Journal of Bioresource Management

Volume 6 | Issue 2 Article 2

4-10-2019

The Physico-Chemical Environment and Aquatic Biodiversity of Head Marala Wetland During 2000-2001

Zahid Bhatti
Center for Bioresource Research (CBR), Islamabad, Pakistan

Muhammad Asif Gondal
COMSATS University Islamabad, Islamabad, Pakistan

Andleeb Batool
Government College University, Lahore Pakistan, andleeb.batool@gcu.edu.pk

Recommended Citation

Bhatti, Z., Gondal, M., & Batool, A. (2019). The Physico-Chemical Environment and Aquatic Biodiversity of Head Marala Wetland During 2000-2001, *Journal of Bioresource Management, 6* (2).
DOI: https://doi.org/10.35691/JBM.9102.0104

THE PHYSICO-CHEMICAL ENVIRONMENT AND AQUATIC BIODIVERSITY OF HEAD MARALA WETLAND DURING 2000-2001

ZAHID BHATTI[1], MUHAMMAD ASIF GONDAL[2] AND ANDLEEB BATOOL[3]*

[1]Center for Bioresource Research (CBR), Islamabad, Pakistan
[2]COMSATS University Islamabad, Islamabad, Pakistan
[3]Department of Zoology, GC University, Lahore, Pakistan

*Corresponding author: andleeb.batool@gcu.edu.pk

ABSTRACT

An ecological study on Head Marala Wetland was undertaken. The study will help in providing sound basis for the future conservation activities and its management, on sounder footing. The Marala wetlands in Bajwat area included river Jammu Tawi, river Chanab and river Manawar Tawi were studied for a period of one year, i.e. from October, 2000 to September, 2001. In this study, 36 Phytoplanktons belonging to six families were observed. The other aquatic fauna observed included 14 species of fish, 2 turtles, one leech, one prawn, one shrimp and one bullfrog. The results showed that physico-chemical parameters had an impact on the biodiversity and population size of the aquatic fauna at Head Marala wetlands.

Keywords: Phytoplanktons, fish, catla catla, carp, turtle

INTRODUCTION

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh water, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters (Ramsar, 1971). Water is the dominant factor determining the nature of the soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al., 1979; Maltby, 1986). Freshwater lakes occupy a relatively small portion of the earth's surface and productive ecosystems which have great importance to living creatures, e.g., fish and waterfowl provide sport to the adventurers, while meat for human consumption and waterfowl which may or may not be dependent on fish are supported by the wetlands.

The most remarkable aspect of wetlands in Pakistan is the abundance of birds present there. Wetlands provide an ideal habitat for migratory waterfowl for the purpose of resting, preening, nesting and breeding. Migratory birds are an abundant renewable source of great economic, recreational and aesthetic value. They face different unique and difficult problems, because of number of species and individuals, wide spread distribution, seasonal migration and difference in population characteristics and mainly due to decline of wetlands habitat used for wintering in Pakistan due to different reasons such as hunting pressure, drainage/conservation of land for agricultural purposes and human settlement, illegal or over-fishing, cutting of wood for domestic purpose, pollution from different sources, overgrazing, commercial logging, cutting of aquatic vegetation for fodder, fuel etc., and eutrophication in lakes. Due to above mentioned reasons more than 50% of the previously existing wetlands have been destroyed since 1964. Different wetlands are being selected through WWF to improve

their conditions and to create awareness about their importance in public of Pakistan.

The present study has been instituted to undertake an ecological study on one of Wetland of international importance, i.e., Head Marala Wetland. The study will help in providing sound basis for the future conservation activities and its management, on sounder footing.

MATERIAL AND METHODS

Marala wetlands are located in the Bajwat Game Reserve at a distance of some 25 km in north of Sialkot City. The State of Jammu and Kashmir lies in the north. Three rivers, i.e., Tawi, Chenab and Manawar Tawi, coming from Jammu and Kashmir, flow into Game Reserve and meet to enter the Head Marala water storage reservoir. River Jammu Tawi, with associated marshes, supports extensive reed beds and an abundant growth of submerged and floating vegetation, and in the first river, while going towards Bajwat. The area of study was from Kikar Post to Head Marala. River Chenab runs in the northwest of the most of Bajwat villages. The area of study was from Kalyal to Head Marala marshy area. The aquatic and forest vegetation provide an open and undisturbed area for the waterfowl. River Manawar Tawi is located in the extreme west of Bajwat area and along the other side of Manawar, District Gujrat. The study area is from Rangpur Kuri to Head Marala. The Marala wetlands in Bajwat area included river Jammu Tawi, river Chanab and river Manawar Tawi were studied for a period of one year, i.e. from October, 2000 to September, 2001 to highlight various aspects of their ecology.

Biotic fluctuations of water

The distribution pattern and seasonal variation of planktons and invertebrates was studied throughout the study period. The samples were collected at a depth of 15 cm from Jammu, Tawi, Chenab and Manawar Tawi from different places with planktonic net. The samples were preserved in 7% commercial grade formaline. Temporary slides were prepared and studied under light microscopic. The phytoplanktons and the other aquatic fauna were identified with the help of literature.

RESULTS

The results on the relative abundance of the different species of the phytoplanktons at different sampling sites during different seasons have been summarized in Table 3. The table suggests that a total of 37 species of phytoplanktons were distributed in the study area. Out of the latest species identified from the complex 12 species belong to family Chlorophyecae, 7 to Cyanophyceae, 14 to Bacillariophyceae and 2 each to the families Rhodophyceae and Euglenophyceae.

Phytoplanktons at River Jammu were represented by 5 families. These classes were represented by twenty-seven species. The most prominent of these was Chlorophyceae with 10 species. The Cynophyceae and Bacillariophyceae were represented by 7 species, each. Maximum species of phytoplanktons were recorded in August, September and October.

Phytoplanktons at river Chenab were represented by 3 families i.e., Bacillariophyceae, Chlorophyceae and Cynophyceae. Bacillareophyceae which was represented by 8 species, was the most dominant among these. The dominant species among them was *Bacillaria povadona*. Chlorophyceae was represented by 7 species and Cynophyceae was represented by 3 species. The phytoplankton density and variability were low from April to July. The species density and variability increased during August and September.

Phytoplanktons at river Manawar Tawi were represented by 4 families (Bacillariophyceae, Cyanophyceae,

Euglenophyceae, Chlorophyceae). Bacillariophyceae was the most dominent family among these, which was represented by 7 species. Among these species *Syndera* sp. was found in abundance. Cyanophyceae was represented by 6 species. Among these *Oscillatoria* sp. and *Chlorococcus* sp. were commonly found throughout the study period. Euglenophyceae and Chlorophyceae were represented only by one and two species, respectively. The population of phytoplanktons in river Manawar Tawi were more in November, December, January and March. The decrease in population followed by an increase in population of phytoplanktons in August and September.

Table 1: Variation in different physico-climatic parameters at Marala wetlands during different months

Month	Temperature (°C)		Rainfall (mm)	Evaporation (at 0300 GMT)	Relative Humidity at 0300 (%)	Conductivity (μ Ohm/cm)	pH	Turbidity (N.T.U.)
	Air	Water						
October	28.0	21.9	0.0	40	0.05	270	8.6	180
November	21.0	15.2	0.03	70	0.01	210	8.6	150
December	23.5	19.8	0.10	42	0.02	380	8.5	130
January	15.5	10.0	0.10	40	0.02	245	8.2	140
February	15.7	10.8	0.10	48	0.03	352	8.4	210
March	17.3	13.1	0.60	53	0.05	441	8.7	340
April	19.3	16.9	8.70	27	0.06	380	8.5	130
May	37.4	29.9	0.98	40	0.08	214	8.0	200
June	41.5	32.0	0.75	30	0.09	315	7.0	170
July	33.4	29.9	11.0	68	0.10	212	8.1	300
August	31.4	28.5	15.5	72	0.22	218	8.3	110
September	29.8	21.5	1.3	65	0.20	200	8.2	110

Table 2: Monthly variation in the chemical parameters of water at Marala wetland during 2000-2001

Month	Chloride mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Sulphate mg/l	Bicarbonate mg/l	Total Alkalinity mg/l	Total Hardness mg/l	T.D.S mg/l	D.O ppm	Free CO_2 ppm
Oct	11	33	10.00	6.5	4.8	142	171	183	314	8	4.0
Nov	10	43	7.50	13.6	4.6	129	168	213	316	7	5.5
Dec	8	46	6.73	15.6	3.2	143	162	209	286	7	5.0
Jan	6	47	4.10	12.0	5.6	156	183	216	270	8	5.0
Feb	9	38	4.80	19.4	6.0	155	00	208	380	9	6.0
Mar	12	53	7.20	10.2	8.2	160	199	233	270	8	6.0
Apr	12	48	7.00	10.2	5.1	135	135	148	270	7	5.0
May	13	59	7.40	13.5	4.0	107	140	149	498	7	5.0
Jun	18	50	4.50	26.3	5.0	180	180	150	390	5	4.0
Jul	13	36	4.90	26.3	3.2	166	218	162	285	7	4.2
Aug	18	19	8.00	18.0	3.8	131	152	188	260	8	5.0
Sep	11	30	7.50	9.3	4.8	125	144	142	272	7	5.0

Table 3: Relative abundance of phytoplanktons recorded during different seasons at different rivers (A=Jammu Tawi, B=Chenab, C=Manawar Tawi) of Marala Head Works between 2000-2001.

Season	Winter (Nov. to Jan.)			Spring (Feb. to Apr.)			Summer (May to July)			Autumn Aug. to Oct.)		
Species	A	B	C	A	B	C	A	B	C	A	B	C
CHLOROPHYCEAE												
Chlamydomonas sp.	++	-	-	-	+	-	-	+	+	-	-	-
Volvox sp.	-	+	+	-	+	-	+	-	++	++	++	+
Oedogonium sp.	+	-	-	-	-	-	-	-	-	-	-	+
Vaucheria sp.	+	+	-	-	+	+	-	-	+	+	+	-
Cladophora sp.	+	+	-	-	-	-	-	-	+	-	-	+
Hydrodictyon sp.	+	+	-	-	+	+	-	-	+	+	+++	++
Ulothrix sp.	+	++	+	+	++	+	++	-	+	++	+	++
Spirogyra sp.	+	++	+	+	+	+	+	-	+	+	+	++
Chara sp.	++	+	+	+	+	-	+	+	+	-	+	++
Myxonemia sp.	+	+	-	-	+	-	-	+	+	+	+	+
Closterium sp.	++	+	+	-	+	-	+	++	++	+	++	+++
Astrophomena sp.	-	-	+	-	-	-	-	+	-	+	+	-

Season	**Winter (Nov. to Jan.)**			**Spring (Feb. to Apr.)**			**Summer (May to July)**			**Autumn Aug. to Oct.)**		
Species	A	B	C	A	B	C	A	B	C	A	B	C
CYANOPHYCEAE												
Anabaena sp.	+	+	-	-	-	+	+	+	+	+	+	+
Nostoc sp.	+	++	++	-	+	+	++	+	++	+	++	+
Oscillatoria sp.	++	+	-	+	+	++	+	++	++	++	++	+++
Chlorococcus sp.	++	++	+	-	+	-	++	+	++	++	+++	+++
Nodularia sp.	-	+	+	-	-	+	-	+	+	++	+++	+
Microcystis sp.	+++	+++	+	++	-	+	+	++	-	-	+	+
Arthrospira sp.	+	-	-	-	++	-	+	+	-	++	++	+
BACILLARIOPHYCEACE												
Cocconius sp.	+	+	-	+	+	++	+	+	++	++	++	++
Bacillaria paradon	+++	++	++	++	++	+	-	+++	+	+++	++	+++
Navicula sp.	+++	++	++	+	++	+++	++	+	+	+	+	+++
Neidium sp.	+	+	-	-	+	+	-	-	+	+	++	+
Diatomella sp.	+	+	+	-	-	-	-	-	+	+	+	++
Staurnius sp.	+	+	-	-	-	-	-	-	-	+	+	+
Cymbella sp.	+	+	+	+	-	-	+	-	-	-	++	+

Season	**Winter (Nov. to Jan.)**			**Spring (Feb. to Apr.)**			**Summer (May to July)**			**Autumn Aug. to Oct.)**		
Species	A	B	C	A	B	C	A	B	C	A	B	C
AMPHORA	-	+	-	-	++	+	-	-	-	+	+	+
Coeconeis sp.	-	+	+	-	-	+	-	-	+	+	+	-
Triceratium sp.	+	-	+	-	-	+	+	-	-	-	+	+
Synedra sp.	+++	++	+++	++	++	++	++	+	+	+	+	++
Satureneis sp.	-	++	++	+	-	+	+	-	-	++	++	-
Microcystis sp.	++	+	-	+	-	-	+	++	-	+	+	+
Mevismopedia sp.	+	-	-	++	-	-	-	+	-	-	+	+
RHODOPHYCEAE												
Batracospermium sp.	+	+	+	+	-	-	+	+	-	+	++	+
Porphyra sp.	+	+	-	+	+	+	-	-	-	-	-	+
EUGLENOPHYCEAE												
Stigcoclonuims sp.	+	+	+	+	+	+	-	-	+	+	+	++
Euglena Viridus	++	++	+	+	++	+	-	-	++	+	+	++

Table 4. Fish observed at Head Marala

S. No.	Common Name	Scientific Name
1.	Mozambique tilapia	*Tilapia mossambica*
2.	Rohu	*Labeo rohita*
3.	Mrigal	*Cirrhinus mrigala*
4.	Major south Asian carp	*Catla catla*
5.	Great snakehead	*Channa marulius*
6.	Common carp	*Cyprinus carpio*
7.	Brown trout	*Salmo faria*
8.	Tor mahseer	*Tor tor*
9.	Giant river catfish	*Mystus seenghala*
10.	Helicopter catfish	*Wallago atto*
11.	Two-spot barb	*Baribus ticto*
12.	Morari	*Aspidoparia morar*
13.	Large razorbelly minnow	*Oxygaster bacaila*
14.	Spotted snakehead	*Channa punctatus*

Table 5. Other aquatic fauna observed at Head Marala

S. No.	Common Name	Scientific Name
1.	Common Indian leech	*Hirudinaria sp.*
2.	Brown-roofed turtle	*Kachuga smithii*
3.	Indian flapshell turtle	*Lissemys punctata*
4.	Kaira river prawn	*Palaemon dayanus*
5.	Indian whisker shrimp	*P. lammarrei*
6.	Indus Valley bullfrog	*Rana tigrina*

DISCUSSION

A total of 14 species of fish were recorded from the water of Marala Wetlands (Table 4). *Labeo rohita*, *Cirrhinus mrigala*, *Catla catla* and *Wallago atto* are the four culturable species and appeared in good populations. The other species were relatively smaller and uncommon. All the living organisms whether terrestrial, aquatic or aerial are dependent on seasonal variations in the physico-chemical and biological components of their environment which has been aptly termed as their ecology.

Wetlands in Pakistan are diverse habitats. They may be considered as a life support system as the inland waters provide natural habitat for a variety of waterfowls, both resident and migratory and for other wildlife.

In an aquatic habitat, the chemical nature and physical conditions of water and the presence of biotic fauna and flora have a profound effect on the physiological processes, life patterns, growth performance, population density and geographical distribution of both animal and plant species (Welch, 1952).

Temperature, turbidity, pH, conductivity dissolved oxygen, free CO_2 carbonate bicarbonate calcium, Magnesium, sodium, sulphates, total alkalinity, total hardness total dissolved solids and planktonic life etc. are important ecological factors of aquatic life. In present study all

such factors were regularly recorded and are given in Table 1 and Table 2.

The air and water temperature of Marala wetland varied during different seasons, when water temperature was the lowest, air temperature was also lowest and the highest temperature was recorded in June. The water temperature followed the same trend. Khan and Siddique (1976) noted that water temperature of some ponds in Aligarh was 2-5^{o}C lower than the air temperature. A similar direct relationship between water and atmospheric temperature had also been noted by Ganapati (1940). The variations in water temperature at different times during present study were probably due to surface heating (evaporation) during the day and cooling during the night, a phenomenon commonly observed within tropical waters as reported by Verma (1967) and Mosely (1983). The difference between water and air temperature during the months of October and November observed was relatively less, possibly due to increase in humidity which greatly decreased the loss of heat through evaporation.

The turbidity values of Marala wetland ranged from 87 N.T to 500 N.T.V. According to Boyd (1981) the apparent color of water is caused by suspended matter which interferes with light penetration. He further explained that the turbidity and color of ponds may result from colloidal, clay particles collected organic matter originating from decay of vegetation or from an abundance of planktons.

According to Khatri (1985) the transparency has an inverse relationship with the phytoplanktons and similar pattern was observed during this study. Overall, the low value of transparency was possibly due to more turbidity of water which was further confirmed from the higher values of suspended particles.

Humidity showed distinct fluctuations ranging from 27% to 72% throughout the study period. Rainfall affected the water level of Marala wetlands; it also affected the depth and position of the wetlands. Rainfall also affected the turbidity that is why turbidity was maximum in July and minimum in October. Increase in turbidity may be due to sediments and changes in land use through rainfall.

pH was found to be mostly alkaline throughout the year with the range from 7.0 to 8.8. As pH showed an increasing trend throughout study period. This evidently point out to the fact that water quality is deteriorating which may affect the water fowl population at this wetland. Aquatic flora benthic (benthic and surface) seem to play a vital role in monitoring the alkaline tendency of water. In photosynthesis they utilize CO_2 and thus the equilibrium moves towards alkalinity (Trivedy, 1986). This statement seems to be applicable for this study as in most of the months, pH values are different at different depths. In bottom benthic flora consumed a large amount of CO_2 and caused alkalinity while in surface water especially during high temperatures there was a smaller number of flora which caused decrease in pH.

Conductivity was maximum in April i.e., 441. And there was no significant change in the overall electric conductivity values. During the period from October to December and June to September, there was a steady increase in conductivity values. The decreased conductivity in January and May, may be due to dilution by rainfall. Show and restricted water and stagnation favour the concentration of dissolved salts and were to increase the conductance and flowing water diluting the concentration of salts and decrease conductance (Ryder, 1972; Prather et al., 1982). The conductivity confirmed this phenomenon.

Chloride values showed the maximum point in August i.e., 17.73 minimum in January 6 mg/l. In other months it fluctuated throughout the investigation period. Similar fluctuations were found in calcium, Magnesium and sulphates. The minimum value in January due to dilution of salts took place due to rain and highest contents of chloride in August were observed due to flowing of rainy water.

Chloride is one of the major ionic components of water and sodium is one of the most abundant elements in streams and ponds. The maximum contents of sodium were also in August and showed a correlation with chlorides contents and which showed similar fluctuation throughout study period.

The calcium followed by Magnesium was the dominant cations and carbonates and bicarbonates were dominant anions. The concentration calcium ranged between 13 mg/l to 45.20 mg/l while Magnesium ranged from 3.3 mg/l to 11.4 mg/l. The strong correlation was observed between increase and decrease in calcium Magnesium contents. Despite considerable, variation in Magnesium and Calcium value. These ions were strongly correlated. Bicarbonates ranged from 38 mg/l i.e. 183 mg/l. This variation resulted in increase of total alkalinity. A strong relation between carbonates bicarbonates and pH of water was observed during this study. Total alkalinity and total dissolved solids showed abrupt changes, which may be due to temperature and other environmental factors (Table 2 and Figure 2).

A wide variation was noticed in total hardness factor (Table 2, Figure 2). The increased hardness during water and spring while relatively poor hardness during summer and autumn (November) indicated that water of river Jammu Tawi was not permanently hard, increased hardness might be due to poor dilution and low precipitation. In monsoon a post monsoon high rains diluted the water and reduces the other salts concentrations. From physicochemical results it can be concluded that concentration was more April to July, i.e. in summer, pre monsoon. This may be due to the more evaporation decreased water level and high temperature. Hence, more birds i.e. Migratory birds were not observed during these months. Similar results were observed in river Chenab and river Manawar Tawi.

One of the typical of features of most phytoplanktons population is their relatively short duration. A population usually originates from a small number of cells and number, grows exponentially for a few weeks. The duration of the whole cycle of growth and decline being 4-8 weeks. The phytoplanktons succession of particular groups of species occur during particular seasons (Golterman 1975). Salt lakes are characterized by low diversity of micro-flora and fauna (Beadle, 1932; Burch, 1988).

During this study it was observed that phytoplanktons were dominant during spring. Thus, the results indicated that seasons had a direct effect on the distribution of plankton species. In river Chenab phytoplanktons were dominated by Bacllariophyceae, chlorophyceae and cyanophyceae, whereas in Manawar Tawi 4 classes i.e. Bacllarcophyceae, cynophyceae and chlorophyceae and euglenophyceae dominated. Among phytoplanktons, the diatomes remained dominant throughout the investigation period at river Jammu, River Chenab and Manwar Tawi.

At river Jammu and river Manawar Tawi a wide variety of phytoplanktons were observed but at river Chenab less variety of phytoplanktons were observed. At river Jammu Tawi the members of class chlorophyceae were maximum showing its dominance over the other phytoplanktons i.e. members of cynophyceae and

euglenophyceae, as these classes were represented by gradual decreases in their representative species.

According to Bursey (1989) turbidity can severely effect zooplanktons. Not only does it interfere with photosynthesis to inhibit food production but clogs feeding apparatus of zooplanktons causing them to accumulate silt in the digestion tract and sink.

After the Monsoon the phytoplanktons were at average size. Phytoplanktons are an important food for zooplanktons (Bursey. 1989). As the pH recorded throughout the year was on the alkaline side it was concluded that diatoms encountered in this study may tolerate alkaline conditions. Trivedy (1988) concluded after his studies that diatoms could be effectively used not only as indicators of water quality but also to assess the water quality of running water. It was concluded that natural and slightly alkaline water may harbour a wide range of algae species (Welch, 1952).

The phytoplanktons increased from monsoon through the post monsoon to the next pre- monsoon. (Table 3). In this study, cynophyceae was the 2nd dominant class in river Jammu Tawi and due to its excessive growth, the water fowl population might have decreased. The members of cynophyceae are known to be highly edaphic and can colonize in the polluted waters. Some members of cynophyceae release toxic alkaloids during the decay and due to the excessive growth of algae, eutrophication may be caused which is harmful for the water fowl population. This study was focused on phytoplanktons and aquatic fauna of Marala Head; the zooplanktons of this area from same time period have been previously reported by Bhatti et al. (2018).

CONCLUSION:

In this study, 36 Phytoplanktons belonging to six families were observed. The other aquatic fauna observed included 14 species of fish, 2 turtles, one leech, one prawn, one shrimp and one bullfrog. The results allude that physico-chemical parameters had an impact on the biodiversity and population size of the aquatic fauna at Head Marala wetlands.

REFERENCES

Beadle LC (1932). Scientific results of the Cambridge expedition of the East African Lakes. J. Limn Soc Zool., 38:157-200.

Bhatti Z, Gondal MA, Ghufran A (2018). Batool. A Checklist of zooplanktons in different rivers of Bajwat area. J Biores Manag. 5 (4): 9-13.

Boyd CE (1981). Water quality in warm water fish ponds. 2nd Ed. Craftmaster Printers Opelika. Alabama: pp359.

Burch MD (1988). Annual cycle of phytoplanktons in Ace lake an ice covered, sazline meronictic lake. Hydrobiolgia, 165:59-76.

Cowardin LM, Carter V, Golct FC, La Roe ET (1979). Classification of wetlands and deepwater habitats of the United States. Biol. Services Program, Fish Wildl. Serv. USA. Dept. International., Washington D.C.

Ganpati SV (1940). The ecology of temple tank containing a permanent bloom of microcystis aeruginosa. Bombay Nat Hist Soc., 42: 65-77.

Golterman HL (1975). Physiological limnology: an approach to the physiology of the lake ecosystems. In: Development in Water Sciences, vol.2. (eds.) Amsterdam, Oxford: pp 48.

Khatri TV (1985). Seasonal variations in the ecosystem of Lakhotia Lake in Rajasthan (India). J. Fish, 31:122-129.

Khan AA, Siddique AQ (1976). Seasonal changes in limnology of a perennial fish pond at Aligarh. India J Fish., 21: 463-478.

Maltby E (1986). Waterlogged wealth, why waste the world's wet places. Internat. Institute Environ. Develop., London and Washington, D.C.: pp 2000.

Mosley M (1983). Variability of water temperatures in the braided Ashley and Rakaia rivers. N. Z. J. Mar. Freshwater Res., 17: 331-342

Prather K, Kinman B, Esisk M, Dobroth D, Gordon M (1982). Biological and chemical evaluation of aquatic environments. Ky. Acad. Sci., 43: 27-42.

Ramsar B (1971). Ramsar convention on wetlands of international importance especially as waterfowl habitat. Source Rep. W.W.F.

Ryder RA (1972). The limnology and fishes of oligotrophic glacial lakes in North America. J. Fish Res. Bd. Can., 29: 617-627.

Trivedy RK, Goel PK (1986). Chemical and biological methods for water pollution studies. Environmental publication (Karad, India), 6: 10-12.

Verma MN (1967). Diurnal variation in a fish pond Seoni, India. Hydrobiologia, 30: 129-132.

Welch PS (1952). Limnology. 2nd ed., McCraw Hill, New York: pp 538.