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LIMNOLOGY AND TROPHIC STATUS OF SHAHPUR DAM RESERVOIR, PAKISTAN

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ABSTRACT

Phytoplankton, because of their role as primary producers in an aquatic ecosystem are the subject of great interest and their qualitative and quantitative estimates can provide good indices of quality and productive capacity of water. Present studies were carried out to determine the seasonal phytoplankton composition and reservoir productivity of Shahpur Dam in Pakistan. Carlson Trophic Index was determined to analyze trophic status of reservoir. A total of 35 genera, belonging to 28 families and 7 classes were identified during the study. Class *Chlorophyceae* and *Cyanobacteria* were found to be most diverse and dominant. It was observed that Morpho-edaphic Index on TDS and Secchi depth were significantly correlated with chlorophyll-a concentration. Chlorophyll-a probably would be better indicator of trophic state of reservoir and in absence of chlorophyll-a data, MEI could be used as practical potential tool for fisheries management.

Keywords: Carlson's TSI, chlorophyll *a,* phytoplankton, reservoirs, Pakistan

INTRODUCTION

Water reservoirs and Dams are major water resources, which are very diverse both in terms of size and fisheries potential. Freshwater fish fauna is considered as highly diverse and representative of all the warm water fish of Pakistan (Khan *et al*. 2008). The biotic components of aquatic ecosystem play an important role in water reservoirs intended for fish production as well as for other functions. Phytoplankton, because of their role as primary producers in an aquatic ecosystem is the subject of great interest. Phytoplankton is very important functional group in all types of aquatic food web reflecting the trophic status of the water bodies (Kallf and Knoechel, 1978). Seasonal changes in mean temperature, radiations, hydraulic throughput and nutrient availability are the most important variables which determine phytoplankton composition and abundance (Reynolds 1990; 1998; Marinho and Huszar, 2002). Their qualitative and quantitative estimates provide good indices of quality and productive capacity of water (Anderson, 1969). Lot of work has been done to estimate productivity and plankton analysis in lakes and reservoirs in temperate regions (Montecino, 1991; Mallin *et al.*, 1994; Watson *et al.*, 1997; Huszar and Caraco, 1998; Trifonova, 1998). However, not much information is available on the distribution, composition and succession of tropical and sub tropical phytoplankton communities and their diversity in relation to environmental gradient in lakes and reservoirs. In tropical and sub tropical lakes, fluctuations in total radiation and water temperature are not as high as those observed in temperate regions (Talling, 1987). Nevertheless, seasonal patterns in tropical phytoplankton communities are still important (Figueredo and Giani, 2001). Although there is a large diversity of standing water bodies in the tropical latitude resulting from climatic and geomorphologic heterogeneity, detailed phytoplankton investigations are rare on their spatial and temporal distribution, growth and survival, loss patterns, periodicity and changes in species composition in relation to environmental variables (Silva, 2005). Very few studies are available on man made reservoirs (Silva, 2005; Nogueira, 2000; Figueredo and Giani, 2001; Akbay *et al.,* 1999; Harris and Baxter, 1996).

The estimation of plankton density, productivity and trophic status of lakes and reservoirs is very important for fisheries management especially in Asian lakes and reservoirs because of dominant carp culture. Fish productivity of water bodies is connected to primary production by many intermediate trophic links. However, true estimation of primary production and phytoplankton density is a very difficult and time consuming process. Secchi depth is a much debated and used variable in lake management. The secchi visibility provides an estimate of water transparency. Secchi disk transparency is a standard indicator of water clarity, which is strongly correlated with biomass and annual productivity of suspended algae (Peckham *et al.*, 2006). This is also closely related to the amount of sandy clay, detritus and organic matter suspended in water and quantity of dissolved elements in water (Sifa and Senlin, 1995).

Over the last few decades, simple or multiple regression analyses have been used to comprehend the type and degree of relationship between water trophic conditions and associated variables. The trophic status of a lake is usually estimated by values of primary production measured for the growing season. Average chlorophyll-a concentration and Secchi depth can be used to study trophic status of lake by measuring Carlson Trophic Index TSI (SD). The values of chlorophyll-*a* ($\mu g.l^{-1}$) are mostly used as the basic criteria because it is relatively easy and inexpensive to measure and it is a generally used biological measure of phytoplankton biomass and relatively few measurements are needed to get reliable mean value (Håkanson and Boulion, 2001). Carlson's Trophic State Index (TSI) classification (Carlson and Simpson, 1996) can be used to provide a single trophic criterion for the purpose of classifying and ranking lakes in complex multi-reservoir systems. Information about the trophic status of water body is very important for environment and fisheries management purpose. It helps managers to estimate stocking density and predict fish yield.

Very little knowledge is available about the general relationship between nutrients and chlorophyll in tropical systems or the primary limiting nutrient in tropical and sub tropical freshwater ecosystems (Kalff, 2002; Huszar *et al.,* 2006). In Pakistan only few studies on phytoplankton and productivity in reservoirs are available in literature. However some studies are available on phytoplankton diversity and seasonal abundance in Lakes (Tasneem and Parvaiz, 1994; Leghari *et al*., 2000; Leghari *et al.,* 2004; Nazneen, 2004; Mahar *et al.* 2009). There is no published knowledge available on trophic status and productivity of man made reservoirs in Pakistan. Present study is focused on studying phytoplankton diversity and to evaluate the trophic status of a sub tropical man made small dam reservoir in Pothohar Pakistan for first time.

The Site: Shahpur Dam Reservoir is situated just out side capital area of Islamabad about 20 km toward south of Tarnol and 8 km north of Fateh Jang town on Tarnol Kohat Road (Figure 1) .The latitude of site is 33º-37'-30" north and longitude 72º-41'-00" east. Physiography is hilly and geologically, area comprises of sedimentary rocks of Eocene limestone with loosely cemented formation comprising of alternate beds of thin shale and sandstone. Soil is generally alluvial and loessial origin. Climate is sub tropical with average annual rainfall in region is 780 mm. Dam stores the flood water as well as perennial flow of the stream. Main purpose of the dam is to store the flood water and to supply the irrigation water for agriculture purpose through out the year. Among indirect benefits are development of fish culture, improvement of aquifer and hydrology, live stock and soil conservation etc.

MATERIALS AND METHODS

Three sites were selected to record physiochemical parameters and water samples collection for analysis and mean values of these sites were taken for compilation of the data. Water quality analysis was done during day time from 11-12 am in middle of every month from July 2001 to June 2002. Temperature, turbidity, dissolved oxygen, conductivity and pH were recorded in the field using YSI and Hanna microprocessor meters. Secchi depth was recorded by standard wooden black and white Secchi disk. Water samples were collected from about 30 cm below water surface in plastic bottles and shifted to laboratory to calculate alkalinity.

In order to collect the phytoplankton, water samples were taken up to one meter using water sampler and fifteen litres of water was passed through plankton net (No. 25 Wisconsin Plankton Net). Planktons were collected in dark colour plastic bottles and preserved with Lugol's solution. Samples were shifted to laboratory where they were identified after Prescott (1951), Edmondson (1959) and John *et al.* (2002). For Chlorophyll-a analysis 100 ml water sample were filtered through Millipore micro filters (47mm; 45µm pores). Concentration of Chlorophyll-a in supernatant was determined by spectrophotometer, with absorbance at 665nm and 750nm (Vollenweider, 1974). Morpho-edaphic indices were derived as MEIt (Mean of TDS/Mean Depth) (Ryder, 1965), MEIc (Mean of Conductivity/Mean Depth) (Henderson and Welcome, 1974) and MEIa (Mean of Alkalinity /Mean Depth) (Nissanka and Amarasinghe, 2001). Trophic state index based on Secchi Depth, TSI (SD) and Trophic state index bases on Chlorophyll-a ($\mu g.l^{-1}$), TSI (Chl-a) were calculated after Carlson and Simpson (1996) and Håkanson and Boulion (2001) using the following equations respectively.

TSI (SD) = 60 - 14.1 In Secchi Depth (m)
TSI (Chl-a) = 9.81(In Chl-a) + 30.6
TSI (Chl-a) = 25(log (Chl-a) + 1)

RESULTS AND DISCUSSION

Phytoplankton composition was studies only four times in the years. The taxonomic listing of the phytoplankton species observed in the Shahpur reservoir during the study period is given in Table 1. A total of 35 genera, belonging to 28 families and 7 classes were identified during the study. The class *Chlorophyceae* and *Cyanobacteria* were most diverse classes represented by 11 genera each followed by class *Charophyceae* with 6 genera. *Bacillariophyceae* was represented with 3 genera followed by *Ulvophyceae* with two genera and *Trebouxiophyceae* & *Xanthophyceae* with one genera each. Maximum numbers of genera were found during the month of June or during summer whereas minimum numbers of genera were found during the month of December or during winter. The percentage occurrence of *Chlorophyceae* was 58%, followed by the *Cyanophyceae* (18%), *Charophyceae* (14%), *Bacillariophyceae* (8%). *Spirogyra* and *Microcystis* sp. were dominant among phytoplankton.

Minimum, maximum and mean of different physical and chemical parameters of Shahpur Dam reservoir during the year 2001-2002 are given in Table 2 and monthly variations of some important parameters are presented in graphic form in Figure 2. Water surface temperature was highest in August and lowest in January. There was clear temperature stratification from July to September and then from March to June. Dissolved Oxygen content (DO) was lowest in month of July and highest in January. There was marked variation in DO from surface to bottom from July to November and then from March to June. Conductivity was relatively higher during the monsoon months of July and August and for remaining part of year, there was no marked variation. Alkalinity was minimum in September and maximum in February with range between 132 $mg.l^{-1}$ to 194 $mg.l^{-1}$. The mean pH was within alkaline range with minimum value in November and maximum in June and August. Total Dissolved Solids were highest during the monsoon month of August and September and lowest in January with mean of 235 $mg.l^{-1}$ during the year. Water turbidity was highest during the monsoon month of July and August and was lowest during February. Secchi depth (water transparency) was minimum during spring month of April and monsoon month of July and maximum during the winter months of December and January (Figure 3). Chlorophyll-a content was highest during the month of June (31.30 $\mu g.l^{-1}$) and lowest during the month of December (9.70 $\mu g.l^{-1}$, Figure 3). Correlation matrix between various physiochemical parameters of Shahpur dam are given in Table 3. Secchi depth showed significant negative correlation with mean temperature and Chlorophyll-a ($P < 0.01$). Chlorophyll-a also showed significant positive relationship with temperature ($P < 0.01$). MEIt showed significant correlation with temperature ($P < 0.01$) and Chlorophyll-a ($P < 0.001$)

Phytoplankton communities in tropical lakes and reservoirs represent summer communities of temperate lakes with a large number of tropical texa including pan-tropical and regional endemic elements (Vyverman, 1996, Offem *et al*. 2009). However there is little information on the distribution, composition and succession of tropical and sub tropical phytoplankton communities and their diversity in relation to environment gradients in tropical lakes and reservoirs (Mukankomeje *et al.,* 1993; Branco and Senna, 1994). Progressive decline in phytoplankton diversity towards tropics has been suggested by many researchers (Lewis, 1996). In Shahpur reservoir, *Chlorophyceae* are dominant class followed by *Cyanophyceae* and *Charophyceae*. *Chlorophyceae* has been found as dominant class in Sri Lankan water bodies followed by *Cynophyceae* (Silva, 2005). The genus *Microcystis* is found as dominant genera in Shahpur reservoir. Same has also been observed for Sri Lankan reservoirs (Silva, 2005). The overwhelming presence of *Microcystis sp.* in Shahpur dam especially in summer is due to presence of bright sunshine, isothermal water column and extensive catchment area draining calcium rich agriculture land. Physiological and behavioural flexibility of *Microcystis* can accommodate environmental stresses better than most fast growing species and it is found to be an excellent example of an extreme k-selected phytoplankton in the tropics (Silva, 2004).

Chlorophyll-a is used by all phytoplankton to capture sunlight for photosynthesis. Its concentration reflects the total algal biomass. Chlorophyll (Chl-a) concentration is a uniquely algal trait of the water column and has been a central metric of phytoplankton biomass in the field and function as a reliable measure of phytoplankton biomass (Behrenfeld and Boss, 2006). In Shahpur reservoir chlorophyll-a concentration increased in spring and summer and started to decrease in autumn and continued to decrease in winter month. During monsoon, mostly in ponds and reservoirs in Asia, phytoplankton minimum can be observed during the rain months (Silva, 2004). According to Sugunan (2000) most of the reservoirs in India have three plankton pulses coinciding with the post-monsoon (September to November), winter (December to February) and summer (March to May) seasons. The monsoon (June-August) flushing disturbs the standing crop of plankton. However, when the destabilising effects wean away, the nutrient input favours an accelerated plankton growth. Abundance of phytoplankton can be low during the peak of rainy season and high during dry season with a noticeable sequential change in species composition. However, in Shahpur Dam catchment, monsoon season mostly start in July so the high temperature, bright sunlight and rapid tropholytic activities by decrease in water level and bringing the deep, nutrient-rich areas into the fold of tropholytic zone increase plankton biomass during summer dry month of June. No winter peak start was observed in December despite being dry month. Comparatively low amount of nutrients was indicated by low values of Alkalinity, TDS and Conductivity during December.

Secchi depth is generally a good indicator of chlorophyll-a concentration and reported to be negatively related to chlorophyll-a concentration (Almazan and Boyd, 1978). In Shahpur reservoir, when minimum Secchi depth was observed, the highest chlorophyll-a value was recorded. However secchi disk visibility may not always be acceptable as an index of high productivity as some regions are less turbid than others. In Shahpur

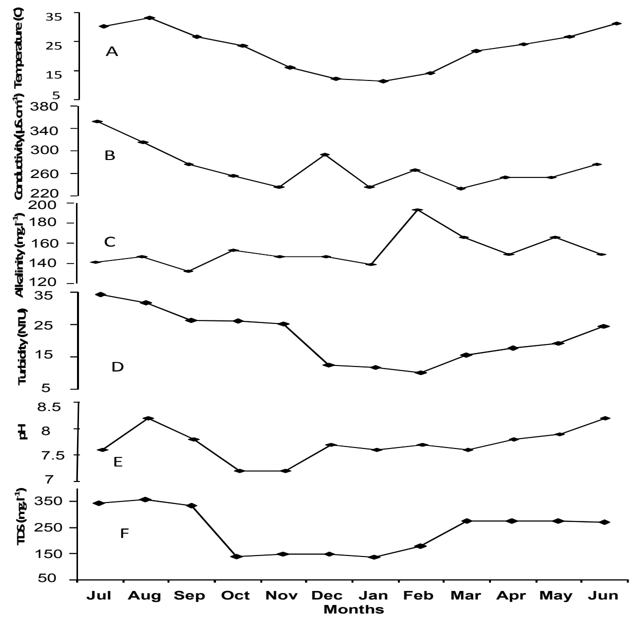
Reservoir, TSI (Chl-a) was found to be 59 and TSI (SD) was found to be 74. TSI value greater than 50 is usually associated with eutophy or high productivity (Table 4). Håkanson and Boulion (2001) derived another trophic classification of lakes based on fixed steps (a factor of 10) of mean summer chlorophyll-a concentrations ($\mu g.l^{-1}$). When applied to Shahpur Dam value TSI value was 57.61 also showing eutrophy (Table 4)

For lakes and reservoirs that have a few rooted aquatic plants and little non-algal turbidity, the TSI (SD) and TSI (Chl-a) are approximately the same (Carlson and Simpson, 1996). For Shahpur Dam, TSI (SD) was found to be 74. But TSI (SD) is only applicable to those lakes or reservoirs where turbidity is only because of algal biomass (Jayasinghe *et al.*, 2005). Here in this case, there was not any significant statistical relationship between chlorophyll-a and turbidity which means that non algal turbidity was also present. Many factors are known to influence Secchi depth including primary production, the amount of resuspended material and the amount of coloured matter in the lake. Secchi depth do not depend solely on autochthonous lake production but also very much on allochthonous influences and resuspension (Håkanson and Boulion, 2001). So it is not correct to classify Shahpur reservoir as eutrophic on basis of secchi depth measurements. Same difference between TSI (SD) and TSI (Chl) values has been found for Sri Lankan reservoirs and TSI (Chl) has been found to be a reliable means for quantifying trophic state at least for fisheries management purposes (Jayasinghe *et al.*, 2005).

Although conductivity and TDS values for Shahpur Dam are high enough to support productivity but they do not show any significant relationship with chlorophyll-a and can not be used for prediction of productivity (Table 3). However, MEIt appears to have significant relationship with both chlorophyll-a ($P < 0.001$)

Figure 1 Location of Shahpur Dam reservoir in the region

Figure 2. Monthly mean values of Surface Temperature (A), Conductivity (B), Alkalinity (C), Turbidity (D), pH (E) and TDS (F) in Shahpur Dam reservoir from July 2001 to June 2002



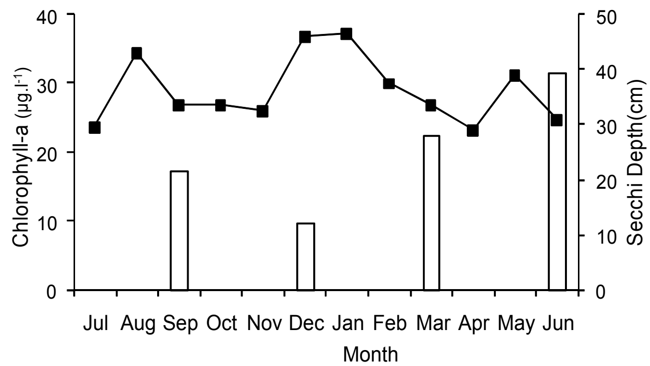


Figure 3. Monthly mean values of Secchi Depth (Line) and seasonal vales of Chorophyll-a (Bars) in Shahpur Dam reservoir from July 2001 to June 2002

and secchi depth ($P < 0.05$). Morpho-edaphic. Index has been used as universally accepted predictive model for deep lakes and reservoirs in temperate regions (Rawson, 1952; Ryder, 1982; Hanson and Leggette, 1982). In contrast to temperate waters, no universally accepted single indicator has been advocated as predictor of lake productivity in tropical and subtropical waters. However, MEI has been found to be a strong predictor of fish yield in Randenigabe Lake in Sri Lanka (Sreenivasan and Thayaparan, 1983) and in Shahpur Dam reservoir (Janjua *et al.* 2008).

Shahpur reservoir can be characterized as eutrophic on the basis of Chlorophyll-a concentration. It is observed that MEIt is significantly correlated with chlorophyll-a concentration in Shahpur reservoir. Although chlorophyll-a would probably be better.

Table 1: List of phytoplanktons genera found in different seasons in shahpur dam

Genera	September	Dec.	March	June
Anabaena sp.	+	+		+
Aphanothece sp.	+			+
Binuclearia sp.	+			+
Chlamydomonas sp.	+	+	+	+
Chlorella sp.	+	+		
Chlorococcum		+	+	
Chroococcus sp.		+		
Closteriopsis sp.	+		+	+
Closterium sp.			+	+
Coleochaete sp.	+			
Desmidium sp.				+
Gloeotrichia sp.	+	+	+	+
Gonatozygon			+	
Lyngbya sp.			+	+
Microcystis sp.	+	+	+	+
Microspora sp.		+		
Navicula sp.	+	+	+	
Nitzschia sp.		+	+	
Nostoc sp.	+			+
Oedogonium sp.	+	+	+	+
Oscillatoria sp.	+		+	+
Pediastrum sp.				
Phormidium sp.	+	+	+	+
Rhizoclonium sp.			+	
Rhopalodia sp	+		+	+
Schroederia sp.			+	+
Sphaerozosma sp.				+
Spirogyra sp.	+	+	+	+
Spirulina sp.	+			+
Tetraedron sp.			+	+
Tetraspora sp.			+	+
Tribonema			+	
Ulothrix sp.		+	+	
Volvox sp.	+	+		+
Xenococcus sp.	+		+	

Table 2: Physical and chemical characteristics of Shahpur Dam reservoir during 2001-2002.

Factor	Mini.	Maxi.	Mean
Total Storage (m^3)	10473672	17564520	14546106
Pond Area (ha)	260.32	299.19	283.40
Mean Depth (m)	4.03	5.87	5.11
Air Temperature (°C)	5.9	40.1	23.9
Surface Temperature (°C)	11.35	33.20	22.58
Turbidity(NTU)	10.25	34.35	21.47
pH	7.20	8.20	7.71
Dissolved Oxygen ($mg.l^{l}$)	4.50	10.63	7.68
Alkalinity ($mg.l^{-1}$)	132	194	154
Conductivity ($\mu S.cm^{-1}$)	232	353	270
TDS ($mg.l^{-1}$)	138	358	240
Secchi Depth(cm)	29	47	36
Chlorophyll-a ($\mu g.^{-1}$)	9.70	31.30	20.17
MEI a	22.56	39.64	30.89
MEI t	24.47	67.44	47.69
MEI c	42.33	68.60	53.10
TSI (SD)	70.79	77.45	74.42
TSI (Chl-a)	52.88	64.38	59.23

Table 3. Correlation matrix between different water quality parameters and MEI of Shahpur dam

	Mean Temp	Turbidity	pH	Condu-ctivity	TDS	Alkalinity	Chl-a	Secchi Depth
Secchi Depth	- 0.815**	-0.671*	0.024	-0.270	-0.619*	-0.004	-0.861**	-
Chl-a	0.864**	0.550	0.706*	-0.388	0.521	0.297	-	-0.861**
MEIa	-0.044	-0.392	0.267	-0.392	0.031	0.760**	0.752*	-0.178
MEIt	0.804**	0.322	0.755**	0.359	0.899***	0.028	0.906***	-0.622*
MEIc	0.559	0.309	0.516	0.457	0.391	0.130	0.709*	-0.333

$^{***}P < 0.001$ $^{**}P < 0.01$ $^{*}P < 0.05$

Table 4. Relations between TSI values, Chlorophyll-a and lake attributes

Carlson and Simpson (1996)		Håkanson and Boulion (2001)		Attributes
TSI (Chl)	Chl-a ($\mu g.l^{-1}$)	TSI (Chl)	Chl-a ($\mu g.l^{-1}$)	
<40	<0.95–2.6	≤25	≤ 1	Oligotrophy
40–50	2.6–7.3	≤50	≤ 10	Mesotrophy
50–70	7.3–56	≤75	≤ 100	Eutrophy
70–80	56–155	≤100	≤ 1000	Hypereutrophy
>80	>155			Over-Hypereutrophy

indicator of productivity, in absence of chlorophyll-a data MEI could be used as practical potential tool to estimate productivity for fisheries management purpose in the reservoir

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