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Trophic State Index, Morphoedaphic index and fish yield prediction in a sub-tropical lake, Manchar (Sindh), Pakistan

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Abstract
Limnological factors of a sub-tropical lake Manchar were studied on seasonal basis. The mean values of various parameters were: Transparency (secchi disc reading): 90.5 cm, Orthophosphate: 0.257 mg/l, TDS: 3310.5 mg/l, Conductivity: 5232 μs/l, Total Chlorophyll (Planktonic): 31.3 μg/l, Planktonic biomass: 5466 μg/l. Trophic state index (TSI) was calculated by using Carlson's (1977) equations. Mean TSI for transparency was 61, while for orthophosphate and chlorophyll, it was 82 and 64 respectively. TSI values indicate advanced eutrophic state of Manchar Lake. Morphoedaphic index (MEI) was also calculated on seasonal basis. The mean values were, TDS: 1103, conductivity: 1744, alkalinity: 60, transparency: 29 and biomass (plankton dry weight): 1746. Fish yield prediction for Manchar Lake (Z = 3m, mean area = 100 km^2) was calculated by using MEI values. The results were quite different among various parameters. Conductivity (89.1mt/y), biomass (67.6 mt/y) and TDS (44.6 mt/y) were found to be good predictors of fish yield. Chlorophyll, transparency and alkalinity values gave very low estimate.

Key words: TSI, MI, Fish yield, Lake

Introduction

Manchar Lake is a floodplain natural lake located at a distance of about 18 km from Sehwan town of district Dadu (Sindh), at longitude 67°-34' E to 67°- 43' E and latitude 26°-23' to 26°-28' N. It is a vast natural depression flanked by Kheerthar mountains in the west Lakhi hills in south and the River Indus in the east. On the north and north-eastern side runs a protective embankment. The lake is saucer shaped depression, about 2.5-3.5 m deep. Its surface area varies between 60-200 km^2, depending upon rains and entry of flood water from Indus river.

The term trophic refers to the level of nutrients which affect the primary productivity of lake (Naurasam 1919). Naurasam (1921) while working on Swedish lakes proposed the concept "Trophic state", based on such studies resulted into typical classification of (a) Oligotrophic (unproductive) and (b) Eutrophic (productive) lakes (Parma, 1980, Horn and Goldman, 1994). Carlson (1977) proposed the concept of "Trophic State Index", based on estimation of key environmental factors such as sechii

depth, chlorophyll and phosphorus. This index gives a numerical rating (on a scale of 0-100) to the degree of eutrophication in lake.

Morphoedaphic index was first calculated by Ryder (1965) for temperate lakes. Latter Welcommi *et al.* (1976) used MEI for some African lakes. Oglesby (1976) developed a model for prediction of fish yield by using MEI. Other workers also used various models for this purpose. Liang *et al.* (1981), Hansen and Lagget (1982), Jenkins (1982), Srunvassam (1992), Hassan and Middendrop (1998) and Hassan *et al.* (1999) used secchi disc readings for calculation of MEI and fish yield prediction in Oxbow lakes of Bangladesh.

The data of limnological factors was recently recorded (2001-2003) for Manchar lake. This study was carried out during the period of drought, when the main source of water for the lake was a drain carrying hyposaline water. Parameters such as TSI, MEI and fish yield prediction have been calculated for the first time on any lake in Pakistan.

Materials and methods

Various limnological parameters were recorded from five stations of Manchar Lake, during the study period (2001-2003). Temperature and secchi disc readings were recorded in the field. Surface water samples were brought to the laboratory for estimation of various parameters. Methods of APHA (1981) were followed for the analysis of water.

Trophic State Index

TSI was calculated according to the method of Carlson (1977). The equations were simplified into a computer program. Mean values of three parameters: transparency (secchi disc), orthophosphate and total chlorophyll were used for calculation of TSI.

Equations

1. TSI (SD) = 10 (6 – In SD/In2)

   or

   TSI (Secchi Disc) = (10 × (6 – (In (SD)/In (2))))
2. TSI (Orthoph) = 10 (6 – In 48 /Orthoph/ In 2)

   or

   TSI (Orthoph) = (10 × (6 – ((In 948 /TP)) / In (2))))
3. TSI (Chl.) = 10 (6 – 0.68 In Chl./ In2)

   or

   TSI (Chl.) = (10 × (6 – ((2.04 – 0.68 × In (Chl.)) / (In (2))))

Morphoedaphic index (MEI) was calculated as proposed by Oglesby (1977a) in its simplest form:

$$\frac{\text{Total dissolved solids (TDS)}}{\text{Z (mean depth of lake in m)}}$$

In present study TDS was replaced by other parameters (conductivity, alkalinity, chlorophyll and plankton biomass) as well to see the variation. Fish yield prediction was calculated by using following two models, developed by Oglesby (1977b).

1. Log yf (g dry weight/m^2/y) = -1.92 + 1.7 log Chl.
2. Log yfc (g carbon/m2/y) = - 2.81 + 1.47 log X (X = MEI)

Various values of MEI calculated for Manchar Lake were replaced in above equation to see the difference in fish yield prediction.

Results

Limnological factors

Seasonal fluctuations in various limnological parameters are shown in Table 1. These variations reflect the effect of sunlight, rain, flood water and organic processes in biotic components of lakes. Correlation co-efficient for some factors are as under:

1. Chlorophyll – Secchi Disc:
   Manchar Lake = Log Chl. = 3.58 – 1.10 Log SD (n = 12, r = 0.55)
   Carlson's equation = In SD = 2.04 – 0.68 In Chl.
2. Orthophosphate – Planktonic biomass:
   Manchar Lake = Log Orthophos = 13.25 – 5.52 Log biomass (n = 12, r = 0.9)
   Carlson's equation = Not considered
3. Orthophosphate – Chlorophyll:
   Manchar Lake = Log Chl. = - 0.25 + 1.19 Log Orthophos (n = 12, r = 0.9)
   Carlson's equation =In Chl. = 1.449 – 244 In TP

Trophic State Index (TSI)

TSI calculated on seasonal basis is shown in Table 2. Mean TSI for secchi disc reading (transparency) was 61, while for Orthophosphate it was 83 and for Chlorophyll it was 64. These values indicate the higher trophic state of Manchar Lake.

Morphoedaphic Index (MEI)

MEI was calculated seasonally for Manchar Lake by using four limnological features (Table 3). MEI for TDS, conductivity and plankton (biomass) was quite high while for alkalinity and transparency (secchi depth), it was very low.

Fish yield prediction

Fish yield prediction was calculated by using mean values of MEI (Table 4). TDS, Conductivity and Planktonic biomass gave a higher fish yield as compared to chlorophyll, alkalinity and transparency of water. Fish yield was calculated in metric tons, considering the mean surface area of lake as 100 km^2.

Table1. Seasonal variation in some limnological parameters of Manchar lake

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean**	**±STD**
Temperature (°C)	17	19.2	25.2	29.2	32.6	32	31.8	34.2	28.4	24.6	18.8	18	25.916 67	± 6.3391
Transparency (cm)	106	67	134	106	105	89	65	56	73	63	116	106	90.5	± 25.101
Orthophosphat e (mg/l)	0.178	0.18	0.264	0.274	0.314	0.37	0.366	0.264	0.372	0.272	0.108	0.122	0.257	± 0.0926
Alkalinity (mg/l)	240.8	213.4	141	146.2	155.8	186.2	184.8	215	173.8	158.4	160	221.8	183.1	± 32.869
TDS (mg/l)	2963.2	4486	3588.6	3677	3825.4	4865.6	3216	2996.6	3072.2	2239	2270.2	2526.2	3310.5	± 820.60
Conductivity (μS/l)	4712	6410	5608	5782	5978	7896	5388	4840	4956	3612	3674	3932	5232.333	± 1234.0
Hardness (mg/l)	753.75	812	833.75	835	900.25	946.25	906	744.5	701	625	655	700	784.375	± 103.97
Chlorophyll (mg/m^3)	30.11	32.3	19.65	30.77	32.66	33.21	23.25	28.34	33.07	37.89	34.15	40.96	31.3633 3	± 5.7637
Plankton (Dry weight, ug/l)	5500	4900	6900	4400	6900	7700	7200	7400	6100	4600	1900	2100	5466.66 7.	± 1965.8

Table 2. Seasonal fluctuation in TSI

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean**	**±STDV**
Transparency (cm)	59	65	55	59	59	61	66	68	64	66	57	59	61.5	± 4.145
Orthophosphate (mg/l)	78	79	84	85	87	89	89	84	89	85	71	73	82.75	± 6.166
Chlorophyll (mg/m^3)	64	64.7	59.8	64.2	64.8	64.9	61.4	63.4	64.9	66.2	65.2	67	64.2	± 2.055

(Oligotrophic, TSI=<40; Mesotrophic, TSI 40-50; Eutrophic, TSI= 60-80; Hypereutrophic, TSI =>80, After Carlson, 1977)

Table 3. Seasonal fluctuation in MEI

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean**	**±STDV**
TDS	978	1495	1196	1225	1275	1621	1072	998	1024	746	756	842	1102.33	± 273.84
Conductivity	1570	2136	1869	1927	1992	2632	1796	1613	1652	1204	1224	1310	1743.75	± 411.40
Alkalinity	80	71	47	48	51	62	61	71	57	52	53	73	60.5	± 10.991
Transparency	35	22	44	35	35	29	21	18	24	21	38	35	29.75	± 8.3462
Plankton	1833	1633	2300	1466	2300	2566	2400	1.566	2033	1533	633	700	1746.91	± 804.26

Table 4. Predicated fish yield calculated from MEI of various environmental factors of Manchar lake (mean surface area = 100 km^2)

S. No.	Parameters	Yfc=(gc/m^2/y)	Yf=(g/m^2 /y)	Fish yield (mt/y)
1	Total dissolved solids (TDS)	44.66	446	44.6
2	Conductivity	89.12	891	89.1
3	Alkalinity	1.57	15	1.5
4	Chlorophyll	8.7	87	8.7
5	Transparency	4.57	45	4.5
6	Planktonic biomass	67.6	676	67.6

Yfc=fish yield/y in grms carbon. Yf=yfc×10=g/m^2/y (Oglesbys 1977)

Discussion

Understanding of lake ecosystem is a prerequisite for proper management of fisheries. Interrelation of factors such as temperature and nutrients with primary and secondary productivity gives a clear insight into the working of food web (Dillon and Riher 1974, Kalff 1983, Lewis 1986). Lake productivity is usually referred in terms of chlorophyll-a and total phosphorus (Wetzel 1983). In lake Manchar, the orthophosphate was found to be on higher side (mean 0.257 mg/l). This indicates hypertonic condition (Bayly and Prather 2003). Total chlorophyll content was also high (31.3 μm/l) in this lake. When orthophosphate and chlorophyll values were compared a very good correlation was obtained (r = 0.9). This agrees well with Carlson's (1977) results. There is some controversy regarding the relationship of chlorophyll and secchi depth readings (Lorenzen 1980, Megard *et al.* 1980). In Manchar Lake this correlation was poor (r = 0.55). Carlson's (1980) described similar values for four different lakes in USA. In another study Randolph and Wilham (1984) reported Chl. – SD relation (r = 0.41) in lake Carl Blackwell of USA. Chl. – SD relationship, whether it is linear or scattered can vary from lake to lake, depending upon environmental conditions. Manchar is a shallow lake (Z = 3m) receiving turbid water from Indus River during summer monsoon. Silt and detritus particles can interfere with light penetration (Edvenondson 1980, Lorenzen 1980). Sigee (2005) stated that if N/P ratio (Redfield ratio) is > 10 in any lake, the phosphorus can act as a limiting factor. N/P ratio in Manchar Lake was found to have a mean value of 8.3, which shows the enrichment of water with phosphorus. This increased phosphorus loading increases the primary productivity resulting into eutrophication. Increase in chlorophyll content of water is also linked with conductivity (Oglesby 1977a). Lower N/P ratio also favors the increase in abundance of Cynophyceae in tropical waters (Sigee, 2005). Similar interaction has been observed in Manchar Lake. In such conditions, blue green algae make up the nitrogen deficiency by fixing atmospheric nitrogen (Schindler 1977).

Trophic state index (Carlson 1977) calculated for Lake Manchar shows seasonal variation. The mean values for Orthophosphate (83), Chlorophyll (64) and secchi depth (61) were different from each other. Recently Janjua *et al.* (2005) reported a TSI value of 76.15 based on secchi depth in Shahpur dam reservoir, Islamabad, Pakistan. Earlier

there was some criticism regarding the validity of Carlson's TSI (Lorenzen 1980, Megard *et al.* 1980) the reason being the light attenuation by monoalgal particles in water. Carlson (1980) replied to these objections and concluded that more research is needed in lakes of temperate and tropical regions, regarding the relation of chlorophyll to transparency of water. Aizaki *et al.* (1981) while working on Japanese lakes also stressed the need for modification in Carlson's equation and scale of TSI. In shallow Manchar Lake there is the possibility of wind stirred sediments affecting light penetration as suggested by Carlson (1980).

Morphoedaphic index (MEI) proposed initially by Ryder (1961) was latter used for prediction of fish yield in lakes (Ryder, 1965, Wellcom *et al.* 1976), Oglesby 1977b). In Manchar Lake, seasonal changes in MEI were calculated by using various environmental parameters. The mean values of MEI were used for calculation of fish yield prediction according to Oglesby (1977b). MEI from conductivity and planktonic biomass were found to be good predictors, but chlorophyll and transparency gave very low estimates of fish yield. The MEI model (Ryder *et al.* 1974) has been applied on very few tropical and sub-tropical water bodies (Sreenavasen 1972, Gunapati 1973, Ganf 1974, Sreenavasen 1992) was unable to find a significant relation between MEI and fish yield in some Indian reservoirs. It is needed that more studies should be conducted on other water bodies of tropical region. Only then generalised models can be developed.

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