Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

European Journal of Experimental Biology, 2015, 5(5):85-97

ISSN: 2248 –9215
CODEN (USA): EJEBAU

A comparative study on physico-chemical characteristics and Zooplankton diversities between natural and man-made Wetlands at Cooch Behar, West Bengal, India

Supratim Pal[1*], Debashis Das[2] and Kaushik Chakraborty[1]

[1]Department of Zoology, University of Gour Banga, Mokdumpur, Malda, West Bengal
[2]Department of Zoology, Tufanganj Mahavidyalaya, Tufanganj, West Bengal

---

ABSTRACT

Plankton diversity and physico-chemical parameters are important criterion for evaluating the suitability of aquatic health. A comparative study on zooplankton diversity in relation to physico-chemical parameters of two selected wetlands [one natural (NWL) and one man-made (MWL) respectively] was studied at Cooch Behar district of West Bengal. In gross nine physical and chemical parameters and fifteen types of zooplankton species were noted. Study reveals that the physico-chemical characteristics like conductivity (424µS/cm in NWL and 243µS/cm in MWL respectively), total hardness (204mg/lit in NWL and 108mg/lit in MWL respectively), total dissolved solids (211ppm in NWL and 121ppm in MWL respectively), dissolved oxygen (9.63mg/lit in NWL and 8.30mg/lit in MWL respectively) and iron concentration (1.18mg/lit in NWL and 0.79mg/lit in MWL respectively) are higher in natural wetland (Panishala Beel) but pH value (6.8 in NWL and 7.4 in MWL respectively), total suspended solids (5.64NTU in NWL and 24.5NTU in MWL respectively) and chloride concentration (63.9mg/lit in NWL and 70.0mg/lit in MWL respectively) are higher in the man-made wetland (Mali dighi). Study reveals the existence of both high species diversity and numerical abundance of zooplankton population in natural wetland in comparison to man-made wetland. But contrary to this, the density of zooplankton in man-made wetland is comparatively higher in comparison to natural wetland. Observation on the gross physico-chemical parameters on both the aquatic source indicates good water quality. However, lesser zooplankton diversity in man-made wetland is probably due to the short time of species succession following its excavation.

Key words: Zooplankton, Water quality, Diversity, Correlation matrix.

INTRODUCTION

Water bodies are considered as the most productive ecosystems as they constitute huge floral as well as faunal diversities [1]. It also plays a very important role in socio-economic condition of the concerned region as it is used for fish culture at commercial level [2]. Wetlands being one of the most productive ecosystems are crucial for biodiversity conservation [3]. Richness of wetlands depends on its plankton community because they are placed on the base of the food pyramid [4].

Zooplanktons play an integral role and may serve as bio-indicator and it is a well-suited tool for understanding water pollution status [5, 6, 7, 8]. Zooplanktons are one of the most important biotic components influencing all the functional aspects of an aquatic ecosystem, such as food chains, food webs, energy flow and cycling of matter [9, 10, 11, 12].

The distribution of zooplankton community depends on complex factors such as, change of climatic conditions, physical and chemical parameters and vegetation cover [13, 14, 15, 16]. The abundance of zooplanktons depends, in gross, on the phytoplankton, aquatic microphytes and macrophytes [17]. The distribution and diversity of zooplankton in aquatic ecosystem are mostly guided by the limnological properties of water [18, 19, 20, 21]. The fishes constitute the higher trophic level of the wetland ecosystem and consume predominantly the aquatic arthropods and zooplanktons [22].

The district Cooch Behar, West Bengal, endeavours a large number of water bodies including natural as well as man-made water bodies. The ecosystem of these two types of wetlands varies in nature, diversity and productivity as well. Keeping in view the importance of such wetlands the present work has been undertaken to assess the physico-chemical quality of water and zooplankton diversity of two wetlands of Cooch Behar District of West Bengal.

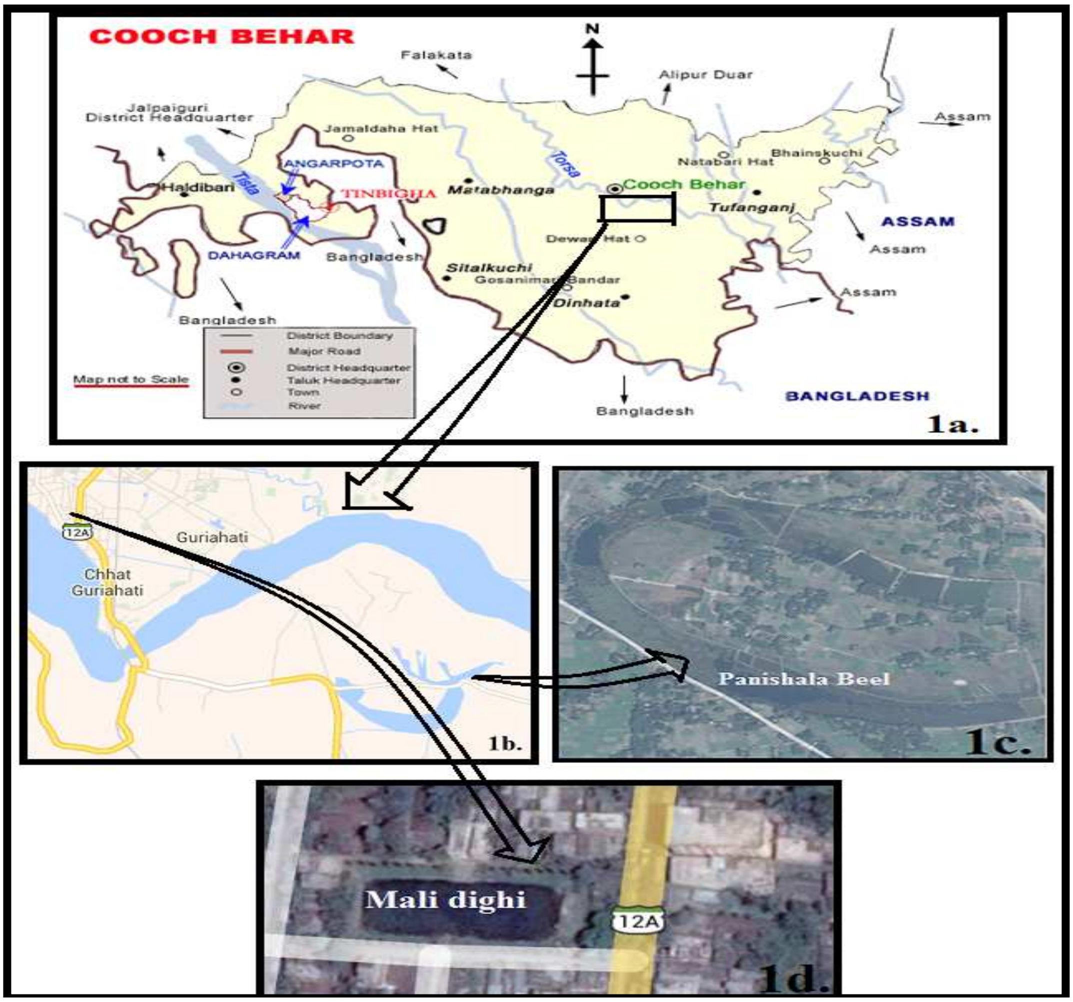


Fig. 1: Location of Study sites. 1a. Map of Cooch Behar. 1b.: Descriptive view of study area. 1c.: Satellite imagery of NWL (*Panishala Beel*). 1d.: Satellite imagery of MWL (*Mali dighi*)

MATERIALS AND METHODS

Geographic location (Fig.1):

The district of Cooch Behar is geographically a part of the *Himalayan Terai* of West Bengal, India. It lies between the parallels of 25° 57´ 56″ and 26° 32´ 46″ North latitude and the longitude of the eastern most point which beings 89° 52´ 00″ East and the longitude of the western most point beings 88° 45´02″ East.

The *Panishala Beel* (NWL) is a natural wetland and is an offshoot from river *Torsa* which in course of time had been disconnected from the river and persists as an impounding water body, presently known as *'beel'*. This site is named "*Panishala Beel*" (Fig.1c.) and is situated under the administrative jurisdiction of *Panishala gram panchayet* of the district. This study site (26° 27´ 89´´ N, 89° 52´ 53´´ E) is situated adjacent to the Dinhata subdivision of Cooch Behar district and is 12 kilometres away from Cooch Behar town. It is a natural wetland and thus embodies a huge geographical and ecological importance. It receives run-off water from the adjacent land area and at present is mainly used for pisciculture.

The *Mali dighi* (MWL) is a man-made wetland situated in the Cooch Behar town. This study site (26°31´21´´ N, 89°44´82´´ E) is situated beside the state highway-12A named *Dinhata Road* (Fig.1d.). It also receives run-off water from the adjacent land area and at present is mainly used for pisciculture. The *Panishala Beel* and *Mali dighi* are separated from each other by an aerial distance of about 11 km.

For physical and chemical analysis of water:

A. Sample collection: Surface water samples for physico-chemical analysis were collected from the selected locations by dipping well labelled sterilized plastic/glass containers of 250 ml to about 6-10 cm below the surface film.

B. Mode of study: The physico-chemical characteristics of water like pH (pH units), conductivity (µS/cm), total hardness (mg/lit), total dissolved solid (ppm), turbidity (NTU), temperature (Celsius), dissolved oxygen (mg/lit), iron concentration (mg/lit) and chloride concentration (mg/lit) of NWL and MWL sample site was assessed following the standard method [23] and with the help of analytical instrument (Table 1).

C. Application protocol:

a) For pH estimation: pH was estimated with the help of Hanna portable pH meter (HI 98128) by dipping it into the water sample after calibration.

b) For Conductivity estimation: Conductivity was estimated by using conductivity meter made by Eutech.

c) For total hardness estimation: Total hardness of the water samples was estimated by following the conventional titration method [23].

d) For TDS estimation: TDS value of the collected water samples was estimated by using HM Digitals Aqua Pro digital water tester (Model AP-1).

e) For turbidity estimation: Turbidity or Total Suspended Solids (TSS) of the water samples was estimated by using the Turbidity meter made by Eutech.

f) For temperature estimation: The surface water temperature of the water bodies was measured by using the Hanna portable Temperature meter (HI 98128).

g) For dissolved Oxygen (DO) estimation: For the estimation of Dissolved Oxygen (DO) of the collected water samples, the portable digital DO meter of Electronic India Pvt. Ltd. was used.

h) For Iron concentration estimation: For the estimation of Iron concentration in the water samples, all the irons are reduced to iron (Fe^{++}) ions firstly. Then in a thio-glycolate buffered medium these iron (Fe^{++}) ions react with a tri-azine derivative to form a red-violet complex. Then the concentration of the red-violet complex was determined photometrically to estimate the iron concentration [23].

i) For Chloride concentration estimation: For the estimation of Chloride concentration in the water samples, at first, all the chloride ions were reacted with mercury-thio-cyanate to form slightly dissociated mercury-chloride. The thio-cyanate released in the process, in turn, reacts with iron (Fe^{+++}) ions to form red iron-thio-cyanate. Then the concentration of the red iron-thio-cyanate was determined photometrically to determine the chloride concentration [23].

Table 1: Water parameters considered, methods followed, instruments used, units of observation and reference zone for each parameters during the experimentation

Parameters	Method followed/instrument used	Unit of observation	Reference zone
pH	Hanna portable HI 98128 water proof pH meter	pH units	6.5 – 8.5
Conductivity	Conductivity meter; made by Eutech.	µS/cm	≤ 1000
Total hardness	Conventional titration method.	mg/lit	--
Total Dissolved Solid (TDS)	HM Digitals Aqua Pro digital water tester (Model AP-1).	Parts per million (ppm)	≤ 500
Turbidity	Turbidity meter ; made by Eutech.	Nephelometric Turbidity Unit (NTU).	--
Temperature	Hanna portable HI 98128 water proof Temperature meter	Celsius (°C)	--
Dissolved oxygen(DO)	Portable digital DO meter, Electronic India Pvt. Ltd.	mg/lit	≥ 6.0
Iron	All irons were reacted to form a red-violet complex and this complex was determined photometrically.	mg/lit	0.3
Chloride	Chloride ions were reacted to create a red coloured complex which was determined photometrically.	mg/lit	≤ 250

***N.B.: (--):** not indicated.*

For zooplankton study:

A. Sample collection: Zooplankton samples were collected from the study sites by filtering 50 litres of the subsurface source water through a fine nylon mesh attached to a conical zooplankton net. The content collected in the plankton tube which was attached to the lower end of the net and the content was then transferred to separate polyethylene tubes. After sedimentation, a subsample of 30ml was taken. Thus the collected zooplankton organisms were preserved in 4% formalin solution and subsequently 4-5 drops of glycerine were added to the samples to ensure good preservation.

B. Mode of study:

a) Quantitative estimation: For quantitative study, the zooplankton count was done by Sedgwick rafter cell counter placed under the microscope.

b) Photography of zooplanktons: Zooplanktons were observed with a binocular compound microscope (Olympus, Model No. CH20*i*) and subsequently, the photography were done with the help of a camera.

c) Systematic identification: Systematic identification of collected zooplanktons was done after following the guideline as given by Edmondson [24] and the references of several workers like Adoni [25], Needham *et al.* [26], Pennak [27], Dhanapathi [28], Reddy [29], Michel *et al.* [30] and Victor *et al.* [31].

For statistical analysis:

The pooled data that was obtained is analysed by INDOSTAT-ANOVA and by PAST, XLSTAT software analytical programme.

A. Correlation:

a) Linear correlation analysis: The purpose of a Linear correlation analysis is to determine whether there is a relationship between two sets of variables. We used it to find a positive correlation or a negative correlation or there is no correlation.

b) Spearman's D: The Spearman's D Rank Correlation Coefficient is used to discover the strength of a link between two sets of data.

c) Spearman's r_s : Spearman's r_s rank correlation coefficient is measured to show the statistical dependence between two variables. It assesses how well the relationship between two variables.

d) Kendall's *tau*: The Kendall rank correlation coefficient, commonly referred to as Kendall's *tau* (τ) coefficient, is a statistic used here to measure the association between two measured quantities. A *tau* test is a non-parametric hypothesis test for statistical dependence based on the *tau* coefficient.

e) Variance-covariance: Variance-covariance analysis is done to measure the variability or spread in a set of data and the extent to which corresponding elements from two sets of ordered data move in same direction.

B. Diagram:

a) Bar: For our study, bar diagrams are used to provide a visual presentation with rectangular bars with lengths proportional to the values that they represent.

b) Pie: The pie chart is a circular statistical graphic representation, which is divided into slices to illustrate numerical proportions.

RESULTS AND DISCUSSION

Assessment on the physico-chemical analysis and zooplankton diversity of two selected wetlands (NWL and MWL) was carried out at Cooch Behar district of West Bengal. The results are delineated below.

Observation on the analysis of the physical and chemical characteristics:

A. In consideration of the relative value (Table 2 and Fig.2): pH of water at NWL is slight acidic (6.80) while that of at MWL is slight alkaline (7.40). As pH levels of both the sites of observation are within the reference limits, it is safe to the aquatic life. The conductivity of water is 424 µS/cm at NWL and 243 µS/cm at MWL respectively. Hardness of water is basically caused by the elements like calcium, magnesium, sodium and occasionally by iron, aluminium and potassium. Hardness of water at NWL is 204 mg/lit while that of at MWL is 108 mg/lit. Result shows that TDS value is higher at NWL (211 ppm) than MWL (121 ppm). Both the results of pH and conductivity show positive correlation with TDS values. Turbidity in consideration of total suspended solids (TSS) is high at MWL (24.5 NTU) than NWL (5.64 NTU). Surface water temperature at NWL was 18.6^{0}C and at MWL was 20.3^{0}C. Dissolved oxygen (DO) is higher at NWL (9.63 mg/lit) than at MWL (8.30 mg/lit). Chloride ion is one of the more abundant anions found in waste water and is a good indicator of pollution sources. Chloride content is higher at MWL (70.00 mg/lit.) than at NWL (63.90 mg/lit.) and it shows positive correlation with pH values. Iron concentration has direct relation with zooplankton diversity. Present study reveals that both the wetlands have high iron concentration from reference values. Out of the two water sources iron concentration is high at NWL (1.18 mg/lit.) than at MWL (0.79 mg/lit.). Different physico-chemical parameters of NWL and MWL are also represented in web pattern (Fig.2).

Table 2: Comparative analytical results of physical and chemical characteristics of NWL and MWL

Characteristics	Units	Observations							
		OBS1		OBS2		OBS3		Average	
		NWL	MWL	NWL	MWL	NWL	MWL	NWL	MWL
pH	pH units	7.0	7.4	6.5	7.3	6.9	7.5	6.80	7.4
Conductivity	µS/cm	426	252	418	242	428	235	424	243
TH	mg/lit.	203	112	205	104	206	108	204	108
TDS	ppm	208	125	210	119	215	119	211	121
TSS	NTU	5.08	26.5	6.00	23.0	5.84	24.0	5.64	24.5
Temp.	Celsius	18.0	18.6	18.8	20.5	19.0	21.8	18.6	20.3
DO	mg/lit.	9.10	8.50	9.06	8.0	9.73	8.40	9.63	8.30
Iron	mg/lit.	1.13	0.83	1.20	0.76	1.21	0.78	1.18	0.79
Chloride	mg/lit.	64.1	74.0	64.2	67.0	63.4	69.0	63.9	70.0

***N.B.:* *T.H.*-*Total Hardness*, *TDS*-*Total Dissolved Solids*, *TSS*-*Total Suspended Solids*, *Temp.*-*Temperature*, *DO*-*Dissolved Oxygen*, *OBS*-*Observation number*.**

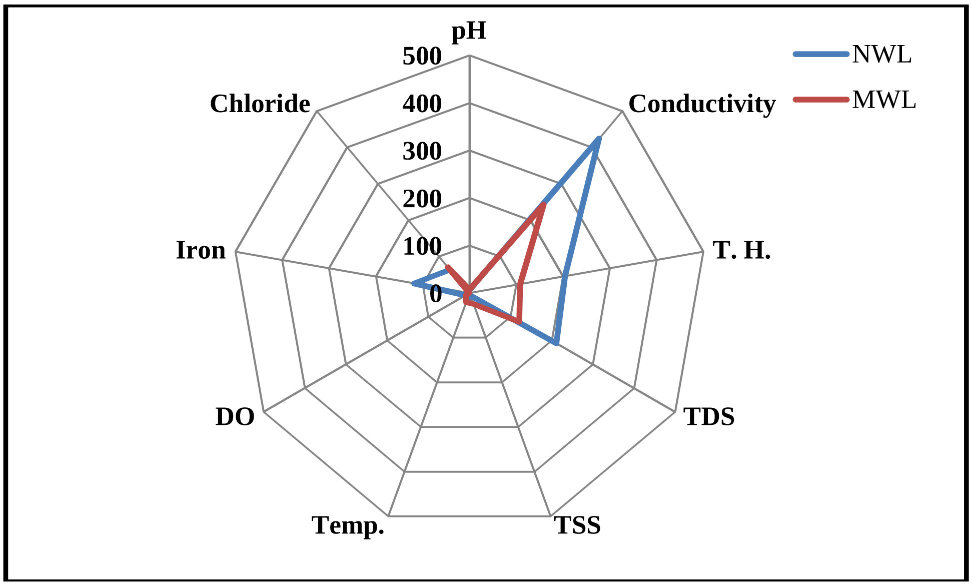


Fig.2: Representation of different physico-chemical factors in two types wetland (NWL and MWL) in web pattern in hue angel

B. In consideration of the interrelation of different factors:

a) Observation on linear correlation analysis (Table 3): Linear correlation between the different physico-chemical parameters of NWL and MWL shows that iron concentration is highly correlated with the pH, conductivity, TDS value, TSS value and temperature. Total hardness is highly correlated to conductivity and chloride shows high correlation with iron.

Table 3: Showing the linear correlation between different physico-chemical factors

Parameters	pH	Conductivity	T. H.	TDS	TSS	Temp.	DO	Iron	Chloride
pH	0.00	0.00	0.38	0.90	0.03	0.21	0.42	1.00	0.28
Conductivity	0.93	0.00	1.00	0.30	0.23	0.74	0.11	1.00	0.04
T.H.	-0.36	0.00	0.00	0.00	0.01	0.00	0.22	0.54	0.08
TDS	0.05	0.42	0.88	0.00	0.12	0.01	0.01	1.00	0.00
TSS	-0.77	-0.48	0.85	0.60	0.00	0.00	0.53	1.00	0.56
Temp.	-0.50	-0.14	0.96	0.84	0.94	0.00	0.17	1.00	0.15
DO	0.33	0.61	0.49	0.83	0.27	0.54	0.00	0.23	0.00
Iron	0.00	0.00	-0.26	0.00	0.00	0.00	0.48	0.00	1.00
Chloride	-0.43	-0.74	-0.65	-0.92	-0.24	-0.56	-0.88	0.00	0.00

b) Observation on the correlation value of Spearman's D (Table 4): Observations on physico-chemical parameters of NWL and MWL are also analysed with Spearman's D and the correlation is summarised in the following table.

Table 4: Showing the correlation value of Spearman's D between NWL and MWL

Parameters	pH	Conductivity	T.H.	TDS	TSS	Temp.	DO	Iron	Chloride
pH	0.00	0.03	0.29	0.60	0.03	0.29	0.29	0.29	0.29
Conductivity	16.00	0.00	0.60	0.29	0.29	0.60	0.03	1.00	0.03
T.H.	112.00	64.00	0.00	0.03	0.03	0.01	0.29	0.29	0.29
TDS	96.00	48.00	16.00	0.00	0.29	0.03	0.03	0.03	0.03
TSS	144.00	112.00	16.00	48.00	0.00	0.03	0.60	0.60	0.60
Temp.	112.00	64.00	0.00	16.00	16.00	0.00	0.29	0.29	0.29
DO	48.00	16.00	48.00	16.00	96.00	48.00	0.00	0.11	0.01
Iron	112.00	80.00	48.00	16.00	64.00	48.00	32.00	0.00	0.11
Chloride	112.00	144.00	112.00	144.00	64.00	112.00	160.00	128.00	0.00

c) Observation on correlation value of Spearman's r_s (Table 5): Observations on physico-chemical parameters of NWL and MWL are also analysed with Spearman's r_s and the correlation is summarised in the following table. Results show that the values are partially elliptical.

Table 5: Showing the correlation value of Spearman's r_s between NWL and MWL

Parameters	pH	Conductivity	T.H.	TDS	TSS	Temp.	DO	Iron	Chloride
pH	0.00	0.04	0.38	0.72	0.04	0.38	0.38	0.38	0.38
Conductivity	0.80	0.00	0.72	0.38	0.38	0.72	0.04	1.00	0.04
T.H.	-0.40	0.20	0.00	0.04	0.04	0.00	0.38	0.38	0.38
TDS	-0.20	0.40	0.80	0.00	0.38	0.04	0.04	0.04	0.04
TSS	-0.80	-0.40	0.80	0.40	0.00	0.04	0.72	0.72	0.72
Temp.	-0.40	0.20	1.00	0.80	0.80	0.00	0.38	0.38	0.38
DO	0.40	0.80	0.40	0.80	-0.20	0.40	0.00	0.17	0.00
Iron	-0.40	0.00	0.40	0.80	0.20	0.40	0.60	0.00	0.17
Chloride	-0.40	-0.80	-0.40	-0.80	0.20	-0.40	-1.00	-0.60	0.00

d)Observation on the correlation analysis with Kendal's *tau* (Table 6): Observations on physico-chemical parameters of NWL and MWL are also analysed with Kendall's *tau* and the correlation is summarised in the following table. Results show that conductivity is highly correlated with total hardness, temperature and iron concentration like pH with TDS whereas chloride concentration is negatively correlated with DO.

Table 6: The correlation analysis with Kendall's *tau* between NWL and MWL

Parameters	pH	Conductivity	T.H.	TDS	TSS	Temp.	DO	Iron	Chloride
pH	0.00	0.02	0.25	1.00	0.02	0.25	0.25	0.25	0.25
Conductivity	0.67	0.00	1.00	0.25	0.25	1.00	0.02	1.00	0.02
T.H.	-0.33	0.00	0.00	0.02	0.02	0.00	0.25	0.25	0.25
TDS	0.00	0.33	0.67	0.00	0.25	0.02	0.02	0.02	0.02
TSS	-0.67	-0.33	0.67	0.33	0.00	0.02	1.00	1.00	1.00
Temp.	-0.33	0.00	1.00	0.67	0.67	0.00	0.25	0.25	0.25
DO	0.33	0.67	0.33	0.67	0.00	0.33	0.00	0.25	0.00
Iron	-0.33	0.00	0.33	0.67	0.00	0.33	0.33	0.00	0.25
Chloride	-0.33	-0.67	-0.33	-0.67	0.00	-0.33	-1.00	-0.33	0.00

e) Observation on the correlation analysis with variance-covariance (Table 7): Observations on physico-chemical parameters of NWL and MWL are also analysed with variance-covariance and the correlation is summarised in the following table.

Table 7: The correlation analysis with Variance-Covariance between NWL and MWL

Parameters	pH	Conductivity	T.H.	TDS	TSS	Temp.	DO	Iron	Chloride
pH	0.04	0.74	-0.09	0.03	-0.06	-0.04	0.02	0.00	-0.03
Conductivity	0.74	16.00	0.00	4.57	-0.71	-0.23	0.79	-0.03	-0.97
T.H.	-0.09	0.00	1.43	2.86	0.38	0.46	0.19	-16.65	-0.26
TDS	0.03	4.57	2.86	7.43	0.61	0.91	0.73	0.07	-0.83
TSS	-0.06	-0.71	0.38	0.61	0.14	0.14	0.03	0.01	-0.03
Temp.	-0.04	-0.23	0.46	0.91	0.14	0.16	0.07	0.01	-0.07
DO	0.02	0.79	0.19	0.73	0.03	0.07	0.10	8.35	-0.09
Iron	0.00	-0.03	-16.65	0.07	0.01	0.01	8.35	2924.30	-0.01
Chloride	-0.03	-0.97	-0.26	-0.83	-0.03	-0.07	-0.09	-0.01	0.11

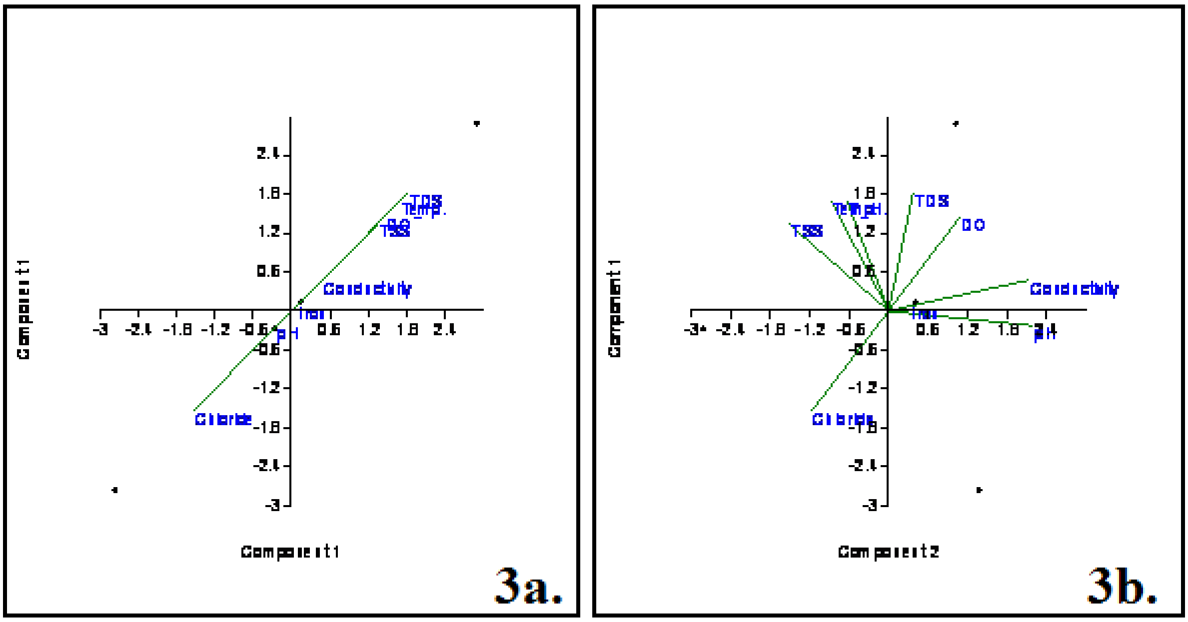
f) Observation on Tukey Kramer multiple comparison test (Table 8): Observations on physico-chemical parameters of NWL and MWL are also analysed with Tukey Kramer multiple comparison test and the observation is summarised in the following table. This is to mention that if the value of "q" is greater, then "p" value is less than 0.05.

Table 8: Comparison with Tukey Kramer multiple comparison test between NWL and MWL

Comparison	Mean Difference	q value	p value
pH *vs* Conductivity	-417.28	65.192	***p<0.001
pH *vs* TH	-197.78	30.899	***p<0.001
pH *vs* TDS value	-204.28	31.915	***p<0.001
pH *vs* TSS value	1.085	0.1695	ns p>0.05
pH *vs* Temprature	-11.875	1.855	ns p>0.05
pH *vs* DO	-2.655	0.414	ns p>0.05
pH *vs* Iron conc.	-23.66	3.696	ns p>0.05
pH *vs* Chloride conc.	-57.175	8.933	***p<0.001
Conductivity *vs* TH	219.5	34.293	***p<0.001
Conductivity *vs* TDS value	213	33.278	***p<0.001
Conductivity *vs* TSS value	418.36	65.362	***p<0.001
Conductivity *vs* Temprature	405.4	63.337	***p<0.001
Conductivity *vs* DO	414.62	64.777	***p<0.001
Conductivity *vs* Iron conc.	393.62	61.496	***p<0.001
Conductivity *vs* Chloride conc.	360.1	56.26	***p<0.001
T.H. *vs* TDS value	-6.5	1.016	ns p>0.05
T.H. *vs* TSS value	198.86	31.069	***p<0.001

N.B.:** ""= significant, "ns"= not significant.*

g) Observation on principal component analysis (PCA) (Fig.3): Observations on physico-chemical parameters of NWL and MWL are also analysed with PCA and the results of PCA analysis are summarised graphically in the following figures. By analysing the PCA it is observed that TSS and TDS are present in different groups and chloride is far from most of other components. It is also observed that conductivity and pH are the related component in our study.



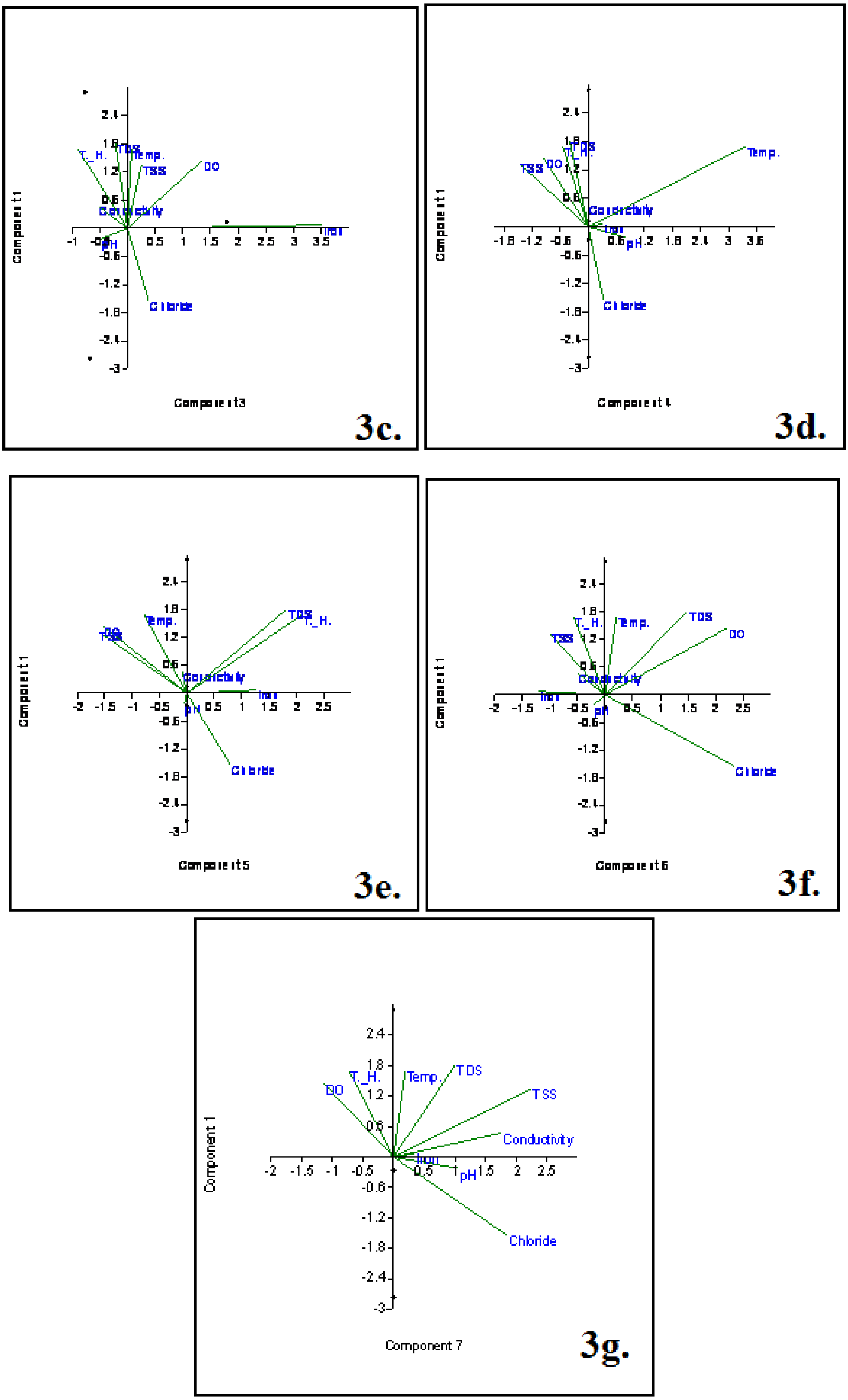


Fig.3(a-g): Principal component analysis (PCA) between the physico-chemical parameters

Observation on the zooplankton:

A. In relation to the major zooplankton species (Fig.4, 5 and 6): Fifteen types of Zooplanktons were primarily identified from the water sample of NWL. Out of those, two are crustacean larvae (*Nauplius sp.* and *Zoea sp.*), five are Cladocerans (*Moina sp.*, *Chydorus sp.*, *Diphanosoma sp.*, *Alona sp.* and *Daphnia sp.*), four are Copepods (*Cyclops sp.*, *Heliodiaptomus sp.*, *Tropocyclops sp.* and *Mesocyclops sp.*), one is Ostracod (*Cypris sp.*) and the remaining three are Rotiferans (*Brachionus sp.*, *Keratella sp.* and *Lacane sp.*). In the water sample of MWL, four types of zooplanktons were primarily identified. All of identified species of MWL are in adult form and all of the species belong to the order-Copepoda (*Cyclops sp.*, *Heliodiaptomus sp.*, *Tropocyclops sp.* and *Mesocyclops sp.*). So, the MWL sample shows copepod dominance. Different types of zooplanktons in two types of wetland (NWL and MWL) are also represented in web pattern (Fig.5).

B.

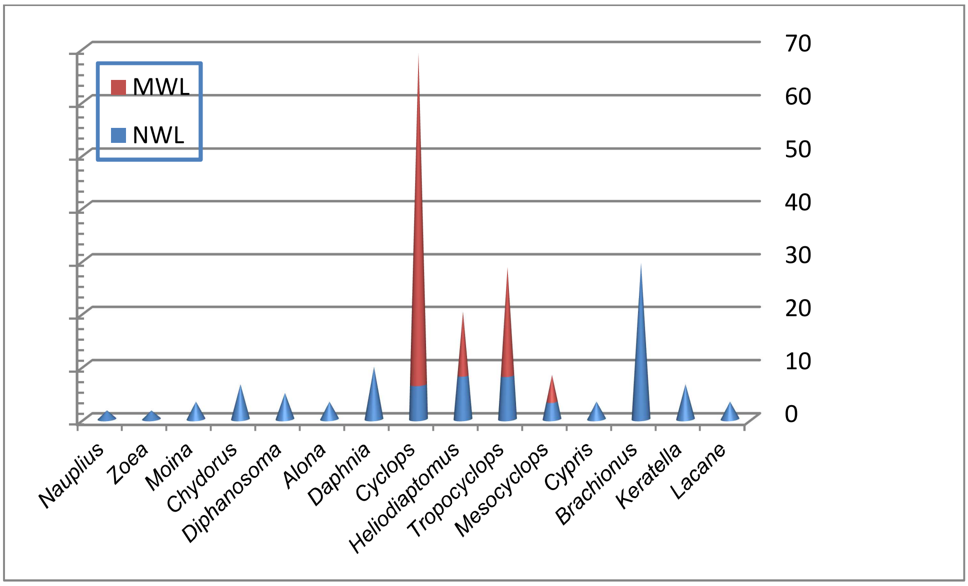


Fig.4: Representation of zooplankton out of the total abundance in two types of wetlands (NWL and MWL)

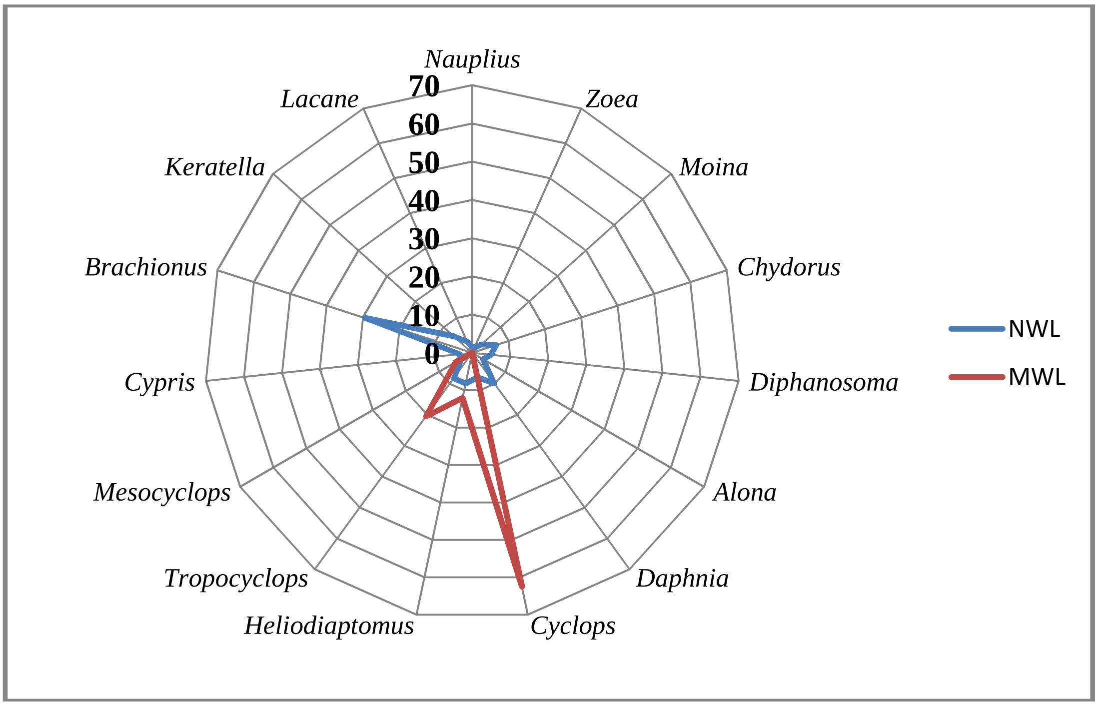


Fig.5: Representation of different types of zooplankton in two type of wetland (NWL and MWL) in web pattern in hue angel

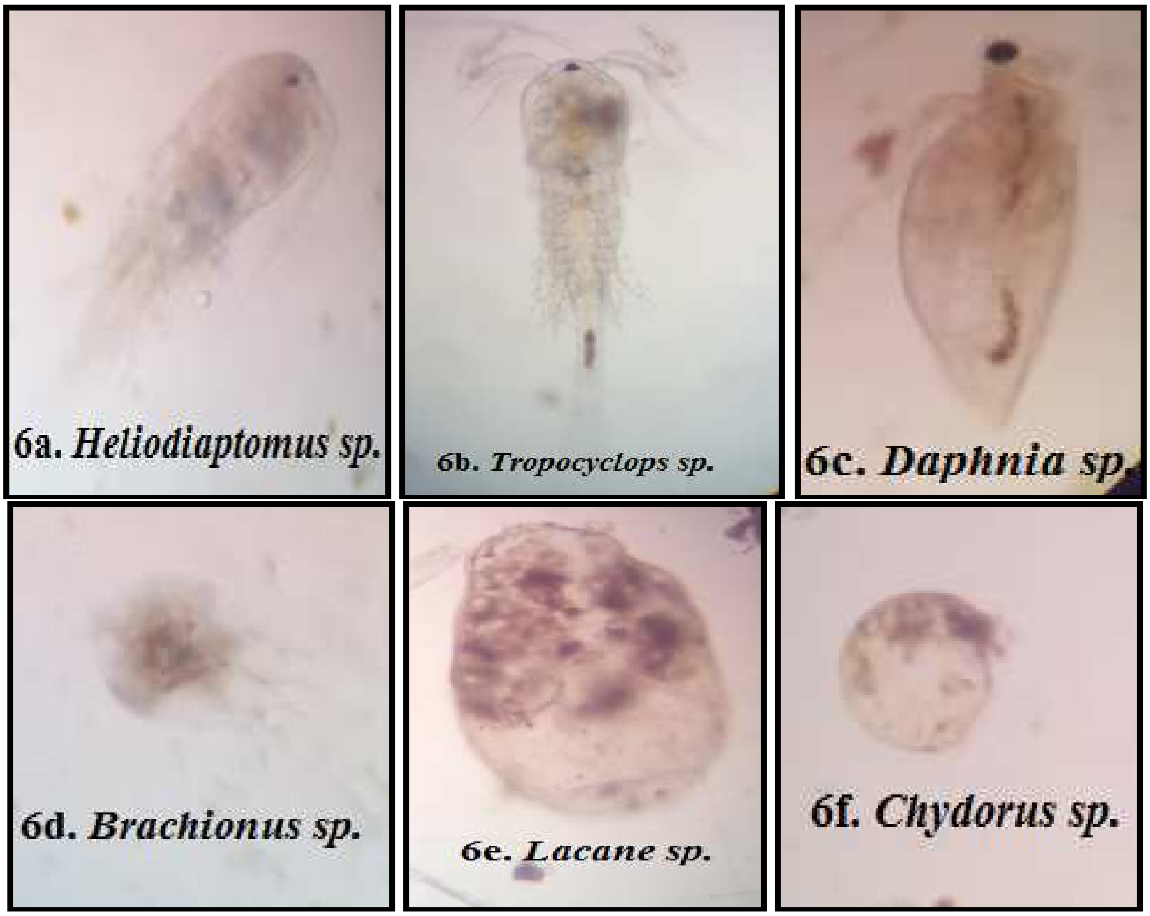


Fig. 6(a-f): Photographs of some collected zooplankton species

C. In relation to diversity: Fifteen types of zooplanktons were primarily identified from the water sample of NWL. Whereas, in the water sample of MWL, only four types of zooplanktons were primarily identified. NWL sample contains two crustacean larvae, five Cladocera species, four Copepod species, one Ostracod species and three Rotifer species. Whereas MWL sample contains only four Copepod species. So, NWL shows higher species diversity than MWL.

D. In relation to zooplankton density: Zooplankton count shows that the approximate zooplankton density at NWL is 240000 zooplanktons per litre while that of MWL is 840000 zooplanktons per litre at the surface water. So, the MWL shows higher zooplankton density.

Table-8: List of zooplanktons with their relative abundance value

Phylum and Subphylum	Class with Order	Stages of the life cycle	Identified Species	Presence or Absence		Relative abundance (%)	
				S1	S2	S1	S2
Arthropoda *Crustacea*	**Branchiopoda** *Cladocera*	L	*Nauplius sp.*	+	-	1.64	..
		L	*Zoea sp.*	+	-	1.62	..
		A	*Moina sp.*	+	-	3.28	..
		A	*Chydorus sp.*	+	-	6.56	..
		A	*Diphanosoma sp.*	+	-	4.92	..
		A	*Alona sp.*	+	-	3.27	..
		A	*Daphnia sp.*	+	-	9.84	..
	Maxillopoda *Copepoda*	A	*Cyclops sp.*	+	+	6.56	62.5
		A	*Heliodiaptomus sp.*	+	+	8.20	12.0
		A	*Tropocyclops sp.*	+	+	8.20	20.5
		A	*Mesocyclops sp.*	+	+	3.28	5.00
	Ostracoda	A	*Cypris sp.*	+	-	3.28	..
Rotifera		A	*Brachionus sp.*	+	-	29.51	..
		A	*Keratella sp.*	+	-	6.56	..
		A	*Lacane sp.*	+	-	3.28	..

N.B.: L*= Larva,* ***A****= Adult,* **"+"***= Present,* **"-"***= Absent, ".."= insignificant*

E. In relation to numerical abundance (Table 8 and Fig.7, 8 and 9)*:* The total zooplankton collection from NWL grossly includes the Cladocerans, Copepods and Ostracods from the subphylum Crustacea. Adult forms are mostly collected but a few larval forms are also noted. Among these, the rotifer *Brachionus* sp. (29.51%) is predominant numerically. On the other hand, the MWL water sample shows only copepod species and among them *Cyclops sp.* (62.50%) shows its greatest abundance. Relative abundance of different zooplanktons in NWL and MWL is also presented at log 10 in the Fig.7. Pie diagrams (Fig.8 and 9) are also made to represent the relative abundances of the two wetlands (NWL and MWL).

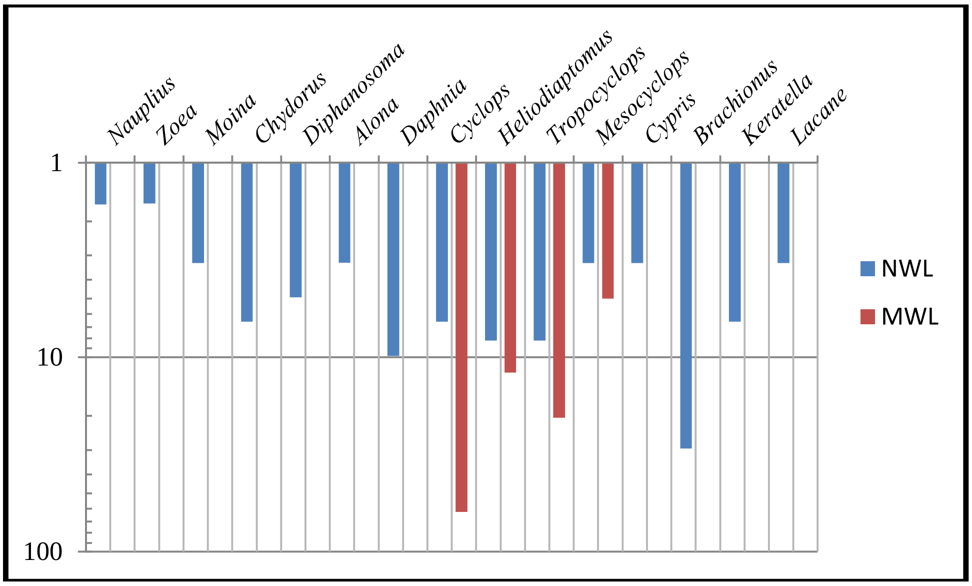


Fig.7: Relative abundance of different zooplankton population (at log 10) in two different sources of water (NWL and MWL)

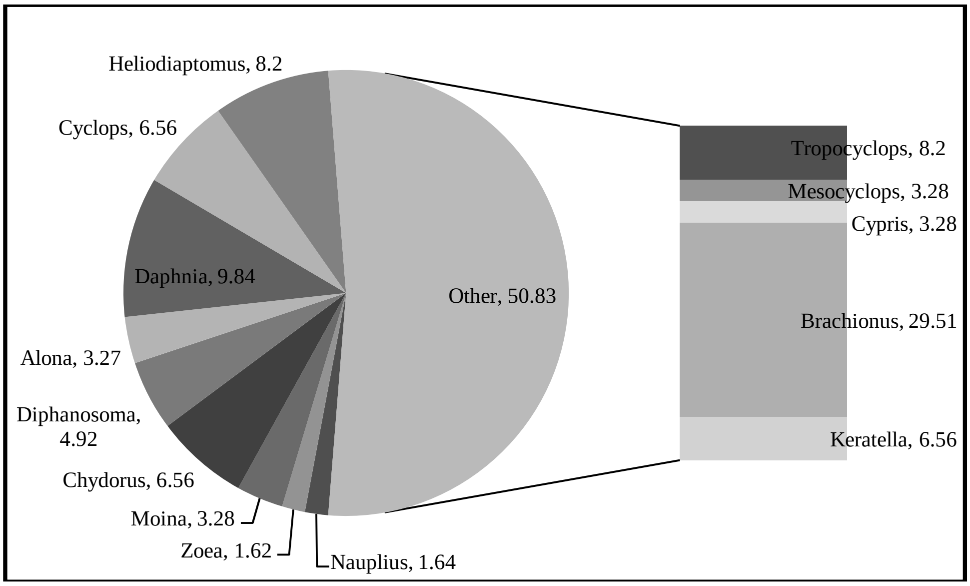


Fig.8: Pie diagram showing the relative abundance of zooplanktons at NWL

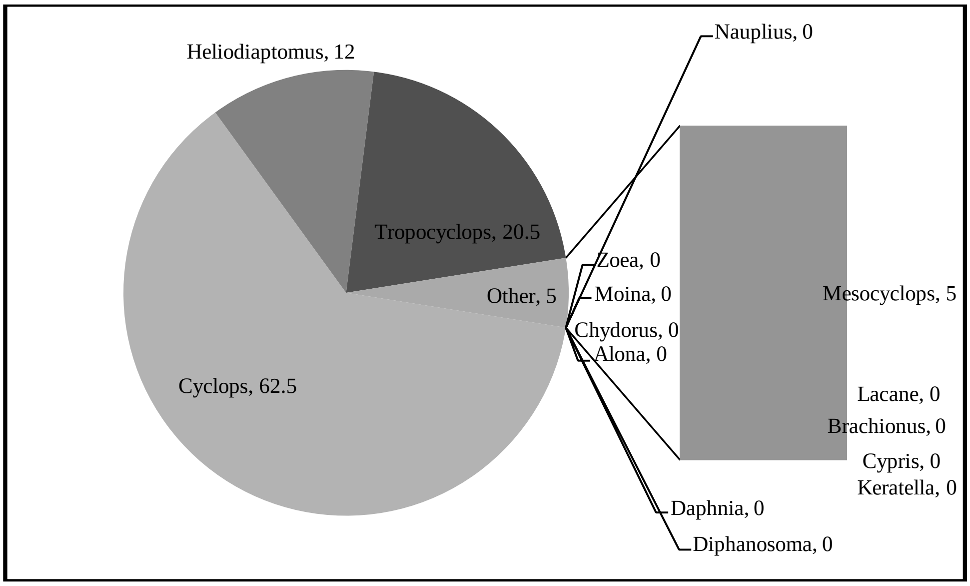


Fig.9: Pie diagram showing the relative abundance of zooplanktons at MWL

Present study corroborated to the observations of Datta (2011)[4] who studied at the two wetlands of Jalpaiguri district of West Bengal and noted a number of zooplanktons which match to the present observation. Diversity of zooplankton population in relation to different physico-chemical parameters of water was also advocated by Ahmad *et al.* [32]. Barbosa *et al.* [33] has noted a high level of abundance of zooplankton population at Dom Helvecio Lake of Brazil due to different ecological zonation which is similar to the present work. Khan [34] also recorded high density of zooplankton in man-made village pond as well as in urban recreational lake. Impact of aquatic pH on the incidence of zooplankton population was also advocated by Lafrancois *et al.* [35]. Basically, pH influences the primary productivity which in turn dictates plankton abundance [20]. In present study pH levels of both the sites of observation are within the reference limits, thus it is safe to the aquatic life. Effect of conductivity on the zooplankton abundance was narrated by Bos *et al.* [36]. They demonstrate that water conductivity has impact on zooplankton population incidence. In present study, conductivity of the two sites is considerable for zooplankton population. Both TDS and TSS are related to water transparency. Ivanova *et al.* [37] advocates the impact of TDS and TSS value on the abundance of zooplankton. But in present study impact of TDS and TSS values at NWL and MWL are in considerable range for the zooplanktons. Effect of temperature as the primary limiting factor on the incidence and abundance of zooplankton population was also demonstrated by Farshad *et al.* [19]. As in the present observation, the variation of temperature at the two water bodies is marginal, variation of zooplankton population due to temperature is supposed to be less. Dissolved oxygen indicates water health and in the present study it is optimum to support aquatic life at both the water bodies. Effect of iron and chloride on the incidence of zooplankton population was also documented by Pitchford *et al.* [38] and Sharma *et al.* [39]. Increasing chloride content indicates the increasing pollution level [40, 41] as recorded in our study. Among the different physical and chemical parameters considered in present study, statistical analysis indicates that iron concentration has a strong correlation with conductivity. In the present study, iron and chloride concentration show a considerable range for zooplankton survivability.

CONCLUSION

On the basis of the results and discussion, this can be concluded that the natural wetland represents higher zooplankton diversity than man-made wetland in Cooch Behar. The man-made wetland shows comparatively more numerical dominance of copepod species. Presence of *Cyclops* sp. at high density in man-made water body indicates organic pollution. Physico-chemical parameters indicate prevalence of desirable quality of water in both the wetlands but the man-made wetland having lesser zooplankton diversity but higher zooplankton density stipulates the gradual deterioration of water bodies at Cooch Behar district of West Bengal.

REFERENCES

[1] J.M. Chase, Drought mediates the importance of stochastic community assembly, Proceedings of the National Academy of Sciences of the United States of America, **2007**, 104, 17430–17434.
[2] M. Williams, *'Understanding Wetlands' in Michael Williams (ed), Wetlands: A threatened Landscape*, Basil Blakewell Ltd., Oxford, **1990**, pp 1-3.

[3] S. Panthi, M. Dhakal, S.S. Thagunna, B.B. Thapa, *Open Journal of Ecology*, **2014**, 4, 245-252.
[4] T. Datta, *International Journal of Applied Biology and Pharmaceutical Technology*. **2011**, 2(3), 576-583.
[5] M.S. Ahmad, *Journal of Environment and Pollution*. **1996**, 3, 147-151.
[6] J.J. Contreras, S.S.S. Sarma, M. Merino-Ibarra, S. Nandini, *Journal of Environmental Biology*, **2009**, 30, 191-195.
[7] V.B. Kushwaha, M. Agrahari, *World Journal of Zoology*, **2014**, 9 (2), 86-92.
[8] S.V. Rankhamb, K.S. Raut, *International Journal of Innovations in Bio-Sciences*, **2012**, 2 (4), 211-216.
[9] N. Murugan, P. Murugavel, M.S. Koderkar, *Freshwater cladocera*. Indian Association of Aquatic Biologists (IAAB), Hyderabad. **1998**, pp 1-47.
[10] N. Dadhick, M.M. Saxena, *Journal of Environment and Pollution*, **1999**, 6, 251-254.
[11] B. Sinha, M.R. Islam. *Ecology Environment and Conservation.* **2002**, 8, 273-278.
[12] K.S. Park, H.W. Shin, *Journal of Environmental Biology*, **2007**, 28, 415-422.
[13] O. Rocha, T. Matsumura-Tundisi, E.L.G. Espindola, K.F. Roche, A.C. Rietzler, *Ecological theory applied to reservoir zooplankton. In: Theoretical reservoir ecology and its application (Eds.: Tundisi J. G. and M. Straskraba)*, International Institute of Ecology in São Carlos, Brazil, **1999**, 457-476.
[14] I.F. Neves, O. Recha, K.F. Roche, A.A. Pinto, *Brazilian Journal of Biology*, **2003**, 63, 1-20.
[15] S.N. Islam, *Research Journal of Fisheries and Hydrobiology*, **2007**, 2(2), 21-25.
[16] T. Rajagopal, A. Thangamani, G. Archunan, *Journal of Environmental Biology*, **2010**, 31(5), 787-794.
[17] A. James, J.W. Pitchford, J. Brindley, *Ecological Modelling*, **2003**, 160, 77-90.
[18] P. Kumar, F. Sonaullah, A. Wanganeo, *J. Exp. Sci.*, 2010, 24(2), 219-226.
[19] H. Farshad, G.V. Venkataramana, *International Research Journal of Environment Sciences*. **2012**, 1(4), 37-42.
[20] J.M. Harris, P. Vinobaba, *Journal of Ecosystem and Ecography*, **2012**, 2(4).
[21] M. Jeelani, H. Kaur, *Journal of Academia and Industrial Research*, **2014**, 2(9), 534-537.
[22] K. Bahura, *J. Aqua. Biol.*, **2001**, 16 (12), 45- 48.
[23] APHA, *Standard methods for examination of water and wastewater*, 21st Edition, American Public Health Association, Washington DC, **2005**.
[24] W.T. Edmondson, *Freshwater biology*, 2nd Edition, John Wiley & Sons, New Experimental Biology, **1959**, 1 (2), 68-76**.**
[25] A.D. Adoni, *Work book on limnology*, Pratibha Publishers, Sagar. **1985**.
[26] J.G. Needham, R.P. Needham, *Journal of Environmental Sociobiology*, **1972**, 2, 15-23.
[27] R.W. Pennak, *Freshwater invertebrates of United States*, 2nd Edition, John Willey Sons Inc., New York, **1978**.
[28] M.V.S.S.S. Dhanapathi, *Hydrobiologia*, **2003**, 48(1), 916.
[29] Y.R. Reddy, *Copepoda, Calanoida, Diaptomidae : Guide to the identification of the micro-invertebrates of the continental waters of the world*, 5th volume, SPB Publishers, The Hague, Netherland, **1994**.
[30] R.G. Michael, B.K. Sharma; Fauna of India and adjacent countries, Indian Cladocera (Crustacea, Branchipoda and Cladocera), Zoological Survey of India, **1988**.
[31] R. Victor, C.H. Fernando, *Records of the zoological survey of India*. **1979**, 74(2), 147-242.
[32] U. Ahmad, S. Parveen, A.A. Khan, H.A. Kabir, H.R.A. Mola, A.H. Ganai, *Frontiers in Life Sciences: Basic and Applied:Biology and Medicine*. **2011**, 3(2), 336-341.
[33] P.M. Barbosa, R.S. Peixoto, A.S. Guimarães, *Brazilian Journal Biology*, **2008**, 68(4).
[34] R.A. Khan, *Faunal diversity of Zooplankton in Freshwater Wetlands of South-eastern West Bengal*, Occasional Paper No. 204, ZSI, Kolkata, India, **2003**.
[35] B.M. Lafrancois, R.K. Nydick, B.M. Johnson, J.S. Baron, *Can. J. Fish. Aquat. Sci*., **2004**, 61, 1153–1165.
[36] D.G. Bos, B.F. Cumming, C.E. Watters, J.P. Smol, *International Journal of Salt Lake Research*, **1996**, 5, 1-15.
[37] M.B. Ivanova, T.I. Kajantseva, *Russian Journal of Ecology*, **2006**, 37(4), 264-270.
[38] J.W. Pitchford, J. Brindley, *Journal of Plankton Research*, **1999**, 21(3), 525-547.
[39] B.K. Sharma, S. Sharma, *Journal of Threatened Taxa*, **2011**, 3(5), 1745– 1755.
[40] G.P. Bhatnagar, Limnology of lower lake, Bhopal with reference to sewage and eutrophication, *Bhopal University Pub. MAB*, UNESCO Project, **1984**.
[41] S.G. Patil, *Hydro-biological Investigations in "Fauna of Nathsagar Wetland and Jaikwadi Bird Sanctuary"*, Wetland Ecosystem Series 7, ZSI, Kolkata, India, **2005**.