CHAPTER – FIVE

DISCUSSION

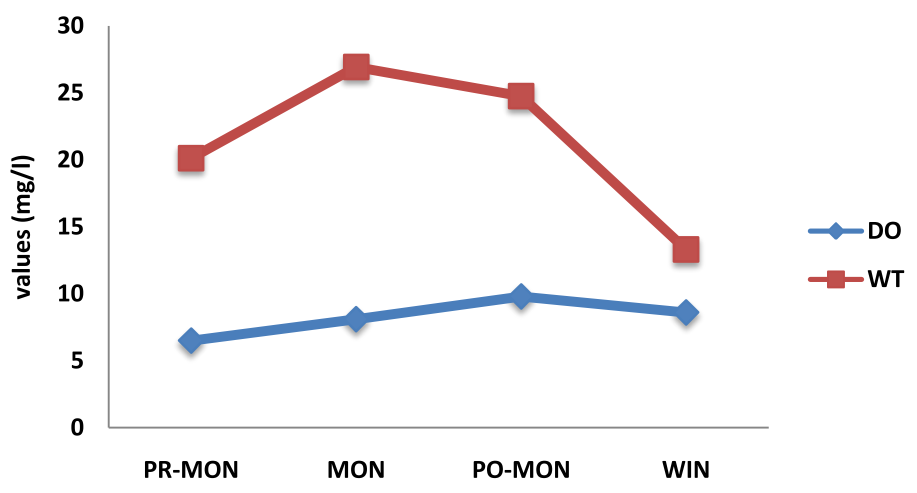
The Urpod beel in the Goalpara district of Assam, India exhibited wide range of plankton and macrophyte diversity in relation to the physico-chemical parameters of the water quality. The Urpod beel remained thermally stable particularly in its water surface and remained identical in different experimental sites in their respective seasons. However, no stratified thermal could be recorded during the investigation, yet all the five different sites of beel demonstrated the very presence of 61 species of phytoplankton community and 44 species of zooplankton community. The Chlorophyceae community of the phytoplankton group is the most dominant group in all the different seasons (Table 3.10). The zooplankton community in Urpod beel comprised of Rotifera, Cladocera, Copepoda, Ostracoda and Protozoans among which the Cladocera dominates in all seasons except pre-monsoon and post-monsoon of the year 2014 where Rotifera is the dominant group in both the seasons (Table 4.10).

The correlation among the different physico-chemical parameters of water and their relation with the phytoplankton and zooplankton has been evaluated to be discernible in the different seasons during the investigation period from 2014 – 2016.

Water temperature is a vital parameter for growth of aquatic organisms. The temperature measurement is useful in indicating the trends of biochemical and biological activities in water body. The Urpod beel exhibited seasonal fluctuation in terms of water temperature at the maximum of 26.92˚C ± 2.07 during monsoon and the minimum 13.30˚C ± 1.28 during winter of the study period (Table 2.9). It is significant that temperature is one of the primary parameters, influences the productivity (Huet, 1986) and the rise of temperature (air and water) during May and June and fall of temperature during December in a given year have well been tabulated (Salam and Parveen, 1996; Salam *et al.*, 2000; Ali *et al.*, 2005; Surve *et al.*, 2005). The water temperature demonstrated negative relationship with the dissolved oxygen

(Fig. 3.1) throughout the study period of this investigation, which could be supported by one works of Khanna and Bhutiani (2007) in Suswa river, Raiwala. Significant positive correlation with Bacillariophyceae, Protozoa, Cladocera and negative correlation with Total Zooplankton in pre-monsoon season (Table. 6.1a) and water temperature could be assessed in this study. The post-monsoon and winter water in five different experimental sites of Urpod beel (Table 2.3, 2.4, 2.7, 2.8 and 2.9) demonstrate negative correlation with the phytoplankton and zooplankton groups (Table 6.3a and 6.4a).

Fig. 3.1: - Seasonal fluctuation of DO and WT



One of the most obvious and familiar properties of water is its transparency. The highest transparency level (57.7 ± 0.2) of water during monsoon and the lower (42.2 ± 0.17) in winter season (Table.2.9) had been recorded in this study. The highest transparency value of ranged between 45 – 65 cm in Urpod beel during monsoon and the minimum at winter had been evaluated during the year 2006 – 2008 by Sarma *et al.*, 2013 which may support the present findings. It might be argued that the lowest transparency of water in winter is due to increase organic matter as well as due to the increased fishing activity.

It has been observed from the present study that the low level of water, the heavy siltation and increase of organic matter as well as due to fishing activity during winter and high level of water due to influx of rain water in monsoon may be the proper reasons for the changes in the transparency. It could be assessed that transparency was significantly correlated with CYN, CHL, BAC, EUG, TPHY and CLA while negatively significantly correlated with XAN in pre-monsoon season (Table 6.1a), while the same was positively significantly correlated with CHL, TPHY and CLA in monsoon season (Table 6.2a). In post-monsoon season transparency showed the positive significant correlation with CYN, CHL, EUG, TPHY, PRO, COP, CLA and TZOO (Table 6.3a). Transparency also showed the significant positive correlation with CHL, ROT, COP, CLA and TZOO and a negative significant correlation with CYN (Table 6.4a). However, recent analysis of the water quality (transparency) and the distribution of the phytoplankton and zooplankton exhibited opposite findings based on the canonical evaluation (Hussain *et al.,* 2015; Devi *et al.*, 2016).

Table 6.1a: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in Pre-monsoon season during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	OST	TZOO
WT	.607	.526	.662*	-.433	.635	.578	.831*	.213	.065	.736*	.464	-.731*
TRN	.860*	.887*	.879*	-.805*	.695*	.899*	.381	-.170	.211	.841*	.002	-.548
p^H	-.486	-.592	-.409	.637*	-.401	-.541	.352	.572	.379	-.165	.096	.235
DO	-.717*	-.732*	-.658*	.794*	-.461	-.716*	.094	.650*	.299	-.421	.047	.038
BOD	-.403	-.534	-.468	.790*	-.034	-.489	.314	.514	-.211	-.295	.536	.080
FCO_2	-.328	-.322	-.222	.345	-.245	-.329	.034	.272	.452	-.209	-.445	.010
TA	-.882*	-.921*	-841*	.848*	-.650*	-.905*	.043	.598	.203	-.644*	.184	-.124
TH	-.814*	-.862*	-.784*	.807*	-.551	-.843*	.116	.676*	.226	-.578	.255	-.035
Ca	-.882*	-.893*	-.806*	.767*	-.683*	-.881*	.059	.651*	.318	-.562	.147	-.042
Mg	-.925*	-.946*	-.885*	.789*	-.748*	-.938*	-.060	.539	.165	.685*	.162	-.198

Varying turbidity during monsoon with the fluctuation of p^H is a normal phenomenon (Sharma *et al.,* 2011). They had recorded low p^H in monsoon period of 2005 – 06 in Lake Pichhola of Rajasthan, which might have been attributed to rain water after long spell of dry period. Further this group of authors showed that DO maintain a significantly negative correlation with temperature, alkalinity, TH, electrical conductance, nitrate, phosphate, chloride and silicate. On the other hand, the high value of DO in winter is caused due to its low solubility at low temperature and less degradation of organic matters and thus such extreme situations in terms of temperature regime could not be expected in this region (Urpod beel).

Table 6.1b: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in Pre-monsoon season during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	OST	TZOO
Cl	-.926*	-.949*	-.880*	.829*	-.722*	-.939*	-.031	.557	.171	-.678*	.150	-.181
BIC	-.902*	-.940*	-.868*	.902*	-.664*	-.928*	-.031	.521	.082	-.677*	.120	-.207
TDS	-.919*	-.952*	-.881*	.837*	-.715*	-.939*	-.022	.559	.131	-.670*	.182	-.177
TSS	-.925*	-.950*	-.878*	.856*	-.710*	-.939*	-.025	.543	.169	-.685*	.138	-.190
Na	-.659*	-.741*	-.722*	.889*	-.359	-.729*	-.094	.419	.034	-.680*	.087	-.266
K	-.872*	-.907*	-.857*	.860*	-.611	-.898*	-.031	.552	.006	-.634*	.229	-.175
SO_4	-.764*	-.845*	-.716*	.747*	-.597	-.812*	.194	.567	.115	-.439	.275	-.018
NO_3	.164	.193	.232	-.415	-.012	.189	.146	.339	.577	.360	-.148	.423
PO_4	-.626	-.687*	-.623	.597	-.465	-.659	.137	.576	.170	-.429	.333	.020
N	.712*	.611	.651*	-.327	.779*	.651*	.521	.029	-.007	.559	.266	.472

p^H is another important parameter effecting species diversity and distribution in an aquatic ecosystem. The higher p^H may be due to increased carbonates, bi-carbonates and higher photosynthetic activities resulting from Phytoplankton production (Chandrasekhar and Rao, 2010). The favourable range of p^H is 6.5 – 9.0 are the most suitable for aquatic organisms (Boyd and Tucker, 1998). In this investigation the ranges of this parameter was found 6.6 ± 0.21 – 7.1 ± 0.15 (Table 2.9). From slightly alkaline to moderately acidic nature of p^H exhibits an identical trend with the natural flood plain wetlands of Assam which is earlier worked out by a number of workers (Dey, 1981; Goswami, 1985 and Thakuria and Sharma, 2006). Marginally p^H in acidic region during winter perhaps related to the higher turbidity and uniform regime of the Urpod beel perhaps enhances the microbial activity resulting the increased CO_2 level (Khan and Khan, 1985). In the present study p^H was found to be positively correlated with XAN (Table 6.1a).

Table 6.2a: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in Monsoon season during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	OST	TZOO
WT	-.274	-.299	.408	-.289	-.317	-.250	.268	-.012	-.486	-.190	.597	-.048
TRN	.550	.899*	-.394	.105	.680*	.772*	-.058	.434	.622	.664*	-.195	.499
pH	-.170	.090	-.037	-.627	.064	-.016	-.365	.316	-.247	-.112	.067	-.002
DO	.276	.510	-.324	.107	.298	.406	.188	.464	.312	.337	.140	.418
BOD	-.038	.450	-.711*	-.474	.526	.194	-.409	.203	-.021	.082	-.360	.013
FCO_2	-.489	-.870*	.557	-.008	-.747*	-.705*	-.135	-.545	-.570	-.645*	.122	-.576
TA	-.466	-.858*	.441	.024	-.710*	-.707*	.110	-.453	-.523	-.607	.197	-.463
TH	-.457	-.847*	.525	-.034	-.672*	-.681*	.086	-.405	-.523	-.574	.221	-.432
Ca	-.331	-.781*	.578	.091	-.784*	-.593	-.146	-.566	-.397	-.583	.014	-.548
Mg	-.362	-.808*	.596	.005	-.714*	-.616	.066	-.366	-.439	-.542	.209	-.396

Dissolved Oxygen (DO) is very essential for the respiratory metabolism of most of the aquatic organisms. Oxygen distribution in water bodies is important as it is the direct need of many aquatic organisms and it favours the solubility and availability of many nutrients of the organisms in turn increased the productivity of the aquatic ecosystem (Wetzel, 1975). In this investigation DO value was recorded to be the highest 9.8 mg/l in post-monsoon and in winter season (8.6 mg/l) and the lowest (6.5 mg/l) in pre-monsoon season (Table 2.9). Identical findings had also been reported from various wetlands and fish ponds of Assam (Hazarika and Dutta, 1998; Sarma *et al.,* 2013). The high values of DO are due to high productivity during clear weather season. Correlation analysis presented in the significant positive relation between DO and the XAN as well ROT, while negative correlation with that of CYN, CHL, BAC and TPHY in pre-monsoon season was recorded (Table 6.1a). Post-monsoon DO showed the significant negative correlation with CYN, CHL, BAC, EUG, TPHY, PRO, COP, CLA and TZOO (Table 6.3a). The DO suggested for positive relation with CHL, PROT, ROT, CLA and TZOO in winter season (Table 6.4a).

Table 6.2b: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in Monsoon season during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	OST	TZOO
Cl	-.489	-.872*	.481	-.033	-.677*	-.717*	.053	-.451	-.539	-.618	.159	-.481
BIC	-.187	.424	-.598	-.561	.479	.148	-.304	.201	-.135	.017	-.226	.003
TDS	-.456	-.855*	.495	-.017	-.651*	-.690*	.084	-.422	-.495	-.582	.157	-.444
TSS	-.455	-.836*	.520	-.014	-.659*	-.672*	.082	-.418	-.492	-.580	.169	-.440
Na	-.208	-.703*	.671*	-.128	-.748*	-.496	.019	-.208	-.425	-.454	.344	-.291
K	.062	.371	.-531	-.272	.623	.216	.561	.638*	.088	.353	.293	.553
SO_4	-.388	-.797*	.536	-.044	-.601	-.621	.212	-.265	-.465	-.469	.326	-.292
NO_3	.244	-.387	.785*	.381	-.642*	-.094	.337	-.008	.030	-.020	.523	.095
PO_4	.356	.618	-.573	.240	.610	.488	.075	.364	.620	.421	-.400	.387
N	.510	.518	-.192	.267	.435	.517	.495	.521	.445	.560	.269	.613

BOD value was recorded with low values in monsoon and high values in pre-monsoon but without significance. Moreover the mean BOD value has been found to be ranged between 5.8 to 6.8 mg/l throughout two years of investigation (Table 2.9). Correlation analysis of BOD with that XAN during pre-monsoon was significant (Table 6.1a). In Monsoon the BOD was negatively correlated with BAC (Table 6.2a) while negative correlation with CYN, CHL, EUG, TPHY and CLA during post-monsoon had been presented (Table 6.3a). BOD also showed the positive correlation with that of CHL, COP, CLA and TZOO while negative correlation was found with EUG (Table 6.4a).

Site specific variation of either DO or BOD could not be recorded in Urpod beel instead the Urpod beel demonstrated congenial conditions. Uniformly medium temperature perhaps is responsible for the attribution of DO in the beel. However there had been reported record of lower values of DO occurs in summer due to higher rate of decomposition of organic matter while the limited flow of water in low oxygen holding environment perhaps due to high temperature (Rani *et al.*, 2004).

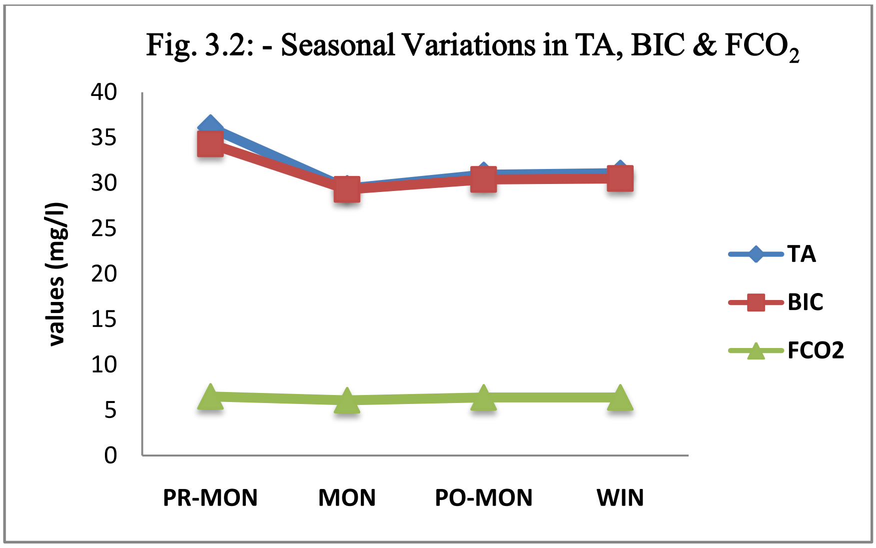
Table 6.3a: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in Post-monsoon season ` during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	OST	TZOO
WT	-717*	-.811*	-.415	-.180	-.921*	-.790*	-726*	.049	-.593	-.759*	-.271	-.686*
TRN	.872*	.945*	.524	.284	.792*	.917*	.848*	-.022	.764*	.878*	.301	.795*
pH	-.604	-.517	-.627	-.242	-.195	-.552	-.556	-.168	-.430	-.426	.291	-.457
DO	-.879*	-.878*	-.652*	-.471	-.800*	-.859*	-.750*	-.011	-.686*	-.819*	-.205	-.733*
BOD	-.714*	-.716*	-.484	-.502	-.751*	-.734*	-.552	-.055	-.444	-.707*	-.009	-.591
FCO_2	-.928*	-.940*	-.484	-.288	-.692*	-.918*	-.924*	.046	-.711*	-.903*	-.164	-.807*
TA	-.848*	-.947*	-.432	-.330	-.897*	-.911*	-.816*	.147	-.691*	-.895*	-.380	-.757*
TH	.869*	.968*	.563	.417	.886*	.950*	.819*	-.064	.757*	.900*	.419	.793*
Ca	-.560	-.680*	-.287	-.237	-.929*	-.658*	-.577	-.055	-.624	-.741*	-.554	-.664*
Mg	-.916*	-.949*	-.469	-.369	-.845*	-.931*	-.855*	.072	-.650*	-.912*	-.193	-.780*

The abundance of Free CO_2 exert specific effect on aquatic biota and helps in buffering the aquatic environment against rapid fluctuation in the acidity, alkalinity and also regulate biological process of aquatic communities. In this observation, the Free CO_2 showed marginal seasonal variation with the lowest level of Free CO_2 (6.1 ± 0.2 mgl^{-1}) observed in monsoon and the highest level (6.5 ± 0.19 mgl^{-1}) was observed in pre-monsoon (Table 2.9). The higher rate of decomposition during pre-monsoon season occurs due to rapidly receding water level and higher temperatures followed by scanty rains, were probably responsible for higher CO_2 and reduced O_2 content. The presence of algal bloom in the monsoon season may be the reason for low level of CO_2 (Chandrasekhar and Rao, 2010). In monsoon season free CO_2 was negatively correlated with these of CHL, EUG, TPHY and CLA (Table 6.2a).

Free CO_2 showed positive correlation with PRO while a negative correlation was found with these of CYN, CHL, EUG, TPHY, COP, CLA and TZOO (Table 6.3a). Free CO_2 also showed the significant correlation with CYN during winter, while negative correlation with CHL, ROT, COP, CLA and TZOO had been recorded (Table 6.4a).

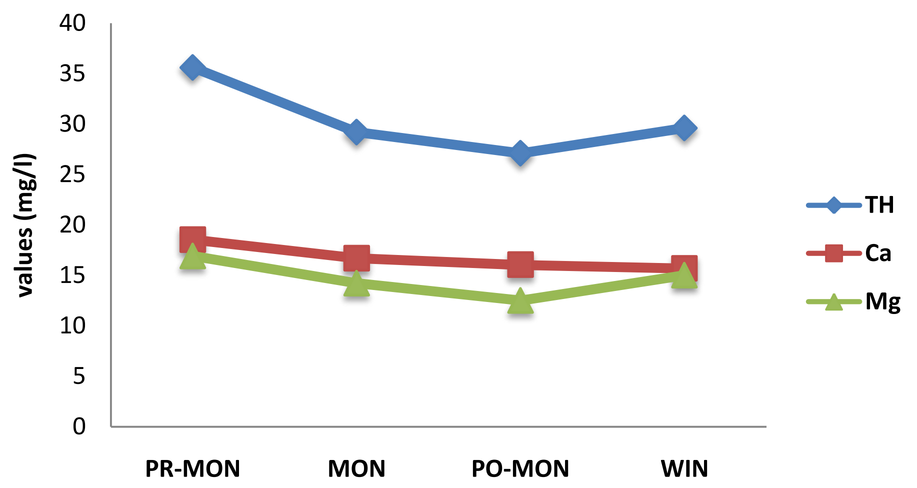
Alkalinity is the acid neutralizing capacity of water which depends on the strength of Carbonates in a sample and it determines the availability of Free CO_2, essential for photosynthesis which is directly related to productivity. In this investigation the seasonal fluctuation of Total Alkalinity (Table 2.9 and Fig. 3.2) showed the similar trend with that of Free CO_2. Mir *et al.*, (2005) also reported that with increased in Free CO_2, the Alkalinity values also get increased. In this observation the minimum level for TA was 29.4 ± 0.12 in monsoon and maximum was 36.1 ± 0.22 in pre-monsoon (Table 2.9). This range of Alkalinity value contains suitable quantities of CO_2 to permit plankton production for fish culture (Offem *et al.*, 2011), that can support the present findings. Yet Garg *et al.* (2010) recorded TA with range variation of 64.25 to146.25 $mgl^{-1}$with the suggestion that the reservoir was nutrient rich and highly productive but against the findings of the present study.



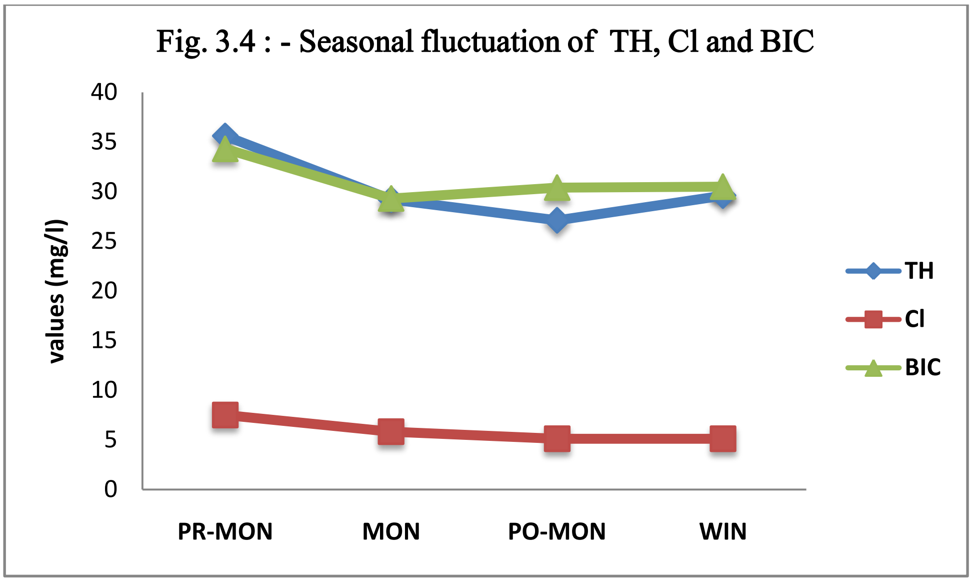
Total Alkalinity significantly correlated with XAN while negatively correlated with these CYN, CHL, BAC, EUG and CLA in pre-monsoon (Table 6.1a). The significantly negative correlation with CHL, EUG and TPHY was evaluated in this study during monsoon season (Table 6.2a). Further Total alkalinity was negatively correlated with these of CYN, CHL, EUG, TPHY, PRO, COP, CLA and TZOO in post-monsoon season (Table 6.3a). Again the Total Alkalinity exhibited positive correlation with CYN and negative correlation with these of CHL, ROT, COP, CLA and TZOO during the winter season (Table 6.4a).

Total Hardness depends on the concentration of carbonate and bicarbonate salts of calcium and magnesium (temporary hardness) or sulphate, chloride (Fig. 3.3 and 6.4) or other anions of mineral acids (permanent hardness). Hardness has great effect on biotic diversity and also restricts the total use of water. According to the range of TH (mgl^{-1}) the water of the lake could be categorized into soft (0 – 30), moderately soft (30 – 60), moderately hard (60 – 120), hard (120 – 180) and very hard (>180) (Carlson, 1977). Accordingly water of the Urpod beel is soft to moderately soft (27.1 ± 0.16 – 35.6 ± 0.23) (Table.2.9). Total Hardness of this study had been evaluated as positively correlated with XAN and ROT, while negatively correlated with these of CYN, CHL, BAC and TPHY in pre-monsoon season (Table 6.1a). In monsoon season TH showed significant negative correlation with these of CHL, EUG and TPHY (Table 6.2a).

Fig. 3.3: - Seasonal fluctuation of TH, Ca and Mg



The TH was positively correlated with these of CYN, CHL, EUG, TPHY, PRO, COP, CLA and TZOO during the post-monsoon period (Table 6.3a). Total Hardness again positively correlated with CHL, ROT, COP, CLA and TZOO, whereas negatively correlated with that of CYN in winter season (Table 6.4a).



Total hardness of a given water body showed an increasing tendency during pre-monsoon period of this investigation could be supported by the works of several workers (Paka and Rao, 1997; Kumar *et al.,* 2007; Tripathi *et al.,* 2008; Shukla *et al.,* 2012).

Calcium was found in all the natural waters and its main source is weathering of rocks from which it leaches out. During the study period its maximum value was in the pre-monsoon and monsoon (18.52 ± 0.61 and 16.69 ± 0.90) and the minimum value was found in winter season (15.60 ± 2.24) (Table 2.9). Recent observation of Devi *et al*. (2016) has recorded almost identical value in Baskandi anua lake, Cachar, District, Assam, could also supported by some other workers (Khanna and Bhutiani, 2007). During pre-monsoon and monsoon input of sewage, drainage water and fertilizers from nearby rice field has led to increase of Ca and other nutrients. Decomposition of these nutrients into water promoted growth of phytoplankton (Francis *et al.*, 1997). Ca dominance in lake water has been quoted in very recent years (Bharti and Niyogi, 2015). Coefficient matrix analysis showed negativity with CYN, CHL, BAC, EUG and TPHY, while positively correlated with XAN and ROT in pre-monsoon season (Table 6.1a). In monsoon season Ca showed negative correlation with CHL and EUG (Table 6.2a). Ca presented negative correlation with these of CHL, EUG, TPHY, CLA and TZOO in post-monsoon season (Table 6.3a). While negative correlation with CHL, ROT, CLA and TZOO as well as positive correlation with CYN had been established (Table 6.4a).

The concentration of Mg in the beel water was found at lowest in post-monsoon (12.5 ± 0.12) against its highest value in pre-monsoon (16.9 ± 0.15) (Table 2.9). This result has been found to be in inconformity with Sharma *et al.* (2010) observed 25.02 ± 9.81 mg/l in Gundolav Lake in Rajasthan. In the present study Mg was negatively correlated with these of CYN, CHL, BAC, EUG, TPHY and CLA, while positive relation had been established with XAN in pre-monsoon season (Table 6.1a). Negative correlation with CHL and EUG has been presented in this investigation (Table 6.2a) as well as with CYN, CHL, EUG, TPHY, PRO, COP, CLA and TZOO in post-monsoon (Table 6.3a). In the winter season Mg also showed the positive correlation with CYN, while negative correlation with CHL, ROT, COP, CLA and TZOO has been established (Table 6.4a).

Chloride level during this study was found higher in pre-monsoon season and lower in post-monsoon and winter season (Table.2.9). The highest chloride value in pre-monsoon followed by monsoon and post-monsoon, at Santragachi and Joypur Jheel, W.B, India had been reported by Patra *et al.*, (2010). Chloride is an important factor that determines the total salinity of the water and accumulation of this factor over a period of time is an indication of anthropogenic pollution (Chandrasekhar and Rao, 2010). Shukla *et al.* (2012) in their studies was very much suggestive of the higher concentration of chloride during post- monsoon, where they have assayed a range variation of 31.0 to 36.0 mgl^{-1} and their findings was supported several workers (Pallui and Jha,2003; Garg *et al.*, 2010; Kumar *et al.*, 2007; Tripathi *et al.*, 2008).

Chloride in fact has been observed to be recorded in the form of salts of Na or Ca. Khanna and Bhutiani (2007) in the study of limnological modelling on the river Suswa observed maximum Cl 24.33 ± 6.58mgl^{-1} in monsoon and minimum of 15.02 ± 1.35mgl^{-1} in winter period. Chloride has been recorded as a chemical indicator for pollution and thereby it could well be inferred that Urpod beel remained fresh to its possible level. During the study period the results of Cl level in this beel were low ($5.1 \pm 0.34 - 7.5 \pm 0.08$ mgl^{-1}) (Table.2.9) which was the indicative of low anthropogenic pollution in Urpod beel.

The minimum value of Bicarbonate was found in monsoon season (29.3 ± 0.12) and the maximum (34.3 ± 0.12) value was found in pre-monsoon season (Table 2.9). The bicarbonate alkalinity is enhanced by increased FCO_2 concentration (Fig. 3.2).

The higher quantity of FCO_2 during summer in Mir Alam Lake in Rajasthan by Anitha *et al.,* (2005) showed identical value with the present findings. The liberation of CO_2 might be due to higher rate of decomposition along with the high temperature regime, however, demands further study in the Urpod beel.

TDS plays an important role in community structure due to its limiting impart on primary production and thermodynamics. TDS of the beel water during the survey period range from 12.5 ± 0.25 to 19.9 ± 0.13 (Table 2.9). The lowest value of this factor was recorded in post-monsoon and the highest value in pre-monsoon season. Total dissolved solids (TDS) had been recorded to be ranged between 210 mgl^{-1} to 278 mgl^{-1} with lowest during winter and the highest during summer of 2005-2006 in the Lake Pichola of Rajasthan were in conformity with the findings of Sumitra *et al.,* (2007) during 1997-1998 against the highest of pre-monsoon and the lowest in post-monsoon of the Urpod beel of this study. The identical observations notify by Sharma *et al.,* (2010) in the Gundolav lake of Rajasthan.

In fact, TDS and total alkalinity (Maruthanayagam *et al.*, 2003), Ca, Mg hardness and conductivity (Kamath *et al.,* 2006) demonstrated their maximum in summer (Sharma *et al*., 2010). The low value of this parameter in post-monsoon followed by gradual increase in winter and summer supports the present findings.

Normally the conductivity and TDS in water ranged between 303.7 to 4456.7 μs/cm and 169 to 2079 mgl^{-1} respectively. These parameters have been the highest in

Ukkadon wetland of Coimbatore, India (Chandra *et al*., 2010). The high TDS in this wetland might be an attribution of effluents from certain industrial units like dyeing etc. Since the wetland acts as sink for nutrient deposition and hence, the high TDS values may also depend on the age of the lake (Anitha *et al*., 2005). Therefore a logical argument could be put inference of Urpod beel in Assam as the unpolluted water body.

TSS of a lake is that portion of Total Solid (TS) that can be retained on a water filter and are capable of settled down. In the present finding TSS was maximum (67.6 ± 0.16) in monsoon season and minimum in pre-monsoon (62.0 ± 0.15) and winter season (63.4 ± 0.09) (Table 2.9).

Table 6.3b: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in Post-monsoon during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	OST	TZOO
Cl	-.901*	-.967*	-.481	-.317	-.870*	-.939*	-.877*	.073	-.714*	-.917*	-.300	-.802*
BIC	-.891*	-.985*	-.484	-.333	-.891*	-.933*	-.860*	.083	-.689*	-.906*	-.318	-.788*
TDS	-.841*	-.916*	-.403	-.135	-.815*	-.877*	-.860*	.159	-.623	-.825*	-.155	-.708*
TSS	-.904*	-.966*	-.514	-.339	-.890*	-.945*	-.868*	.030	-.718*	-.917*	-.289	-.811*
Na	-.834*	-.890*	-.245	-.313	-.759*	-.849*	-.807*	.172	-.581	-.889*	-.233	-.722
K	-.814*	-.797*	-.241	-.310	-.634*	-.774*	-.789*	.041	-.498	-.838*	-.118	-.705*
SO_4	-.575	-.720*	.005	-.115	-.777*	-.646*	-.637*	.377	-.426	-.742*	-.344	-.534
NO_3	-.709*	-.681*	-.620	-.730*	-.701*	-.726*	-.491	-.405	-.511	-.706*	-.252	-.681*
PO_4	.714*	.839*	.250	.141	.866*	.786*	.712*	-.136	.532	.770*	.306	.640
N	.940*	.937*	.713*	.662*	.831*	.959*	.729*	.126	.741*	.881*	.383	.804*

Table 6.4a: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in winter season during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	TZOO
WT	.233	-.761*	-.001	-.713*	.197	-.659*	-.276	-.606	-.650*	-.758*	-.694*
TRN	-764*	.894*	-.401	.250	-.515	.346	.202	.847*	.978**	.871**	.911*
pH	-.142	.246	-.567	.152	-.267	-.014	-.345	.483	.405	.455	.404
DO	-.540	.675*	.211	-.119	-.267	.420	.742*	.654*	.631	.674*	.720*
BOD	-.214	.711*	.087	.552	-.695*	.562	.359	.553	.637*	.724*	.670*
FCO_2	.748*	-.811*	.468	-.183	.438	-.260	-.089	-.831*	-.932*	-.842*	-.869*
TA	.743*	-.896*	.399	-.239	.570	-.347	-.159	-.853*	-.984*	-.860*	-.907*
TH	-.691*	.904*	-.241	.234	-.612	.417	.230	.817*	.945*	.817*	.875*
Ca	.682*	-.784*	.285	-.166	.625	-.276	-.372	-.712*	-.831*	-.747*	-.795*
Mg	.747*	-.892*	.345	-.205	.619	-.343	-.196	-.827*	-.978*	-.832*	-.891*

Turbidity and total suspended particles (TSS) refers particles larger than 2 microns found in the water columns. Generally most of the suspended solids are made up of inorganic materials though bacteria and algae could also attribute to the total solid concentrations. Therefore TSS is a measurement of mass (mgl^{-1}) of water. During the monsoon period, the Urpod beel water body showed 67.6 ± 0.16 mg/l and maintains almost at this level (Table 2.9). There has been a consideration that NO_3 and PO_4 are often pollutant, but as they are soluble could not contribute directly to the suspended solids concentration (Brobst, 2006). Instead they are the indirect contributors since they induce algal blooms, which do not affect TSS and turbidity. The higher concentration of TSS in the beel might be due to higher rainfall. Since rain can affect directly to increase the level of suspended solids through run off and even the runoff could increase the bottom sediments with further rise in TSS (Periman, 2014).

The most important inorganic nitrogen compound in water is NO_3. In the present findings, the NO_3 value has been observed at range variation of 0.80 ± 0.44 to 0.98 ± 0.19 in winter and pre-monsoon seasons (Table 2.9) respectively. The desirable limit of this factor is 0 – 2mgl^{-1} and the acceptable limit is < 4 mgl^{-1} (DWAMD, 1994). Thus it remains within the desirable limit during the study period. Barman *et al*. (2015) recorded seasonal mean of $NO3^-$ at 0.025 and 0.08mgl^{-1} during the year 2012-2013 and 2013-2014 in the wetlands of Garo hills. Higher nitrate content was also recorded in the summer season and less in winter, supports the present findings. The present study showed the negative correlation between the nitrate and the phytoplankton group (Table 6.3b).

Table 6.4b: - Correlation coefficient matrix between the Plankton group(s) with certain physico-chemical parameter(s) of Urpod beel in winter season during March, 2014 – Feb, 2016.

	CYN	CHL	BAC	XAN	EUG	TPHY	PRO	ROT	COP	CLA	TZOO
Cl	.752*	-.875*	.417	-.212	.612	-.305	-.137	-.834*	-.981*	-.849*	-.894*
BIC	.815*	-.845*	.503	-.154	.538	-.228	-.097	-.822*	-.963*	-.808*	-.866*
TDS	.862*	-.781*	.480	.022	.567	-.122	-.085	-.805*	-.937*	-.791*	-.845*
TSS	.756*	-.862*	.387	-.204	.590	-.301	-.181	-.779*	-.967*	-.795*	-.859*
Na	.742*	-.812*	.301	-.040	.636*	-.258	-.218	-.800*	-.931*	-.832*	-.869*
K	.492	-.661*	.245	-.261	.743*	-.242	-.191	-.597	-.786*	-.781*	-.738*
SO_4	.741*	-.834*	.445	-.303	.287	-.333	-.126	-.796*	-.889*	-.788*	-.829*
NO_3	.072	.198	-.046	.329	.446	.348	.137	.288	.070	.173	.181
PO_4	.517	-.318	.469	-.106	.387	.141	-.045	-.254	-.505	-.426	-.403
N	.567	-.332	.639*	.091	.677*	.266	.297	-.437	-.582	-.475	-.465

In general, aquatic ecosystem receives excess of nutrients through untreated domestic sewage and agriculture runoff. Higher level of PO_4 acts as a limiting nutrients responsible for the process of eutrophication and leads to ultimate degradation of an aquatic ecosystem (Willem *et al*., 1972). Phosphate is important nutrient that restricts microbial production in fresh water environments on reported by Hudson *et al*. (2000). The actual concentration of phosphate in phosphorus limited water is largely unknown. Yet inorganic phosphate has been considered to be one of the most significant factors in the maintenance of an aquatic ecosystem. Saha (1991) had been able to present the phytoplankton count between 487 and 1711 individual ul^{-1}

against the phosphorus ranging between 0.18 and 1.23mgl^{-1}. A correlation has been drawn between the changes in phosphate concentration and phytoplankton abundance revealed and inverse relationship ($r = -0.0773$, $P < 0.05$) indicates its link in the cycle of autotroph. During the course of the study the PO_4 concentration was low in the Beel water. The maximum of 0.16 ± 0.01mgl^{-1} was recorded in pre-monsoon season (Table 2.9). The present observation is in conformity with Raina and Peter (1999) who reported the low values of PO_4 from various Himalayan lakes and reservoirs and confirms the findings of Barman *et al*. (2015) in wetlands of West Garo Hill, Meghalaya. However phosphate has demonstrated negative correlation with that of Rotifer group (Table 6.3b).

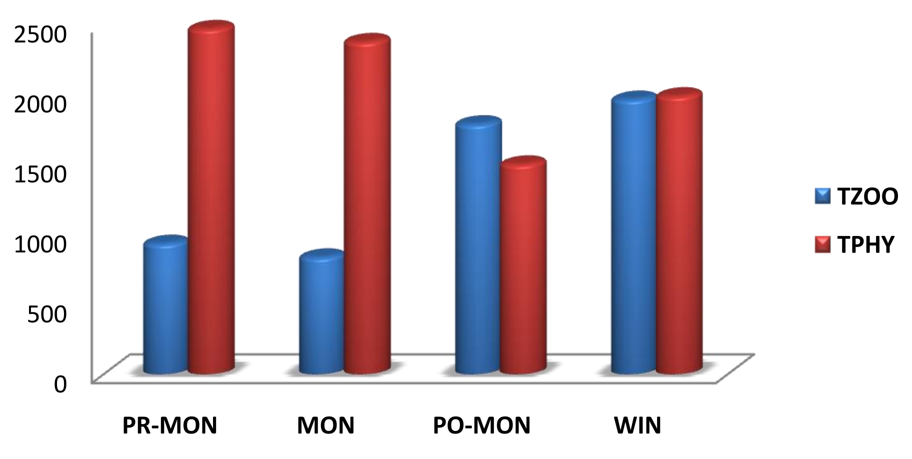
The range of SO_4 in the beel water was $4.5 \pm 0.11 – 6.4 \pm 0.14$ in winter and pre-monsoon seasons respectively (Table 2.9). The high values of this factor may have been caused by the used detergents and soaps by neighbours which got into the water body (Mishra, 1991).

Sulphate in water body has been stated as second to bicarbonate as the major anion in hard water. The source of SO_4 in fresh water has been happened to be naturally occurring, possibly as a result of the breakdown of leaves of vegetation specifically the macrophytes. The amount of SO_4 as the highest quantity has been recorded in this investigation was during pre-monsoon (6.4 mgl^{-1}) and the lowest during winter 4.5 mgl^{-1} in Urpod beel of this study (Table 2.9). The argument could be extended in favours perhaps due to breakdown and drying up of many of macrophytes, however demands in depth through investigation. Otherwise, such an amount of SO_4 in this water body might be due to runoff from fertilized agricultural lands. The SO_4 level was detected at 0.68 ± 0.18mgl^{-1} in the Veeranam reservoir of Tamilnadu in the month of April (Sivakumar and Kuruppasamy, 2008) which seems parallel with that pre-monsoon period of study, however, much lower than this investigation. It is in fact, that a direct link between the naturally occurring SO_4 and plankton community or very indirectly with the fish community as such, yet, it has been attempted to establish that Copepoda biomass in copper sulphate treated pond showed excess against the reduction of zooplankton cladocera (Jacob *et al*., 2016). It has been suggested that the low levels of SO_4 in other periods or seasons possibly due to uptake of primary productivity and the activity of sulphate reducing bacteria and high sulphate due to entry of sulphate dissolved in monsoon water.

The nutrients like Ca, Mg, and Cu were examined; their higher concentrations were recorded during pre-monsoon period which was in conformity with the findings of Sivakumar and Kuruppasamy (2008). Calcium being abundant in a beel water body like Urpod beel (18.52 ± 0.61) is the most abundant ion and is significantly important in crustacean shell growth (Daphnia etc), bone building plant precipitation of lime (Jhingran, 1975). Further, it also suggests that the considerable amount of Mg (16.9 ± 0.15 in pre-monsoon) influences water quality as reported in Adayan River (Govindom and Devika, 1991). Being cations Ca^+ and Mg^+ behave in identical way in ion exchange reaction and influences the absorption of Na^+ equally (Paliwal and Yadav, 1976). The amount of Na in the Urpod beel has been recorded without significant changes throughout the year. Magnesium is absolutely essential for chlorophyll bearing algae and plants indirectly enhance the phytoplankton. It may be well inferred that Mg enters into a combination with other anions like Cl^- and SO_4 apart from CO_2 in lakes (Jhingran, 1975). It has been recorded that under limited level of K, (1.45mgl^{-1} in winter) the growth and photosynthesis of algae are poor while the respiration is recorded to be on the higher side (Cole, 1983). The present finding has been able to demonstrate the equivalency order of cations in the Urpod beel as Ca > Mg > K > Na against the findings of other workers (Zutshi *et al*., 1980) is the order of Ca > Mg > Na > K. Earlier, Sondargaard and Sand-Jensen (1979) have suggested that the relative amount of cations in surface water were Na > Ca > Mg > K, however such gradation of sample collection either from surface or deep water had not been performed. The high level of Ca and Mg in the water body might be due to bioaccumulation by living organism, demand in depth study. The highest amount of nitrogen recorded during monsoon season (1.8±0.07 mgl^{-1}) due to possible influx of rich flood water into the lake water. And the lowest amount of nitrogen in water was recorded during pre-monsoon was 1.6±0.08 mgl^{-1} (Table 2.9) possibly due to the utilization by plankton and aquatic plants for metabolic activites (Umerfaruq and Solanki, 2015). The beel water has been able to demonstrate the presence of negligible quantity of heavy metals like Cu, Cd and Cr suggestive of the no polluted water. Apart from these the Zn presented its value as 0.26mgl^{-1} below the permissible level, yet its presence is necessary for many of the biological activity. Heavy metals are readily and rapidly absorbed to particulate materials like detritus, plankton; suspended particles etc are always used to assimilate by living organisms (Khanna and Bhutiani, 2007).

CCA analysis has been able to project the influence of 16 parameters on the richness of phytoplankton species like *Navicula rhynchocephala*, *Microcystis aeruginosa*, *Volvox aureus*, *Tetraedron pusillum*, *Nostoc muscorum*, *Micrasterias foliacea*, *Gomphospharea aponina*, *Euastrum ansatum*, *Anabaena orientalis*, *Ankistrodesmus falcatus* and zooplankton species like *Arcella vulgaris*, *Mesocyclops leuckarti* (male), *M. leuckarti* (female), *Arcella discoides*, *Testudinella patina*, *Alona rectangula*, *Horaella brehmi*, *Macrothrix spinosa*, *M. triseralis*, *Acroperus harpae* in Urpod beel. The environmental requirements of different species differ, hence defing how they respond to variations in these factors. From the Cannonical analysis, it was revealed that the distribution of phytoplankton and zooplankton community in the Urpod beel depends on the physico-chemical characteristics of the water (Fig.2.3 to Fig.2.6).

Fig. 3.5:- Seasonal variation of plankton population in Urpod beel during the study period

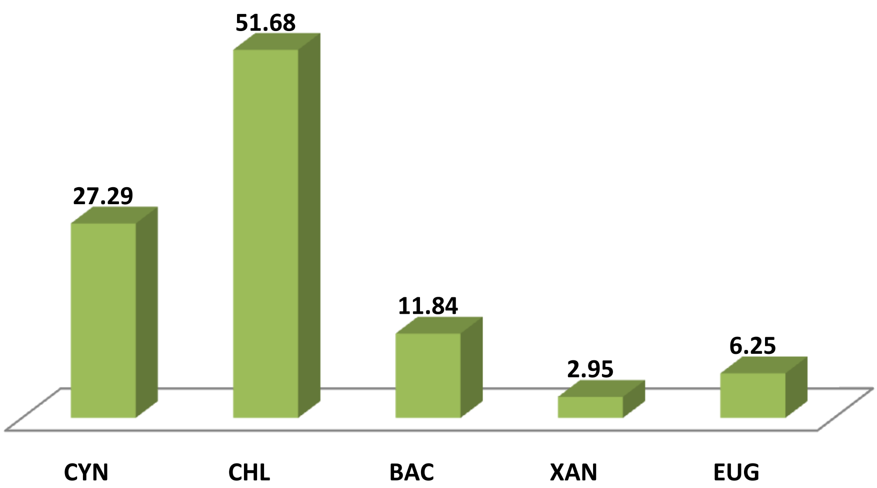


Planktons, being heterogeneous, assemblage of suspended minute organisms floating/moving freely in a given water body more specifically in a lentic water body like Urpod beel in Assam, India. Though their association with human being is indirect, yet they are the major indicators of the water quality. The two divisions of plankton viz. the phytoplankton and the zooplankton have been found to abundant the said beel during the study period 2014-2016. Phytoplankton, being categorised as the producer group has been recorded to be comprised of 5 different classes (Cyanophyceae; Chlorophyceae; Bacillariophyceae; Xanthophyceae; Euglenophyceae) carrying 15, 30, 10, 2 and 4 numbers of species respectively as the total phytoplankton (TPHY). The nature and abundance of phytoplankton, its quality, temporal and spatial distribution are governed by the physico-chemical parameters of the water (Singh, 2015). Sensitivity as well as variations in the species composition, belonging to each class, could be projected as the reflection of significant alteration in a given ecosystem (Senthilkumar and Shivakumar, 2008). Further the limnological features of given lentic water body in relation to different seasons are related to the hydrological conditions, which are reflected in the physico-chemical characters and the planktonic community of water (Singh and Gupta 2010).

The most abundant group among the phytoplankton community has been recorded as the CHL (30 species) in terms of density followed by the group CYN (Table 3.10 & 6.5). The Chlorophyceae dominance in various water bodies has earlier recorded by many workers in Assam flood plain context (Goswami, 1985; Dutta *et al*., 1990; Hazarika and Dutta, 1994). Further the dominance of Chlorophyceae has been described by many workers in recent years (Ajayan and Ajit Kumar, 2015 in a lake of Thiruvanthepum of Kerala ; Laskar and Gupta, 2009 in the Chatla plain lake of Barak valley, Assam and Bhat *et al*., 2015 in Bhoj wetland of Bhopal) support the present findings of this investigation. The dominant species of Chlorophyceae has been recorded as *Volvox aures*, *Micrasterias foliacea*, *Ankistrodesmus falcatus* (Photo Plate -4) and *Tetraedron pusilum* (Table 3.9) in all the five different experimental sites in the pre-monsoon and monsoon season of a given year of study. The abundance of this species could be logically argued that the increased temperature and long photoperiod may explain their high numbers and increased diversity (Bhat *et al*., 2015). It could well along be inferred that moderately high content of Ca (18.52 mgl^{-1}), PO_4 (0.16 mgl^{-1}), NO_3 (0.98 mgl^{-1}) and N (1.6 mgl^{-1}) during the pre-monsoon period of this study (Table 2.9) might have influenced the growth of these species as well the Chlorophyceae diversity (Nandan and Aher, 2005; Tiwari and Chauhan, 2006). Under this condition of these parameters, might have attributed to high growth of the four species including the *Volvox*, since the green algae (Chlorophyceae) are known to proliferate (Ayoade, 2000). It has been argued in the recent past that the bloom of Chlorophyceae during the monsoon period might be an attribution of water temperature, rainfall and resultant dilution of water (Valecha and Bhatnagar, 1988). Moreover, the Chlorophyceae has been recorded to be associated with the open water, a characteristic of Floodplain Lake with prolonged annual flood duration (Van den Brink *et al.,* 1994; Laskar and Gupta, 2009). Ghos *et al*., 2012 observed the dominance of Chlorophyta in the Satragachi Lake, West Bengal, India and stated their dominance in variety and percentage composition and the lowest number of Euglenophyceae. However Chlorophyceae has been projected as the second dominant group (21% contribution) in Baldi stream of Garhwal, Himalayas (Sharma *et al*, .2016). Analysis of community structure suggested higher Shannon index (5.585) and Berger- perker dominance index (0.0769) during pre-monsoon period (Table 6.6). The records of high numbers of phytoplankton during pre-monsoon and monsoon might be an attribution of drainage water and fertilizers from the nearby agricultural fields (Urpod beel) leading to the increase of nutrient into the water, which influences the higher growth of phytoplankton in flood plain beel like Urpod and validate the inference that the high relative abundance of chlorophyta is an indicator of productive water (Boyd, 1981).

The present observation in the phytoplankton group showed that the second dominant group of TPHY was Cyanophyceae with a density of 606ul^{-1} in summer (Table 3.10). In fact, the group CYN has been well dominated by *Anabaena orientalis, Microcystis aeruginosa, Anabaena fertilissima, Gomphospheria aponina* in Urpod beel during pre-monsoon and monsoon period (Table 3.9). It has been stated that the most abundant phytoplankton group in a reservoir like open pond Deeg during the monsoon period (Singh, 2015).

Fig. 3.6: - Abundance % of Phytoplankton Groups



The higher density of Cyanophyceae might be due to the higher concentration of nitrates ($0.98 mgl^{-1}$) and phosphate ($0.16 mgl^{-1}$) in winter in Urpod beel (Table 2.9). Earlier, it has been recorded that higher Cyanophyceae growth is associated with the nutrients like phosphate and nitrate (Smith, 1983). Further higher turbidity and also the TDS extend favour of higher growth of Cyanophyceae (Harsha and Malammanavar, 2004). The presence of higher density of cyanophyceae has been considered as a pollution load as well nutrient rich condition (Muhammad *et al*., 2005; Tas and Gonulol, 2007). But such view could not be applied to the Urpod beel, but a logical argument could be forwarded that the Cyanophyceae diversity is more in this beel, may demand elaborative study. However, the group Cyanophyceae has been projected as the most dominant group in an open pond in Bharatpur, India, where *Microcystis aeruginosa* has occupied 47% relative abundance as well dominance (Singh, 2015). Even, the *Microcystis* has dominated the phytoplankton group of Cyanophyceae in Lake George Uganda, while the *Anabaena*, a filamentous form of blue-green algae was reported as the dominant group of phytoplankton in lake Rudlof, Kenya and diatoms in Lake Alberts (Prescott, 1954; Shivakumar and Karuppasamy, 2008). The Urpod beel of this study gradually might have been experienced with anthropogenic intervention, result, being dominated by *Anabaena* and *Microcystis* group (Table 3.9) with a relative density 714.0 ul^{-1} during pre-monsoon period 2015 – 16 (Table 3.10). However CYN, has been demonstrated as the dominant group in terms of density (1272 ul^{-1}) during the month of June (Monsoon) in Wular Lake of Kashmir with species dominance record of 0.2485 (Baba and Pandit, 2014). It is argued that the Wular Lake is subjected to pollution due to addition of fertilizer from agricultural lands and domestic sewage from human habitation. The correlation coefficient matrix analysis between Cyanophyceae and the other phytoplankton groups have been able to demonstrate positive correlation with those of the CHL, BAC and EUG and as such with that of TPHY against the negative correlation with that of XAN during pre-monsoon period (Table 3.11) against all positive correlation in monsoon (Table 3.12), post-monsoon (Table 3.13) and in winter season except CHL (Table 3.14).

The group Bacillariophyceae has been represented by 10 numbers of species dominated by *Navicula rhynchocephala* followed by *Nitzschia* species during the pre-monsoon season (Table 3.9). The total abundance of BAC has been recorded at 299.0 (monsoon) and 351.0 (pre-monsoon) during the year 2014-15 and 2015-16 respectively (Table 3.12). Maximum growth of BAC in a floodplain lake of the Barak valley, Assam has been projected during the pre-monsoon (39.47%) and in monsoon (23.22%) of the year 2006-07 respectively (Laskar and Gupta, 2009). The higher growth of BAC during pre-monsoon or monsoon might be liked with the rise of water temperature (Kant and Anand, 1978) followed by their depletion in winter in the present study (Table 3.9), validating the logic of fall of temperature. The group BAC has been found to be dominated in the Baldi stream of Garwal with 71% of the total phytoplankton (Sharma *et al*., 2016). Presence of BAC as the dominant group in the Jhelum river in Kashmir Himalayas was recorded (Hafiz *et al*., 2014) in the Emo river of Nigeria (Ogbuagu and Ayoade, 2012), in Kenti river, Republic of Karelia (Chekryzheva, 2014) and in Greater Zab river of Iraq (Ali, 2010). It has been argued that rich calcareous rock favoured the high growth of Bacillariophyceae (Sharma *et al.,* 2016). Earlier Pattrick (1977) had suggested that calcium carbonate and bicarbonate promote the growth of Bacillariophyceae. The present study has been able to demonstrate a reasonably higher quantity of bi-carbonate throughout the year (Table 3.9) and showed a positive correlation with Ca and Mg as well with Na and K and with SO_4 and PO_4 but showed negative correlation with the NO_3 and nitrogen quantity in water body in pre-monsoon period (Table 2.10c). Further demonstrated that the monsoon bi-carbonate presented negative correlation except with K and PO_4 during the monsoon period (Table 2.11c).The highest density of BAC was noted at 712 individuals ul^{-1} during winter in the Balbi stream by Sharma *et al*. (2016) and such results were also reported from the river Ganga and its tributaries (Negi *et al*., 2012) and Chandrabhaga River of Garhwal Himalays (Sharma *et al*., 2007). The higher density of BAC might be due to the less TDS and TSS (Table 3.9) which might have influenced the enhancement of photosynthesis possibly led to the growth of Bacillariophyceae. Moreover, this group of phytoplankton (BAC) could be used as bio-indicators for water quality evaluation (Goma *et al*., 2005). BAC has been recorded to be positively correlated with that of EUG and the total phytoplankton community in the Urpod beel against the negative correlation with that of Xanthophyceae during pre-monsoon period (Table 3.11). Further this phytoplankton group showed a positive correlation with XAN during post-monsoon period (Table 3.13).

The phytoplankton group Xanthophyceae has been represented by range variation of 51.0 to 87.6 (2014-2015) and 32.8 to 66.6 (2015-2016) during the pre-monsoon to post- monsoon period respectively (Table 3.10 and 3.9). The major representations of this class of phytoplankton are filled up by the Botryococcus (62.0 ± 7.0 ul^{-1}) with the highest density of 87.6ul^{-1} during the pre-monsoon period. This group of phytoplankton are rich in chlorophyll, but marked by brown or yellow pigment. Presence of two species (*Voucheria* sp. and *Tribonema* sp.) of Xanthophyceae in Riperian wetland of the river Subansiri of North Eastern India has been documented (Sarmah and Baruah, 2014).

The class Euglenophyceae of the Urpod beel has been comprised of different form of species were found to dominate during pre-monsoon and monsoon period of the study year (Table 3.9). But the species *Euglena viridis* has been able to project its higher numbers during whole of the study period (Table 3.9). Yet the species *Phacus acuminatus* had shown its higher mean value at 69.0 ± 8.0 during pre-monsoon period of the study years (Table 3.9). Euglenophyceae has exhibited positive correlation with the TPHY during pre-monsoon and monsoon period (Table 3.11 and 3.12) against negative correlation with that of TPHY as well with the Zooplankton group in winter season (Table 3.14). There has been a significant correlation of Euglenophyceae with the Ca hardness and total hardness by way of an attribution to the fact that Ca^{+} plays an important part over plant tissue enhancing the availability of other ions in water (Manna and Das, 2004). Even, Khan and Bhat (2000) put forwarded the importance of calcium in stimulating the growth of *Euglena*. It is suggestive that *Euglena* bloom with rise of temperature (pre-monsoon) might be an attribution to the growth of this group of phytoplankton supports the findings of Bhat *et al*., (2015). *Euglena* blooming (Bowling, 2009) and the identical situation were recorded in flood plain wetlands of Assam (Duttagupta *et al*., 2004).

Euglenoid blooming has been reported from shallow water body as well as Dal and Manasbal lakes in Jammu and Kashmir (Khan and Bhat , 2000). The conditions that favours the predisposition of blooming includes warm temperatures, high organic load resulted as the runoff rain water, fertilizers from the paddy and elevated concentration of Fe, Mn, Silica and PO_4 either in combination or in group affect the water body leading to the euglenoid bloom (Choudhury *et al*.,1998 ; Duttagupta *et al*.,2004). Euglenophyceae has been found to be abundant in water rich organic matters and as such presence of the genus *Phacus* might be indicator to pollution load being their dominance in a given polluted water (Alam and Khan,1996) and thereby it may be speculated that the Urpod beel either sooner or later might be contaminated , demands further in depth evaluation. Higher level of CO_2, PO_4, NO_3 and low content of dissolved oxygen (Table 2.9) may favour the growth of euglenoids. Therefore it is concluded that the high organic load, low transparency, low dissolved oxygen and higher range of alkalinity may favour euglenoid growth and a relation is possible between the euglenoid numbers and organic pollution (Singh, 1979).

The diversity of the group Euglenophyceae has shown four species under two different genera during the study period. It has been favoured that the Euglenophyceae, as such prefer to grow in abundance in polluted water. In fact, they are supposed to grow luxuriantly and often develop into water blooms in water, which are originally rich as recorded in wetlands Taluk, Karnataka (Jagadeeshappa and Kumara, 2013). It has been put forwarded that free carbon dioxide; dissolved oxygen and phosphate are the chief factors to regulate the euglenoid distribution in fresh water bodies (Munawar, 1974; Hedge and Bharati 1985; Puttiah and Somasekhar, 1987).

The diversity of phytoplankton community exhibits a higher degree of abundance mostly during the pre-monsoon period of this investigation (Table 6.5) contrary to the findings of Brraich and Saini (2015) in the Ranjit Sagar wetland of Punjab (India). The density of the Chlorophyceae group of planktons during the pre-monsoon period is due to the higher photosynthetic rate in the wetlands. Fluctuation in the density of total phytoplankton group (Fig 3.7) should increased growth during pre-monsoon to post-monsoon period.

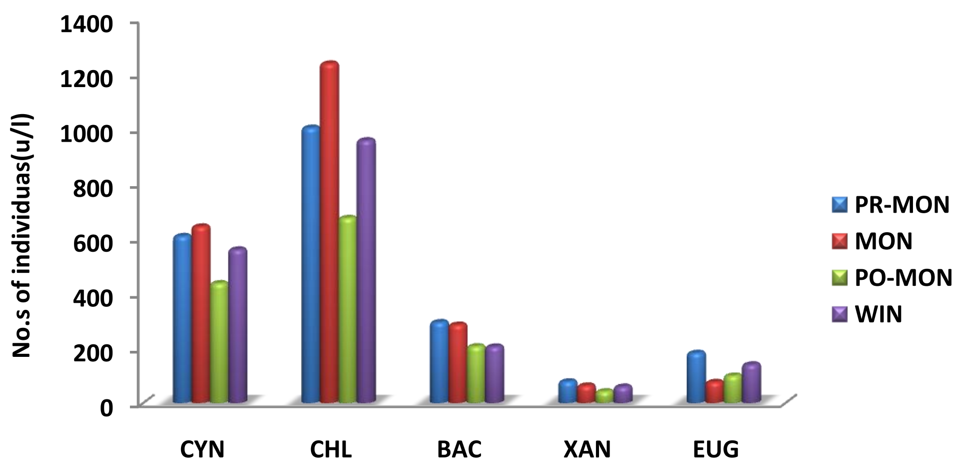


Fig. 3.7 : - Seasonal fluctuation in Phytoplankton Richness

Table 6.5: - Phytoplankton (Mean for the study period) of the Urpod beel studied during the year 2014 – 2016. (Superscripts indicate the significant differences in numbers amongst the different group of phytoplankton, P<0.001).

	CYN	CHL	BAC	XAN	EUG
PR-MON	604.9 ± 52.1	1309.9[a] ± 71.3	285.5[ab] ± 38.0	77.1[abc] ± 5.2	181.0[abcd] ± 9.9
MON	638.4 ± 49.6	1223.8[a] ± 78.0	276.6[ab] ± 30.8	59.9[abc] ± 11.1	147.8[abcd] ± 7.0
PO-MON	431.90 ± 44.18	716.90[a] ± 50.67	202.20[ab] ± 26.35	41.90[abc] ± 11.27	97.30[abcd] ± 13.71
WIN	549.50 ± 25.40	1129.40[a] ± 247.30	201.0[ab] ± 26.7	60.1[abc] ± 5.4	109.0[abcd] ± 8.1

In contrast to Chlorophyceae and Cyanophyceae, the abundance of Bacillariophyceae was less. Maximum availability of Bacillariophyceae was observed in pre-monsoon and monsoon season (Fig.3.7). This is mainly due to excessive development of *Navicula* and *Nittzschia* sp. The genera encountered were in the following order of dominance of cyanophyceae during the study period were *Navicula* > *Nitzschia* > *Gomphonema* > *Amphora* > *Cyclotella* > *Cymbella* > *Pinularia* > *Fragelaria*.

Changes of season has significant impact on phytoplankton population especially diatoms and they have exhibited bimodal peaks of growth in pre-monsoon and monsoon period against monsoon and winter in the Ranjit Sagar wetland (Brriach and Saini, 2015 ; Sawhney, 2008). Phytoplankton density in order of summer > winter > monsoon has been projected by various workers (Verma *et al.*, 2001, Hujare, 2008) against the present order pre-monsoon > monsoon > post-monsoon > winter in the fresh water beel Urpod by this investigation. However Wang *et al.*, (2013) recorded 133 species of phytoplankton belonging to Cyanophyta, Chlorophyta and Bacillariophyta in Baiyangdian Lake in China during 2009. The phytoplankton density had been recorded from 496×10^4 to 625×10^4 cell/L with an average of 2384×10^4 cells/L giving an indication for eutrophication lake, which could not be proposed for in the Urpod beel under this circumstances, though the beel catchment area has gradually been shrinking.

Phytoplankton cell densities are variable to a larger degree due to water temperature and other environmental factors. It has well been represented that various unknown factors pertaining to physical, chemical conditions and biological factors influence on the numbers of phytoplankton in a certain way since the growth of this plankton related to other factors for example water stability, climate, wetland area, wetland depth, spatial distribution of organic matter and heavy metals in soils, community structure and hydrophytes density (Arhonditsis *et al*.,2004; Huang *et al*., 2012; Na and Park, 2006; Bai *et al*.,2011). However, it has been pointed out that in the lake or wetland the density of filtering feeding fish could be a factor, closely related with the variety and numbers of phytoplankton. But such attempts to assess the phytoplankton abundance in Urpod beel in Assam could not be performed and therefore, it is suggested that in future research work more efforts be made to study wetland type, depth, amount of water retention in dry season, climatic characteristics, surrounding environment and simulated experiments be included to get the impact factors on variation of the phytoplankton numbers.

In the present investigation TPHY abundance was inversely correlated with WT, FCO_2 and TDS in all seasons except in pre-monsoon where the WT showed the positive correlation with TPHY (Table 6.1a – 6.4b) also observed in the Loktak lake of Manipur (Sharma ,2009) .

Sixty one species of phytoplankton group belonging to 5 different classes (Table 3.9) perhaps reflect the heterogeneity of variation in relation to abiotic component of Urpod beel. In an identical situation Sharma (2009) demonstrated 75 species of phytoplankton in the Ramsar Site of Loktak Lake in Manipur. The dominance *Volvox*, *Micrastarias*, *Closterium* and *Ankistrodesmus* (Photo Plate-5) (Table 3.9) exhibited qualitative and quantitative dominance against the Desmid diversity of Loktak lake (Sharma, 2009).Yet the slightly acidic condition of Urpod beel and found to be in conformity with the findings of Goswami and Goswami in Mori beel of Assam (2001).

Table 6.6: - Diversity Indices of phytoplankton species of Urpod beel during the study period

Diversity Indices	PR-MON	MON	PO-MON	WIN
No of Species	61	61	61	61
No of Organisms	2468	2375	1500	1987
Simpson Index	0.0255	0.0258	0.0208	0.0221
Dominance Index	0.974	0.974	0.979	0.978
Shanon Index	5.585	5.579	5.724	5.672
Berger – Parker Dominance Index	0.0769	0.0673	0.0466	0.0452
Margalef Richness Index	7.681	7.719	8.204	7.901

Diversity indices analyses for the study for all phytoplankton groups showed that high Simpson value during monsoon season (0.0258) and low value (0.0208) during post-monsoon. Shannon Index value exhibited high degree of value during post-monsoon (5.724) and low during the monsoon (5.579). The high Dominance Index Value (0.979) was observed in post-monsoon season and lower in pre-monsoon and monsoon season. The higher Berger – Parker Dominance Index value (0.0769) presented during in pre-monsoon and low value (0.0452) during winter season. The higher Margalef Richness Index value (8.204) was recorded for post-monsoon and lower (7.681) in pre-monsoon (Table 6.6). These values indicate the higher phytoplankton diversity in pre-monsoon. In this observation phytoplankton diversity is higher during the pre-monsoon and monsoon seasons (Fig. 3.7) where Simpson Index and Berger – Parker Dominance Index were high but Dominance Index, Shanon Index, Margalef Richness Index were low and the lower Phytoplankton diversity could be suggested for post-monsoon and winter seasons (Fig. 3.7), whereas Simpson, Berger – Parker Dominance Index value(s) were low; but Dominance Index, Shanon Index, Margalef Richness Index value(s) were high. Thus the high value(s) of Shanon Index indicate the high phytoplankton diversity in this given wetland *i.e* Urpod beel.

Certain species of phytoplankton are listed as useful plankton which has the potentiality of bioremediation (Pradhan *et al.*, 2008). The useful planktons reported in this investigation were such as *Chlorella, Nitzchia, Scandesmus, Cyclotella,* *Microcystis, Navicula, Anabaena, Tetraedron, Euglena, Ankistrodesmus, Cosmerium* and *Fragilaria* has played a putative role in bioremediation.

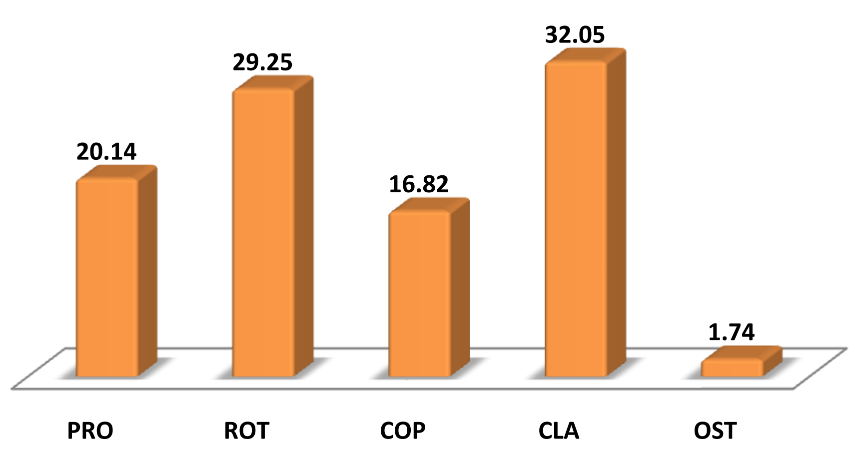
In this context, it may be referred that species diversity is positively correlated with the phytoplankton richness (r = 0.645) and Chlorophyta (0.633) and is negatively correlated with abundance (r = 0.623) in the Loktak lake of Manipur (Sharma, 2009). However, the Urpod beel indicates higher species diversity than these of Dighali beel (Acharjee *et al*., 1995) and Samujan beel (Sharma, 2004) under Assam condition, yet identical with the Loktak lake of Manipur (Sharma, 2009). The phytoplankton community as such in the Urpod Beel has been characterized by distinct qualitative as well as quantitative importance for Chlorophyceae. The phytoplankton group in totality exhibited greater diversity but lesser dominance and high degree of evenness. Individual physico-chemical parameters could influence a little marginal on richness and abundance.

Zooplankton communities are known for their definite roles in aquaculture management system (Boyd, 1981) and they are susceptible to the various environmental factors, temporal abundance, seasonality and their diversity. They are considered as the primary producer of the wetland ecosystem and make up a major part of the biomass; hence they occupy a major portion in any given ecosystem. Their structure and assemblage are governed by many of the physico-chemical and environmental factors like rainfall, air and water temperature, nutrient constituents and the p^H status of the water body.

The abundance and distribution of zooplankton are always influenced by different ecological components including both the abiotic and biotic factors. The abiotic characters like water temperature, p^H, organic and inorganic constituents and their interrelationship with their organism demonstrate significant role in the process of determining the nature and pattern of fluctuation of population diversities in a given ecosystem like wetland (Joshi, 2011). However, these parameters are variable both at spatial and temporal level, they exhibit either interaction or interrelation between and among them in a variety of ways in a given wetland ecosystem like the Urpod beel of this investigation could be supported by the work of Joshi (2011). In fact, it is difficult to draw specific and reasonable inferences upon the effects of the physico-chemical parameters and the population density of the zooplankton community. Yet, it could be expressed that fluctuating pattern of these abiotic factors affect the faunal planktonic distribution.

Zooplankton forms the major micro-faunal component and they are the secondary producer and demonstrate a secondary relationship between phytoplankton and zooplankton. Moreover, selective grazing by zooplankton is an important factor affecting the structure of phytoplankton community and their dominance play a vital role in the functioning of fresh-water ecosystems. Even, seasonal changes in the zooplankton community have been slightly associated with the water quality and biological regime of the aquatic environment. The bulk of the zooplanktonic assemblages of Urpod beel have been contributed primarily by Cladocerans followed by Rotifers, Protozoans, Copepodes and Ostracods. The zooplankton community as such demonstrated their numerical variation in terms of seasonality (Fig.3.8).

Fig. 3.8: - Abundance % of Zooplankton Groups



The highest number of zooplankton community has been recorded during post-monsoon and winter seasons against the lower number in pre-monsoon and monsoon seasons in the present study site (Fig. 3.9).

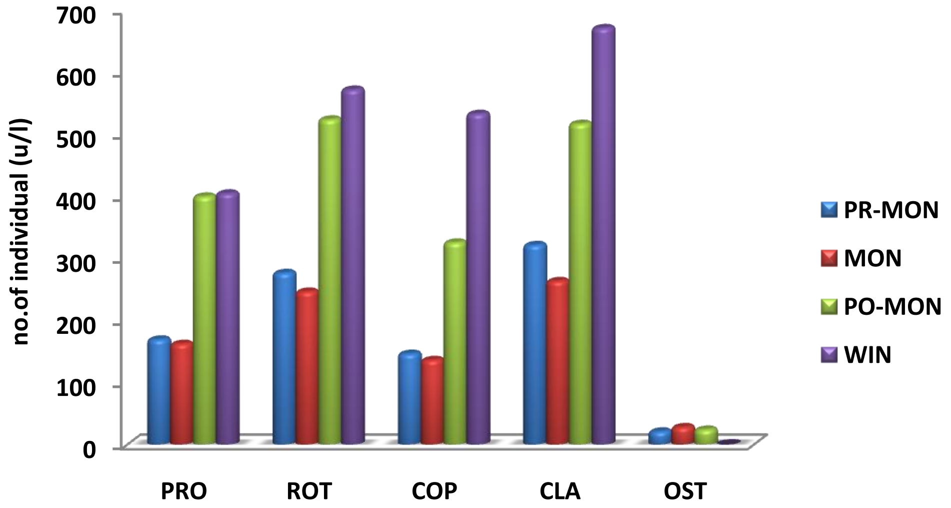


Fig. 3.9: - Seasonal fluctuation in Zooplankton Richness

The zooplankton community dominated by Cladocera (pre-monsoon, monsoon and in winter) as well dominance of Rotifera during Post-monsoon period of this investigation might be in accordance with the findings of Egborge (1977) as well with the documentation of Offem *et al.*, (2011). Marginal abundance was observed between Rotifers and Cladocerans which might be the fish food (Egborge, 1981). Yet it could be argued that seasonal variation in the zooplankton density as well growth could largely be due to the group Rotifera since they normally constitute major food items of the larger zooplankton (Offem *et al.*, 2011). It may be recalled that the species of Rotifers and Crustaceans are judged as reasonable indicators of the trophic states of the beel which are recorded as the zooplanktonic community.

The fresh water zooplankton plays significant key role in preserving the maintenance of balance in a given ecosystem (Water body like beel) and the productivity of the zooplankton are governed by the physico-chemical parameters of the water (Rahman and Hussain, 2008; Shanthi *et al.*, 2010; Manickam *et al.*, 2014). Factors such as light intensity, food availability, dissolved oxygen and predation are used to affect the population dynamics of zooplankton and low and higher salinity can reduce their density and diversity (Horne and Goldman, 1994).

The relative composition of the plankton group are found to be for Protozoa (20.14%), Rotifera (29.25%), Copepoda (16.82%), Cladocera (32.05%) and Ostracoda was at (1.74%) during the year 2014-2016 (Table 4.11).

The total numerical density of the zooplankton group of the Urpod beel has been assessed at 1590 ul^{-1} and 1933 ul^{-1} in post-monsoon as well 1533 ul^{-1} and 2248 ul^{-1} in winter during the year 2014-2015 and 2015-2016 respectively (Table 4.10). Interesting none of the species belonging to Ostracoda could be observed in winter season of the study period. The diversification of the species has been found to be with 44 species. The numbers of the species dominance belonging to the group were mostly noticed in winter season of a year. It may well be mentioned that freshwater floodplain wetlands of West Bengal (Ox-bow lake) has been able to project 70 species of zooplankton carrying enormously higher degree of numerical density per litre against the present findings. However the group wise species diversity of zooplankton during the post-monsoon season (Ganesan and Khan, 2008) to be identical in nature with the present study.

Five different types of protozoan species, mostly dominated by *Arcella discoides* and *Centropyxis minuta* followed *Difflugia oblongata* were detected (Photo Plate-9). The role of these protozoan species in a given ecosystem are normally heterotrophic and are recognized as the major consumer of the microbial production. They function as predator of bacteria and small phytoplankton, as prey for larger zooplankton and as catalyst for the remineralisation and recycling of elements essential for phytoplankton and microbial growth in a given wetland ecosystem (Porter *et al.,* 1985). Even Protozoan are grazing of bacterial and Picoplankton could play a distinctive role in the recycling process of phosphate and nitrate in a given water body (Vadstein *et al.,* 1993; Kirchman, 1994).

The Protozoans investigation in the study are of mostly belong to the group Rhizopods and the wetland could be considered as high diversity group carrying higher numerical density of the species *Arcella discoides* and *A. vulgaris* (Plate - 9) during winter in each year (Table 4.1). The correlation analysis provides information on direct relationships among variables, where they are positively correlated with the monsoon period.

The group Rotifera has been observed as the second most dominating group of Zooplankton carrying 13 species in the beel (Table 4.9) having density of 519.4 ± 69.25 ul^{-1} in the post-monsoon period as well 643 ± 34.44 ul^{-1} during winter of the next year (Table 4.10). The species richness of Rotifera having 10 genera and their density dominance was well recorded during winter season. Rotifers are "Wheel – bearer" refers to the crown of rotating cilia around the mouth, which is used for locomotion and sweeping of food particles towards the mouth (Bhavan *et al*., 2015). Rotifers have short reproductive stages and increase their abundance very rapidly under favourable environmental conditions (Dhanapathi, 2000). Rotifers are primarily omnivores, yet some exhibits cannibalistic attitude within them (Bhavan *et al*., 2015). However, they could be designated as the opportunistic feeders due to their higher intrinsic rates of natural increase among the major zooplankton groups (Sharma, 1983). The abundance of 148 species of Rotifers, predominantly genus *Brachionus* has been reported from West Bengal (Sharma, 1992). Even the present study demonstrated two species of *Brachionus* in the study area. However, many workers have recorded good numbers of *Brachionus* might be good indicator of eutrophication and accumulation of organic matters (Rajagopal *et al*., 2010; Manickam *et al*., 2014). Therefore, it may be well inferred that the present water body are yet to be accumulated and eutrophicated.

The group Rotifers has been projected as the most dominant group among the zooplankton in many of the wetlands of Assam (Sharma and Sharma 2013) as well as in other parts of India (Ahmad *et al*., 2011 ; Ghantaloo *et al*., 2011; Ganesan and Khan, 2008; Koli and Muley, 2012) , yet the present study has been failed to support their findings, perhaps due to the very of physico-chemical characteristics of the beel , most possibly due to suppression of Rotifers by Cladocerans through exploitative competition for shared limiting food resources (Mukhopadhyay *et al*., 2007) and the group Rotifers which normally constitute major food items of larger zooplanktons

(Chandrasekhar, 2010). It has been reported that *Brachionous quadridentalus* and *B. diversicornis* had been used to thrive in eutrophication and organically polluted water (Dutta and Patra, 2013). The population of genus *Keratella tropica*, even recorded in the investigation too (Table 4.9) has been mentioned as oligotrophic indicator (Sharma, 1992). It has well been mentioned that along a trophic scale, the number of planktonic Rotifers successively increased up to mesotrophic condition after which the numbers declined till hypertrophic stage (Pejler, 1983) which had not been noticed in the present investigation. This generalization might be due to the increased inflow of agricultural and household waste waters. The presence of the species *Filinia longiseta* has been recorded throughout the year occupying moderate position in terms of numerical of this investigation could be supported by the work of Bhavan *et al*., 2015 and presence of this species has been ascribed by many workers as an indicator of eutrophication (Nasar 1977; Sharma, 1992). Further there has been an inverse relationship between the Rotifers and certain physico- chemical parameters like TSS are being degraded by both the sessile and pelagic rotifers. Also, they release nutrients in one hand and increasing light penetration and on the other way augmented phytoplankton productivity leading to the increase of DO profile (Mukhopadhyay *et al*., 2007). The group Rotifers recorded in Urpod beel carries identical numerical diversity of Deepor beel (Ramsar site) and the qualitative importance in favour of Rotifers for several flood plain wetland have already been described (Sharma, 2011) and the species richness for rotifers (110 species) could be in agreement with the present findings. The diversity of rotifer represented by 20 species with its dominance in winter of a flood plain Ox-bow lake of Cachar district of Assam (Kar and Kar, 2016) is in agreement with the present findings.

The higher rotifer biodiversity (131 species) in diverse nature flood plain wetlands of Majuli, Assam indicates its richness and suggested that *Keratella edmondsoni*, *Filinia camasecla* might be oriental endemics (Sharma, 2014). Therefore further in depth study in terms of rotifers diversity in Urpod beel may perhaps elucidated many aspects. Interestingly it could well be suggested that Rotifera maintain a positive correlation with that of Cladocera (Table 3.12 and 3.14).

The group copepod in the Urpod beel has been able to show its highest number of density in 451± 10.01 ul^{-1} in winter season (Table 4.10). The highest growth of *Mesocyclops leuckarti* (male and female) and *Cyclopoid copepoidite* are found in the Urpod beel of this study. The group copepods occupied 16.82% of abundance in the Urpod beel and highest has been recorded during the winter period. The dominating species of Copepoda are the *Mesocyclops* (both male and female) followed by *cyclopoid*, *Haliodiaptomus* and *Neodiaptomus* as well (Table 4.9). The richness of copepods is 7 species (Table 4.9) are in agreement with Ganesan and Khan (2008). They also had recorded the identical number of species in a floodplain wetland of West-Bengal. Copepoda abundance might be caused by increase in *Cyclopoid copepoidite* and *Mesocyclops*, which are indicative of good water quality (Sendacz *et al.*, 1985). However, such controlled study could not be performed in this investigation.

Copepoda abundance was caused by the dominance of *Mesocyclops* and *Cyclopoid copepoidite* during the study period. This result was in conformity with Offem *et al.* (2011), who observed the dominance of *Mesocyclops* and *Cyclopoid copepoidite* in Ikwori Lake, South Eastern Nizeria which are the indicative of good water quality. Zooplankton occurrence is generally high during the dry season because the temperature and the availability of food are about the most important factors controlling the abundance of Zooplankton in lakes. In the dry season the Zooplankton population appeared to have great stability and in the rainy season, the population is suspected to lake stability (Sugunan, 2000).

Copepods constitute a significant link between pelagic primary producer and higher trophic levels in a given aquatic system (Turner, 2004) and comprised a grazers, detrivorous, omnivores, carnivores as well parasitic forms and many of them live in symbiotic relationships with the organisms (Heuch *et al.*,2007; Heuschele and Selander, 2014). Interestingly copepods have been able to selectively feed upon varieties of food species. They are able to discriminate against their water prey (Selander *et al.*, 2006) as well their ability to distinguish between morphologically similar cells which are supposed to be mediated by chemosensory mediation (Paffenhofer and Van Sant, 1985). However, such in depth study on copepods are missing in wetland copepods, and this it may be demanded for such characterization.

Interestingly, the group copepod in a given aquatic system show increased mortality as well as reduced egg production after ingesting algae (Koski *et al*.,1999) or they avoid toxic prey in feeding environment (Teegarden, 1999). Adverse effects may consequently be confounded by other traits correlated with the presence of phytoplankton (Selander *et al*., 2006). Such an indirect correlation could be suggested between Copepod and Cyanophyceae (-.047) in pre-monsoon and (0.-749) in winter season (Table 3.11 and 3.14). The group Copepod exhibit a negative correlation with of FCO_2 and DO in post-monsoon (-.711, -.686) as well with Mg (-0.650) (Table 6.3a) at significant level in Urpod beel, which might be a bench maker information for limnological information.

Cyclopods are primarily benthic. Bhavan *et al.* (2015) has recorded the copepod as the third dominant group having 7 species and their presence were recorded throughout the year and their higher numbers were noted during the summer period in lake in Coimbatore. Lewis (1978) opined that Cyclopodia production shows strong evidence of association with diatoms (Bacillariophyceae) and blue green algae (Cyanophyceae), support the present findings, and these phytoplankton groups are significantly important resource for the development stage of the *Cyclopoid copepods*.

The Copepod domination might be correlated with their feeding dependence on diatoms, Rotifers and Cladoceran (Hutchinson, 1967) and high reproduction capability (Bhavan *et al.,* 2015). It has also been recorded that calanoid copepods occupied peak position (April, July and October) in Keenjhar Lake, Pakistan (Baqai and Ishrat, 1973). Calanoid Copepods are a good indicator of oligotrophic water.The high density of copepods in a lake of Coimbatore their tolerance of higher salinity during summer, (Bhavan, 2015) through such observation had not been made in this investigation.

The Cladoceran had been represented by a dominance of 32.05% in totality (Table 4.11) in Urpod beel and their highest abundance was noted at 747.8 ± 63.98 ul^{-1} during the winter in the year 2015-16 (Table 4.10). They are represented by 14 species dominated by *Acroperus harpae* with numerical abundance of 104.0 ± 15.0 in winter season followed by *Macrothrix triseralis* and *M. spinosa* (Table 4.9). They occupy the highest dominant group followed by the Rotifera as described elsewhere. Even they are dominating in monsoon, pre-monsoon and winter season of the year. However, they were positioned at second during post-monsoon period. The dominance of Cladoceran in of context flood plain beel of Assam has been earlier illustrated. Sharma (2011) described that Cladocera form a second important group (142 ± 59 and 148 ± 48 ul^{-1}) comprising 28.7 ± 7.0% and 30.6 ± 4.9% of general abundance and considerably influences the zooplankton temporal variation at the different sites in Deepor beel of Assam. It also stated that Cladoceran density oscillates with annual frequency demonstrating their peak during winter of a year and minimal frequency during April. Thus it could well be recorded in favour of the present findings with a minor variation that Cladocerans were minimal during pre-monsoon to early monsoon period of Urpod beel. Moreover, their abundance was higher those flood plain lakes of Kashmir (Khan, 1987), and Assam (Sharma and Sharma, 2008). The richness of the Cladocera recorded from the Loktak lake of Manipur has been recorded to higher from that of the Deepor beel with 45 species (Sharma and Sharma 2008 and Sharma, 2009) has categorically stated that the species composition of these two Ramar sites (Deepor beel and Loktak lake) presented almost identical diversity (at 75%) in term of species. The species like *Chydrous flaviformis, C. sphaericus, Acroperus harpae, Alona globulosa, A. rectangula ha*ve been found to be common in Loktak Lake (Sharma, 2009) and the Urpod beel in Assam. The Chydoridae, the most diverse family of Cladocera contributes 29 species (16 genera) in Loktak Lake as well in Deepor beel in Assam (Sharma, 2009). Therefore the Urpod beel with such richness demands further in depth study with greater detail. Further, Sharma and Sharma, 2008 has been able to project similarities between 60 - 70 % during 2002 - 2003. While in majority instance it within 60.6% with a range variation of 70 – 80% during the year 2003 - 2004 in the flood plain lake of the Brahmaputra river basin. The higher similarity among the

Cladoceran group in terms of occurrence in floodplain lakes of Assam might be an attribution to more perennial or near perennial species. Presence of Cladoceran with 8 species in Nira left Bank Canel of Pune has earlier been projected and stated to be the third dominant group (Ghantaloo *et al.*, 2011).

Cladocerans are stated to be small crustaceans (water fleas) with 620 species in totality with many more little described so far (Jagadeeshappa and Kumara 2013). They exhibit the diurnal vertical migration and greatly influenced by temperature. The correlation study of Cladoceran with that of temperature showed negative correlation with water temperature during winter period (- 0.758) (Table 6.4a) in Urpod beel. They have presented a negative correlation with Ca, Mg, Cl, HCO_3, Na, K, NO_3 except positive correlation with that of N and PO_4 (0.881 and 0.770) during post-monsoon period respectively (Table 6.3a and 6.3b). Moreover they presented a negative correlation with WT, FCO_2, TA, Ca, Mg, Cl, BIC, TDS, TSS, Na, K, SO_4, except the positive correlation with TRN, DO and TH during the winter period (Table 6.4a and 6.4b).

Cladocerans are mostly parthenogenic and of the 620 species throughout the globe. India alone enriched with 110 species (Korovchinsky, 1996). Among the fresh water form, a few genera are planktonic against many littoral live among weed and some of them live bottom mud. Earlier, Begum (1958) described 16 genera of Cladocera from the Hub Dam Lake, Pakistan while Iqbal and Kazmi (1990) recorded 15 species from the same site. Reports on the presence of 7 species of Cladocera in Haledhouma puri Lake, Dharmapuri Town in India (Manickam *et al.*, 2012) and 14 species from Thoppaiyan Dharmapuri district in India (Sivakumar and Altaf, 2004; Manickam *et al.*, 2014). But they have observed highest number of Cladocerans during post-monsoon and summer months in their study period (Bhavan, 2015) against the higher density during winter period of this investigation.

Cladocerans are extremely mobile provided with specialized feeding mechanism. Even they are sensitive to their very habitat (Walls and Ventella, 1998).

Most of the Cladocerans are herbivorous in nature mainly feed on phytoplankton, decaying organic matters and bacteria. They feed as filter feeders using complex movement of their legs to induce a constant stream of water washing towards their mouth (Pennak, 1978).Two of the Cladoceran genera, *Polyphemus* and *Leptodora*, are predators and they capture prey with the help of their legs, modified for seizing prey. Rotifers are the main source of foods of these predators (Pennak, 1978).

The Ostracoda in the Urpod beel are represented only two species viz. *Centrocypris* and *Heterocypris* group with the least abundance at 1.74% (Table 4.11) as well with their negative representation during winter of the study period (Table 4.9). Their highest abundance has been noted at 27.2 ± 7.0 during post-monsoon period of 2015-16 (Table 4.10).

Ostracods are generally made up of low Mg-calcite carapace attached by a dorsal hinge and a ligament. Out of total 1700 available species only one third of them are fresh water form (Bhvan *et al*, 2015). On the other way, Ostracoda was considered as the most dominant group (32.16%) in Medical pond of Aligarh and the highest density against the Ostracod group had been evaluated at (744 and 375 ul^{-1}) during summer at Medical pond and Chautal pond respectively (Parveen and Mola., 2013). The highest density of Ostracods in this Medical pond might be due to the mixing of epibenthic forms from sediment phase. This group of authors has categorically stated that due to the effect of high temperature it has no replenishment to the water level recorded lowest and the salts were recorded at the highest during summer. The findings were in agreement with the reports or EL- Serafy *et al*., (2009), where there has been the increase of physico-chimical parameters and all the zooplankton groups. The highest positive correlation coefficient matrix (0.99) was recorded between the Ostracods and water temperature as well CO_2, through such correlation could not be as certain due to their poor representative in this beel. Poor representation of Ostracod by two species viz., *Cypris* and *Stenocypris* in the Tulshi reservoir of Kolhapur (MS) district of India (Koli and Muley 2012) are found to be in order with the present data.

The reason for detection of such a low representation of this species perhaps be related to sampling timing, hence demands in depth study.

Yet it has been attempted to a relationship between Ostracod occurrence and ecological variable in the Yumrukeya Reedbeds (Bolu, Turkey), a small fresh water wetland, during May 2000 and July 2002. Seven Ostracod species were recorded, which are provided with cosmopolotial characters carrying a wide range of tolerance to the various ecological variables (Kulkoyluoglu, 2005). Even the correlation analysis indicated that salinity and percent of oxygen saturation had been significantly associated with species richness, demands such study in Urpod beel.

The zooplankton numbering 44 species were identical in the study belonging to Protozoans, Rotifera, Cladocera, Copepoda and Ostracoda and all of them are having for characters of holoplankton. The low number of plankton group belonging to the Ostracods particular in winter perhaps is due to fluctuation of p^H values and reduced level of dissolved oxygen. Mageed (2005) claimed that certain death occurrence was due to stress by high $p^{H,}$ which exerts a synergistic action upon zooplankton together with ammonia and that there had been a direct relationship increase water temperature and elevated zooplankton. And such detail at point by details to better understanding of the plankton biology and laboratory condition is very much essential.

The highest positive correlation matrix is the study has been obtained between transparency and the group Copepoda (0.978) in winter (Table 6.4a) was recorded. Even, pre-monsoon period showed the same positive trend against Cladocera with transparency (0.841, Table 6.1a) for Urpod beel. This indicate that zooplankton group can tolerate the presence of high organic matters occur as a result of macrophytes breakdown. However, Dugel *et al*. (2008) suggesting that the plankton like ostracod could sustain in all types of aquatic environment like water temperature, electrical conductivity, contrary to the present findings that they could not detected during winter season (Table 4.10).

Physical characteristics including transparency exhibit a significant (+ve) correlation with the total zooplankton in the Urpod beel (Table 6.3a and 6.4a) during the post-monsoon and winter period. The dominance of Cladoceran group in all the seasons (Fig.3.9) could be positively correlated with the physical parameters like TH (0.817) and transparency (8.71) (Table 6.4a). On the other hand, except, TRN, p^H, DO, BOD, TH, NO_3 the group Cladoceran presented (-ve) correlation with all other water parameters (Table 6.4a and 6.4b). E L-Serafy *et al*. (2009) has claimed that the dominant group like Copepod (here Cladocera) in lake Nasser, Egypt is an attribution to the optimal condition of the lake. Earlier study of Patalas and Salki (1992) observed that higher temperature could affect physiologically of several living organisms and their distribution. Gerten and Adrian (2002) noted that the abundance of *Cyclopoid copepoidite* particularly in summer time was related to the water temperature.

During the study period Rotifera, Copepoda, Cladocera and Ostracoda were found significantly different with Protozoa in pre-monsoon season. Rotifera, Cladocera and Ostracoda were significantly different with Protozoa in monsoon season; Ostracoda was significantly different with Protozoa in post-monsoon and winter seasons during the study period.

Table 6.7: - Zooplankton (Mean for the study period) of the Urpod beel studied during the year 2014 – 2016. (Superscripts indicate the significant differences in numbers amongst the different group of zooplankton, P<0.001)

	PRO	ROT	COP	CLA	OST
PR-MON	165.90 ± 26.88	267.90[a] ± 37.75	143.40[a] ± 15.28	311.00[a] ± 65.64	19.80[a] ± 7.19
MON	161.60 ± 27.08	245.70[a] ± 62.16	133.30 ±18.80	270.30[a] ± 53.52	27.80[a] ± 10.12
PO-MON	397.30 ± 54.77	515.30 ± 57.50	324.30 ± 39.82	511.50 ± 127.31	24.60[a] ± 8.30
WIN	402.38 ± 30.38	573.40 ± 86.06	351.50 ± 106.16	665.10 ± 101.45	0

High Simpson value during winter season (0.0345) and low value (0.0248) during monsoon for zooplanktons has been obtained in this study (Table 6.8). Shannon

Index values showing high during monsoon (5.358) and low during the winter (5.064). The high Dominance Index Value (0.975) was observed in monsoon season and lower (0.965) in winter season. The higher Berger – Parker Dominance Index value (0.060) showed during winter and low value (0.046) during pre-monsoon and monsoon seasons. The higher Margalef Richness Index value (6.392) was observed in monsoon season and lower (5.671) in winter (Table 6.8). In this observation Zooplankton diversity is higher during the winter season (Fig.3.9) where Simpson Index and Berger – Parker Dominance Index were high but Dominance Index, Shanon Index, Margalef Richness Index values were low and the lower Zooplankton diversity observed during monsoon season (Fig. 3.9) where Simpson, Berger – Parker Dominance Index values were low but Dominance Index, Shanon Index, Margalef Richness Index values were high. So the high value of Shanon Index indicates the high Zooplankton Diversity in the beel during the study period.

Table 6.8: - Diversity Indices of zooplankton species of Urpod beel.

Diversity Indices	PR-MON	MON	PO-MON	WIN
No of Species	44	44	44	44
No of Organisms	933	835	1787	1963
Simpson Index	0.0259	0.0248	0.0313	0.0345
Dominance Index	0.974	0.975	0.968	0.965
Shanon Index	5.326	5.358	5.158	5.064
Berger – Parker Dominance Index	0.046	0.046	0.050	0.060
Margalef Richness Index	6.288	6.392	5.742	5.671

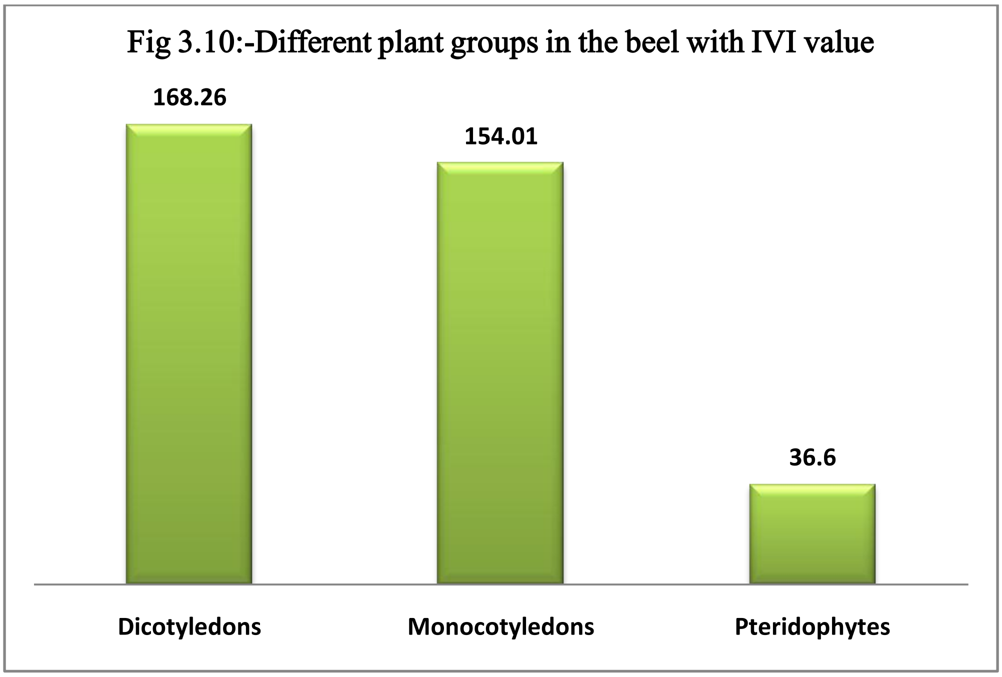
The total number of species (44) richness, Shanon Index (5.064 for winter), Simpson Index values (0.0345) were on the higher side in all the seasons of a given year (Table 6.8) and the present day beel suggested for higher species diversity. Yet it has been stated that the species diversity could not be affected due to disturbances like flood in summer or post monsoon period (Bajpai and Agarker, 1997), though such situation has not been comforted in this study. The highest diversity indices were recorded during winter and post-monsoon period notably for Cladocera and Rotifera (Fig 3.9, Table 6.8).

The total number of zooplankton (44 species) in this wetland (Urpod beel) could well be considered in wider diversity particularly Cladocera and Rotifer group of spaciose. However measre amount of zooplankton analysis, in context to the Indian flood plain lakes certainly emphasises the need of this study, particularly in beel (Sharma, 2011). This might be first hand information in term of the diversity of zooplankton diversity in net plankton communities. Zooplankton occurrence is generally high during winter and post-monsoon period and because of temperature and the availability of food which turned out to be important controlling factors. In this season the zooplankton population showed stability. The lack of clean temporal and spatial variation within the beel at different depths and in monthly trends need further in depth evaluation. The physical parameters like ($p^{H,}$ Na, K, Cl, Mg, Ca, PO_4) etc have been recorded within the permissible limit (Table 2.9), hence an assumption could be extended that beel is not in immediate threat of eutrophication. Moreover, those nutrients nitrate, nitrite, $PO_{4,}$ etc were in trace quantities. The pre-monsoon period presented higher amount of $SO_{4,}$ possibly due to the decomposition of water weeds. Thus the water parameters suggest for mesotrophic wetland, of course needs survey.

Table 6.9: - Quantitative analysis of different plant groups in Urpod beel during the year 2014 – 2016.

Plant group		Families		Genera		Species	
		Total No.	%	Total No.	%	Total No.	%
Pteridophytes		4	12.12	4	6.66	4	4.88
Angiosperms	Dicot	18	54.5	23	38.33	38	46.34
	Monocot	11	33.33	33	55.0	40	48.78
Total		33		60		82	

The macrophytic population in Urpod beel showed all together 82 species belongs to 33 families and 60 genera out of which 29 families belongs to Angiosperms (18 Dicot and 11 Monocot) and 4 families to pteridophytes (4.88% Table 6.9) in the said beel. Among these groups Dicot (168.26) possesses the highest IVI value followed by Monocot (154.01) and Pteridophytes (36.6) (Fig. 3.10) and the monocot have been occupied by 48.78% of representation (Table. 6.9).



The study reveals that the family Polygonaceae (24.44), Poaceae (30.62) and Azolaceae (13.78) showed the highest IVI value among Dicotyledons, Monocotyledons and Pteridophytes respectively (Table 5.8).

Based on IVI value *Azolla pinnata* (13.78 ± 5.63), *Salvinia natans* (12.76± 4.83), *Ipomoea aquatic* (10.68±3.14) , *Echhornia crassipes* (10.8±1.31) , *Lemna perpusilla* (10.02±3.12) , *Marsilea quadrifolia* (9.08±2.72), *Hygroryza aristata* (8.98 ±2.57), *Hydrila verticillata* (7.98 ±1.78), *Centela asiatica* (7.96 ±3.42), *Alternanthera sessilis* (7.32±3.31), *Polygonum hydropiper* (7.38±1.65), *Euryale ferox* (7.24±3.64), *Sagittaria sagittifolia* (7.16 ±2.88) have been recorded as the dominant species of the beel irrespective of sites and seasons (Table 5.7).

The dominance of the plant species by different growth forms are the Free Floating (FF) species, *Azolla pinnata* possesses the highest IVI value (13.78±5.63); among the Submerged Aquatic (SA) *Hydrila verticillata* (7.98±1.78) possesses the highest IVI value. The Marshy Amphibious (MA) C*entela asiatica* (7.96 ±3.42) possesses the highest IVI value against the *Ipomoea aquatica* (10.68 ± 3.14) possesses the highest IVI value belonging to the Emergent Aquatic (EA). The Floating Aquatic (FA) *Marsilea quadrifolia* (9.08±2.72) possesses the highest IVI value in this investigation (Table 5.7).

The beel Urpod has been able to demonstrate a wide range of diversity interms of macrophytes. Further, this macrophyte diversity perhaps is related with a wide range of phytoplankton and zooplankton along with the physico-chemical parameters of water. The results of the physico-chemical parameters indicate that transparency (TRN), Total Suspended Solids (TSS), NO_3, PO_4, and water temperature perhaps are the most influential water variables on the distribution of the aquatic macrophytes as well the zooplaktonic communities could be supported by the work of Ali *et al*.(2007). The water variables like PO_4, Na, K, Mg, Ca, Cl and DO were the most dominant factors which might have associated with the phytoplankton and zooplankton populations as well as in controlling the distribution of zooplankton group in particular. In this content, the reference could be made that the abundance and preferences of individuals of zooplankton perhaps be closely be associated with the substrates provided by plant structures and open-water areas (Ali *et al*., 2007).

In fact, macrophytes extend dense beds either to protect or supply food materials with accumulated organic matter in the form of food for invertebrates possibly for the zooplankton group (Hann, 1995). The presence of 82 species for macrophytes recorded in this beel for the first time, followed temporal and spatial distribution in the Urpod beel. Deka and Sarma (2014) was very categorical in the p^H of the beel water might be significant attributor for such wide range of diversity. Since the p^H has been recorded to be within the range variation of 6.6 to 7.10 (Table 2.9). It has also been noted by this group of author that 82 macrophyte species in two nearby flood plain beels viz Batua and Ghoga beel, almost identical in nature with that of Urpod beel.

Studies on the diversity of macrophytes in Ponni Lake of Bombay demonstrated the presence of 34 species belonging to 22 families and Cyperaceae had been proud to be the dominant group followed by Poaceae with a wide range of diversity in the month of June (Rasal *et al*., 2014). They are suggestive for the rooted emergent plants as dominant group followed by floating and submerged species.

Sharip (2011) in his analytical assessment on the macrophyte group in Lak Chini (Japan) described that macrophyte community is highly dynamic with possible alternate states dominated by floating leaved and submerged species. In fact flood regime has a strong effect in controlling the variation in plant community dominance; support such events in Urpod beel, particularly in post-monsoon period. Further, the spatial variation in plant community composition in supposed to be influenced by total depth, nutrient concentrations and substrate. Moreover the author suggested that both floating leaved and submerged vegetation contributed to thermal structure and water exchange dynamics in the system. Even higher consumption of DO by sediment communities and micro flora associated with *Cabomba furcata* beds increased respiratory activities (Sharip, 2011). It is believed that temporal changes in the distribution of certain species of macrophytes as mainly temperature driven (Kors *et al*., 2012). The variations that occur in the species composition and distribution of aquatic macrophytes perhaps due to thermal changes is always indicative in favour of temperature like light, influencing competitive interaction among co-existing species (Barko *et al*., 1986). Species like *Nymphaea rubra*, *Ludwigia perennis*, *Jussea repens*, *Trapa natans*, *Centela asiatica*, *Enhydra fluctans*, *Limnophila*, *Hydrilla verticillata*, *Ottelia alismoides*, *Cyperus*, *Oryza rufipogon* are some of the macrophytes has been recorded during the period of post-monsoon to winter (Table 5.1). Yet many of the species with wide range of diversity had been articulated mostly during pre-monsoon to monsoon temperature with the rise of water temperature in beel. Very interestingly emergent aquatic (26%), submerged aquatic species (24%), marshy amphibious (24%)

and floating aquatic (18%) species and free floating (8%) aquatic species could be evaluated during the study period (Fig. 2.8). The difference in term of species variation of five different sampling collection sites in the Urpod beel extending the more or less identical occurrence, where Site S-1 and S-2 showed the highest similarity index against lowest similarity index in S-5 (Table 5.10). The diversity of aquatic macrophytes, being diverse have been grouped into submerged, emergent and floating are described in the part of Central Ganga plain, Aligarh (Ahmad *et al*., 2015).

Some macrophytes like *Salvinia, Pistia, Lemna, Spirodela, Wolfia* and *Alternanthera* were found the ability to reducing pollutants from the beel water. *Salvania natans* has found a good absorber of heavy metals like Cu and Cr (Murugesan and Sukumaran, 1999). In this investigation these types of macrophytes were available in the beel and the level of the heavy metals like Cu and Cr were found in below detectable level (Table 2.9). Among the Free floating macrophytes, *Azolla pinnata* recorded with highest IVI values which may be considered as a nitrogen source of the wetland (Dey and Kar, 1989). *Vallisneria spiralis* and *Hydrilla verticillata* were also recorded as a dominant species during the periods of observation in the beel and these macrophytic species had been identified as an indicator of wetland productivity by Goawami and Goswami (2001) in Mori beel of Assam. Free Floating aquatic macrophytes such as *Azolla pinnata*, *Eichhornia crassipes* which were found in the wetlands of the study sites are used as manure by the local farmers in the nearby agricultural fields. The beel was found with its rich species diversity of macrophytes but the IVI values were found low in many species of macrophytes. This may be due to the low level of PO_4 and NO_3 present in the beel water because the nutrient rich environments particularly nitrate and phosphate which have been noted to favour macrophytes growth (Frankouich *et al.,* 2006). In this observation high species diversity of phytoplankton were observed. The development of aquatic macrophytes in a wetland limit the growth of planktonic algae happens either by shading or by competing for nutrients (Goswami, 1997).

Therefore, it may well be inferred that this indicates that macrophytes provided excellent microhabitats of special characteristics that increases the establishment and colonisation of many of the invertebrates including zooplankrons (Ali *et al*., 2007).

Shannon diversity index of aquatic macrophytes in various sites of the Urpod beel was calculated to a range from 5.402 to 5.849 during the study period. The dominance index was calculated at 0.9739 to 0.9792 followed by Simpson index 0.0208 to 0.0261 (Table 5.9). The index values are considered to be in favour of wide range of diversity of macrophytes. The suitability of diverse indices analysis was discussed (Cook, 1996), but none was able to provide universal information.

The differential plankton population either in the sample site or as a whole in the beel has been noted as non homogeneous. And perhaps this distribution might be dependent on the structure of their microhabitat and their location in relation to the water quality as well for better refuse (De Stasio, 1993).

The present study showed that the species belong to Nymphacace (due to their abundance) during monsoon might be related to the high TSS (Mageed, 1995) and some invertebrate species like annelid were characterized by the presence of NO_2 and Ca. The great amount of Ca and Mg also increases the detriphagous oligochaeta (Krzyzanek, 1986), yet such attempt could not be made in this study. The presence of high abundance of Cladocera, Rotifera in aquatic macrophytes (Sakuma *et al*., 2002, Ali *et al*., 2007) have been noted to be attached with solid plant surface.

The comparatively higher richness of the beel could be related to the diverse macrophytic community consisting of 82 species, while Khan (2002) in Rovindra Sarovar, Calcutta recorded 17 taxa to declare it species rich wetland. The significances of diverse macrophyte flora in the distribution of micro invertebrate had been well documented (Pieczynska and Ozimek, 1976) and it was inferred that diverse flora are responsible for greater faunal assemblage (Boyd, 1971). Khan (2002a) has categorically articulated that lower species diversity in the pond was mainly due to dense growth of *Eichhornea* sp., which does not allow the growth of the species.

Gaskill (2014) examined the effects of p^H and macrophytic diversity on benthic macro-invertebrate assemblage in Adriondacle Lake and inferred that macrophyte diversity is a study indicator of ecosystem is meant for reduction and acidification which may restore lower trophic levels.

Impact effect of macrophytes on the diversity of plankton showed that relative abundance and composite of invertebrates including zooplankton group are expected to be varied depending on the type of microhabitats (Ali *et al*., 2007). It has earlier been assessed that the group Rotifera preferred macrophytes of small size, sessile in nature and feeding on epiphytic micro-organism (Hann, 1995; Green, 2003), yet such attempts are essential in the present day studies.

During the present study, it has been noted that the species like *Alona globolusa* and *A. rectangula* have been found to be associated with *Nymphaea* species in Urpod beel, which might be their macrophyte preference. Such observation on *Alona* species and *Chydorus spharicus* preferred the littoral vegetation zone compared to planktonic deeper vegetation, which might be an attribution to the special microhabitat extended by the submerged macrophytes (Mastrantuono and Mancinelli, 2005). Earlier Hann (1995) recorded certain copepods either in littoral zone or in the lateral vegetation-free deeper water zone. It has been indicated that the abundance of epiphytic invertebrates including zooplankton could be influenced by differential plant architecture types (Cheruvelil *et al*., 2002).

A number of reports indicate that certain species of aquatic macrophytes (submerged macrophytes) usually extends into the depth in order to maximise their absorption of the light and CO_2 needed for photosynthesis. For example, *Hydrilla* species (found in abundant in Urpod beel) is very effective in elongating its shoots (Maberly and Madsen, 2002). Even, certain studies indicate that the climatic difference associated with geographic latitudes might have strong influence on the relationship between water transparency and the depth distribution of submerged plants (Duarte and Kalff, 1987).

The range of alkalinity (29.4±0.12 – 36.1±0.22, Table 2.9) of Urpod beel might have controlled the diversity and distribution of Macrophytes. In this context the effect of alkalinity has been well documented as the most significant factor in the distribution of aquatic macrophytes (Riis *et al.*, 2000).

Therefore, it is evident that both the biotic and the abiotic factors lead to considerable variation in distribution, diversity and abundance of aquatic macrophytes in fresh water ecosystem like Urpod beel, yet demand further in depth evaluation.