a widely studied species (Sladecek, 1983). According to Sladecek (1983), it was a common cosmopolitan species of alkaline pond and considered as highly tolerant species towards pollution (Wilkens, 1972; Dhanapathi, 1977). Whereas, *Brachionus plictilis* an indicator species of hard water (Edmonson, 1963) was observed only at SVP and only during monsoon. At JIR, *Colurella obtuse* and *Lecane luna* species were found. They were indicators of saprobity (Sladecek, 1983). *Colurella obtuse* was a littoral species and had been reported to survive for days in an alpha-mesosaprobic environment in waters adjacent to the Danube in Vienna (Donner, 1978). The comparatively high percentile distributions of rotifer were noted during monsoon at SVP this may be due to the eutophication which was high as compared to JIR.

In present study total plankton density showed negative correlation with temperature and nitrite at SVP and positive correlation with oxygen at JIR (Chapter VI). However, Saxena and Bhargava (1981) have negatively correlated Cyclops sp. with oxygen level. This needs further evaluation with individual groups. According to Yildiz et al., (2007) temperature and oxygen concentration were the key factors in restricting zooplankton occurrence. The water temperature ranged between 13.10 ± 0.58 °C (winter) and 29.42 ± 0.15 °C (Monsoon) at SVP and 13.27 ± 0.7 °C (winter) and 28.83 ± 0.3 °C (Monsoon) at JIR. Whereas, dissolved oxygen ranged from 2.72 ± 0.3 mg/l in Monsoon at SVP and maximum 6.89 ± 0.6 mg/l in winter at JIR (Chapter VI). According to Mikschi (1989) physiological and population parameters are influenced by temperature and the population development of rotifers was limited by the combined effect of oxygen concentration and temperature.

CONCLUSION

SVP that is under anthropogenic pressures have higher density of plankton where the pollution indicator species of rotifers were noted whereas JIR that has no anthropogenic pressures showed low density of plankton and here lotic species of rotifers were noted. The crustacean dominated the ponds almost all throughout the year except monsoon when rotifer preferring lotic system dominated. At the pond under anthropogenic pressures plankton densities was always higher throughout the present study period, probably due to higher organic input and resultant higher temperature due to decomposition of organic matter.

PLATE XX

Spyirogyra (At 200X Magnification)
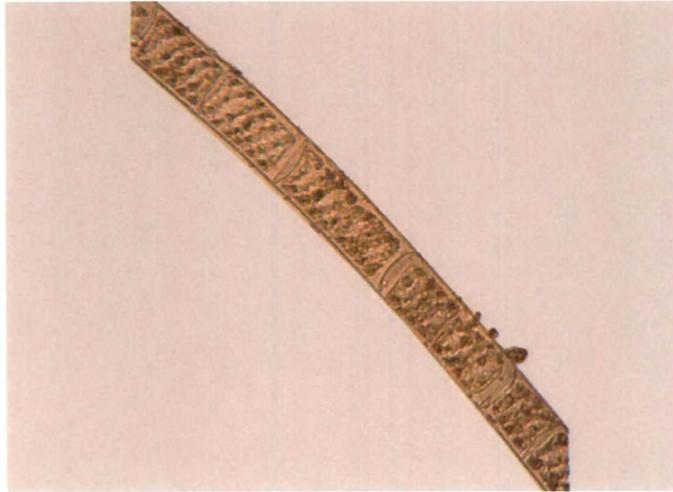
Lecane luna

Brachionous hayanaensis

PLATE XXI

Cyclop species

Daphnia smile