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The physico-chemical environment and the plankton of managed ponds in Haryana, India

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Abstract. An investigation was made of the physical, chemical conditions of the water and substrate of nursery-cum-research-cum-rearing-cum-stocking ponds at Central Inland Fisheries Research Institute, Karnal. Temperature, pH, CO_2, dissolved oxygen, chloride, phosphate, alkalinity, nitrates, organic matter, total solids, turbidity, electric conductivity, nitrogen, P_2O_5, sand, silt, clay, $CaCO_3$, etc. were measured monthly. Statistical analysis of these factors showed some significant correlations. The phyto- and zooplankton were also sampled and the seasonal changes in abundance recorded.

Keywords. Plankton; physico-chemical properties; substrate; pond; phyto-plankton; zooplankton.

1. Introduction

Early attempts to explain lentic plankton communities attempted to relate the biota to a variety of water quality parameters e.g. Noland (1925) and Ward (1940). The distribution of certain species were correlated with pH (Carter 1971; Sprules 1975; Sharma 1981), salinity (Moore 1952; LaBarbera and Kilham 1974; Singhal and DattaGupta 1980; Yoshioka 1982), temperature (Vijayraghavan 1969; Vasisht and Sharma 1975), or dissolved oxygen (Hutchinson 1975). However, most species have rather broad tolerance ranges and, correlations with physico-chemical parameters have little predictive value except at extreme ranges (Macan 1961; Yongue *et al* 1973; Moore 1978; Bamforth 1980).

In India, pond ecology has been studied by Ganapati (1943), Alikunhi *et al* (1955), Moitra and Mukherji (1972), Badola and Singh (1981), Dobriyal and Singh (1981) and Singh *et al* (1982), but these studies were restricted to one season of the year. More detailed studies were carried out by Vasisht and Sharma (1975) on a typical urban pond in Ambala (Haryana), Mathew (1975) on Govindgarh lake, Rewa, Madhya Pradesh, Khan and Siddiqui (1977) on perennial fish ponds in Aligarh (UP), and Sharma (1980) in Kumaun lakes. There is thus very little information available on the ecology of plankton in managed ponds of Haryana and this study is an attempt to partially rectify this deficiency.

2. Material and methods

2.1 *Study area*

The study was conducted during 1982 and 1983 at Karnal. Karnal is situated on the southern bank of the Yamuna Canal at 29°45'N lat. and 77°0'E long. in the Karnal district of Haryana State, approximately 252 m above sea level.

The climate of Karnal is more or less tropical with only 3 seasons—winter, summer and rainy. The winter season starts in November, whereas, the summer and rainy seasons begin in March and July, respectively. The minimum and maximum temperatures, and average annual rainfall in the area are 3·2°C, 41·2°C and 210 mm.

The total area of the farm of the Central Inland Fisheries Research Institute, Karnal is 1·3 ha with a water surface of 1·09 ha. There are 5 stocking ponds each with an area of 0·1 to 0·23 ha and mean depth of 1·0 m. There are also 7 nursery ponds and two rearing ponds. Each nursery pond measures 0·02 ha with an average depth of 0·06 m and each rearing pond has an area of 0·07 ha with an average depth of 0·8 m. The stocking ponds at Karnal have a perennial source of water supply through a feeder channel from the main western Yamuna canal. The nursery and rearing ponds are seasonal and receive water supply through an inlet from a tubewell. There are no drainage channels. Water is pumped out of the ponds during the early winter months to permit clearing.

The bottom of the ponds is covered with alluvium. The aquatic macrophytic flora in the study ponds is not rich and is restricted to a depth of 0·2 m. The benthos consists of Oligocheta, Mollusca, Insecta and Nematehelminthes.

2.2 *Analysis of physico-chemical properties*

The conductivity, water temperature, pH, free carbon dioxide, dissolved oxygen, chlorides, alkalinity, total solids, turbidity, nitrates, phosphates and organic matter were recorded weekly using standard methods (APHA 1971). Characteristics of the substrate such as pH, organic contents, available N_2, available P_2O_5, total N_2, total P_2O_5, sand, silt, clay and $CaCO_3$ were recorded every 3 months from four 15–20 cm deep samples taken from the bottom of the ponds with an Ekman dredge. These analyses were also carried out using standard methods (APHA 1971). Monthly plankton samples were collected with Freshwater Biological Association standard conical bolting silk plankton-nets (70 meshes/cm) with a 30·5 cm diameter mouth from 14 (5 stocking, 7 nursery and 2 rearing) ponds. As no significant differences were found between the ponds, data from only one is presented as representative of all the ponds. Vertical hauls were taken and the plankters identified to genus, counted using a Sidgewick Rafter Counting cell and categorized as abundant, common, rare or accidental. Plankters which made up more than 50% of the total were classified as abundant; those making up less than 50% but more than 15% were classified as common; those making up less than 15% as rare; and those recorded only occasionally were classified as accidental.

3. Results

3.1 *Temperature*

Water temperature varied from 12·5° (January) to 38·5°C (July through September) (table 1), with the rapid decrease in water temperature in November indicating the start of winter. The average difference between air and water temperatures was 5 C.

3.2 *pH, free carbon dioxide and dissolved oxygen*

The pH of the water in all the ponds ranged from 7·3 in February to 8·2 in May and readings taken 1 cm above the substrate surface showed no differences from those

Table 1. Monthly mean readings of the physico-chemical parameters measured in a pond at Central Inland Fisheries Research Institute, Karnal.

Months	Water Temperature (°C)	pH	Free CO_2 (ppm)	Dissolved oxygen (ppm)	Chlorides (ppm)	Alkalinity (ppm)	Total solids (ppm)	Turbidity (ppm)	Nitrates (ppm)	Phosphates (ppm)	Organic matter (ppm)
August, 1982	31·0	8·0	6·10	6·00	9·2	129·0	140	48·0	0·16	0·48	0·12
September	31·5	7·8	6·70	8·75	8·6	134·0	136	65·2	0·17	0·49	0·16
October	28·5	8·0	7·04	8·25	10·3	138·0	800	67·5	0·21	0·56	0·17
November	20·5	7·7	7·03	13·25	14·2	138·0	902	63·2	0·19	0·52	0·13
December	15·5	7·4	6·80	8·95	16·0	139·0	1003	58·2	0·18	0·41	0·14
January, 1983	12·5	7·4	5·00	9·98	20·0	139·2	1088	35·5	0·13	0·38	0·12
February	16·5	7·8	3·00	10·59	22·0	139·4	1106	34·8	0·11	0·45	0·15
March	30·0	8·2	0·00	18·25	33·00	141·0	1498	20·1	0·05	0·42	0·07
April	30·0	8·0	2·10	8·15	38·0	143·0	1552	15·0	0·00	0·20	0·00
May	30·0	8·2	3·30	11·08	33·0	144·2	1430	30·2	0·08	0·35	0·09
June	27·8	8·0	5·40	5·90	32·0	148·0	1398	30·1	0·11	0·38	0·01
July	38·5	8·0	5·90	5·44	31·0	109·0	1200	60·2	0·15	0·45	0·12

taken in the surface water. Free carbon dioxide varied between 0·0 (March) and 7·04 ppm (October). The dissolved oxygen concentration ranged from 3·15 (March) to 18·25 ppm (April) (table 1).

3.3 *Chlorides, phosphates and alkalinity*

The chloride and phosphate concentrations ranged from 8·6–38·0 ppm and 0·30–0·55 ppm, respectively. The maximum chloride concentration was recorded in April and minimum in September. Alkalinity showed no seasonal trends and varied between 108 (July) and 146 ppm (June).

3.4 *Nitrates and organic matter*

Nitrate concentration in the ponds varies between 0 and 0·21 ppm and the organic matter varied between 0·0 (April) and 0·17 ppm (October). Particulate organic matter concentrations were sometimes less than the concentration of dissolved organic matter.

3.5 *Total solids and turbidity*

Total solids showed little variations ranging from 134 (September) to 1552 ppm (April). Turbidity ranged from 15·0 (April) to 67·5 ppm (October).

3.6 *Chemical composition of the substrate*

The organic content of the pond substrate is largely colloidal (humus) and varied between 0·031% (March) and 1·282% (October) (table 2). The pH varied from 7·0 (August and March) to 7·2 (January). The electric conductivity range was from 0·23–0·44 mmh/cm.

Available nitrogen and P_2O_5 varied from 21·38–38·98 mg/100 g and 2·36–10·35 mg/100 g, respectively. Available N_2 was recorded maximum in October and minimum in April. However, total N_2 was reported to be maximum (0·760 mg/100 g) in December and minimum (0·084 m/100 g) in April, whereas available P_2O_5 was found to be maximum in October and minimum in March (table 2).

The percentage sand, silt and clay of the dried soil of the ponds showed little variation, ranging from 32–44%, 25–30% and 26–38%, respectively. The percent values of $CaCO_3$ in the substrate varied between 5·5 in July and 14·5 in December.

3.7 *Correlation and regression*

Data on the measured physico-chemical properties of the water and substrate were analyzed to determine whether correlations occurred between parameters. The correlation matrix of physico-chemical properties of water indicated that water temperature is significantly positively correlated to atmospheric temperature

Table 2. Monthly mean readings of the physico-chemical properties of the substrates measured in a pond at Central Inland Fisheries Research Institute, Karnal.

Months	Electric conductivity mmh/cm	pH	Organic content (%)	Available N_2 (mg/100g)	Available P_2O_5 (mg/100g)	Total N_2 (mg/100g)	Sand (%)	Silt (%)	Clay (%)	$CaCO_3$ (%)
August	0·44	7·0	1·121	26·98	4·21	0·098	36	27	29	8·5
September	0·43	7·1	1·213	31·28	9·90	0·154	36	28	31	9·1
October	0·23	7·0	1·282	38·98	10·35	0·531	35	29	30	8·9
November	0·35	7·1	1·101	33·10	10·12	0·632	33	29	34	10·8
December	0·29	7·1	0·980	34·30	9·82	0·760	32	30	38	14·5
January, 1983	0·41	7·2	0·781	30·10	10·22	0·562	32	30	38	14·5
February	0·28	7·1	0·098	25·12	7·98	0·403	39	30	38	14·5
March	0·36	7·0	0·031	24·24	2·36	0·092	42	30	38	12·5
April	0·30	7·0	0·987	21·38	4·21	0·084	44	26	34	5·5
May	0·28	7·1	1·212	26·21	6·31	0·097	44	25	26	5·5
June	0·39	7·2	1·501	30·10	7·21	0·154	43	25	26	5·5
July	0·42	7·0	0·923	28·40	8·28	0·098	42	26	26	5·5

($r = 0{\cdot}941$; $P > 0{\cdot}01$), and is negatively correlated with dissolved oxygen concentrations ($r = 0{\cdot}713$; $P > 0{\cdot}05$). Excepting for the positive correlation with water temperature, pH exhibited no other significant (positive or negative) correlations. Free CO_2 is negatively correlated to chlorides and total solids and positively correlated to turbidity, nitrates, phosphates and organic matter. Chlorides are significantly negatively correlated with turbidity, nitrates, phosphates and organic matter; and positively correlated to total solids. Total solids in the ponds are positively correlated with turbidity, nitrates, phosphates and organic matter.

The correlation matrix for the substrate parameters shows several significant correlations. Electric conductivity is negatively correlated with pH ($r = -0{\cdot}589$) and the organic content is positively correlated with available N_2 and negatively correlated with silt, clay and $CaCO_3$.

There is a positive significant correlation between available N_2, available P_2O_5, and total N_2 but is negatively correlated with sand. The available P_2O_5 is negatively correlated with total N_2 and sand while total N_2 has a positive correlation with silt and $CaCO_3$, and a negative correlation with sand.

The data on the physico-chemical properties of the water and the substrate were also statistically analyzed for simple regressions.

The mean values of the physico-chemical properties of the water and the substrate were also used in multiple regression analysis (tables 3 and 4).

3.8 *Biological features*

Table 5 contains the names of the various phytoplankton and zooplankton recorded in the ponds. *Chlamydomonas*, *Chlorogonium* (Protozoa: Mastigophora) and *Peridinium* are abundant in the ponds almost throughout the year whereas many species of Algae, Protozoa, Rotifera and Copepoda (table 5) are commonly found in the warmer months of the year. On the basis of the number of different plankters occurring in the ponds at different parts of the year they are categorized as abundant, common, rare and accidental (table 5). The fishes which are stocked and cultured in the ponds include *Catla catla*, *Labeo rohita*, *L. calbasu*, *Cirrhinus mrigala*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella* and *Cyprinus carpio*. In addition to these fishes, the other fishes which are cultured and found in the study ponds in different months are *Ophiocephalus*, *Mystus sor*, *M. scanghala*, *M. tengara*, *Barbus* and *Wallago attu*.

4. Discussion

The physico-chemical properties of water are important determinants of an aquatic ecosystem although they are greatly influenced and modified by climate and riparian vegetation (Hutchinson 1975). The nursery-cum-research-cum-stocking ponds of Central Inland Fisheries Research Institute, Karnal exhibit some similarity in terms of some of their physical and chemical properties of the water and substrate with other water bodies in Haryana but differ appreciably in terms of others. Sharma (1981) reached a similar conclusion in his earlier work on the two natural tanks of Kurukshetra and Jyotisar.

The fluctuations in water temperature in the ponds at Karnal are almost identical

Table 3. Significant ($p > 0{\cdot}01$) multiple regressions for the physico-chemical parameters of the water from a pond at Central Inland Fisheries Research Institute, Karnal.

Dependent variables	Values of A	Independent variables (X)	Values of R
Water temperature	144·460	X_1 - pH X_2 - Turbidity X_3 - Dissolved oxygen X_4 - Alkalinity X_5 - Carbon dioxide	0·916
pH	6·811	X_1 - Air temperature X_2 - Water temperature X_3 - Chlorides X_4 - Total solids	0·816
Turbidity	−15·333	X_1 - Water X_2 - Free carbon dioxide X_3 - Nitrates X_4 - Phosphates X_5 - Organic matter	0·975
Phosphate	0·309	X_1 - Carbon dioxide X_2 - Turbidity X_3 - Nitrate X_4 - Organic matter	0·921
Free carbon	4·076	X_1 - Turbidity X_2 - Nitrates X_3 - Phosphates X_4 - Organic matter	0·974
Total solids	−697·317	X_1 - pH X_2 - Dissolved oxygen X_3 - Chlorides X_4 - Alkalinity	0·925
Organic matter	0·336	X_1 - Carbon dioxide X_2 - Dissolved oxygen X_3 - Turbidity X_4 - Nitrates X_5 - Phosphates	0·923

with those reported by Sharma (1981) in the natural tanks at Jyotisar and a similar range of temperature ($11 \pm 1{\cdot}32 \pm 1$°C) was recorded by Das and Srivastava (1956), George (1966) and Vasisht and Sharma (1975). Alikunhi *et al* (1955) reported a small variation of water temperature from 29°C to 37·2°C in the ponds at Cuttack, Orissa; Chacko and Krishnamurthy (1954) found the range from 34·2–42·8°C in their ponds in Madras and Vijayraghavan (1969) reported the range of water temperature from a minimum of 25°C to a maximum of 34°C in a natural pond at Madurai.

The major physico-chemical features at Karnal were the alternation between the dry season high concentrations and the relatively lower wet season concentrations of major chemicals. This fluctuation is caused by the annual rainfall being restricted to a few contiguous months, coupled with a high evaporation rate. The pond water was alkaline throughout the period of study and the pH also had a narrow range. An almost similar range of variation in pH ($7{\cdot}4 \pm 1{\cdot}9{\cdot}0 \pm 1$) has been recorded by Das and Srivastava (1956), Moitra and Bhowmick (1968), Nayar (1970) and Sharma (1981). It was generally

Table 4. Significant ($p > 0.01$) multiple regressions for the physico-chemical parameters of the substrate from a pond at Central Inland Fisheries Research Institute, Karnal.

Dependent variables (Y)	Values of A	Independent variables (X)	Values of R
Available nitrogen	−1·272	X_1 – Organic content X_2 – Available P_2O_5 X_3 – Total nitrogen X_4 – Silt X_5 – $CaCO_3$	0·877
Available P_2O_5	670·860	X_1 – pH X_2 – Organic content X_3 – Available nitrogen X_4 – Total nitrogen X_5 – Silt	0·866
Total nitrogen	2·306	X_1 – pH X_2 – Available P_2O_5 X_3 – Silt X_4 – Clay X_5 – $CaCO_3$	0·889
Clay	68·839	X_1 – pH X_2 – Total nitrogen X_3 – Silt X_4 – $CaCO_3$	0·822
Silt	16·226	X_1 – Available nitrogen X_2 – Available P_2O_5 X_3 – Total nitrogen X_4 – Clay X_5 – $CaCO_3$	0·955
Calcium carbonate	−114·263	X_1 – pH X_2 – Total nitrogen X_3 – Silt X_4 – Clay	0·975

seen that the higher pH values in the ponds at Karnal coincided with the periods of greater photosynthetic activity which received support from the relationship between the estimation of dissolved oxygen content and pH. Vasisht and Sharma (1975) also reported that a high pH value always coincided with phytoplankton abundance peaks in the ponds they studied.

The dissolved oxygen content showed numerous fluctuations throughout the period of study in each pond. The highest peaks of dissolved oxygen in each pond at Karnal were recorded during winter, when colder water has a greater capacity for holding dissolved gases (Hutchinson 1975). The depletion of oxygen content which occurred in August could be attributed to low photosynthetic activity or respiratory activity of heterotrophic organisms overbalancing the photosynthetic production of oxygen. The concentration of free CO_2 was not dependent upon temperature but was low when the aquatic vegetation was fully developed and was high when the ponds were flooded with rain water. In contrast, Singh *et al* (1982) reported that the concentration of free CO_2 was low when the water temperature of river Nayar was also low. The increase in the values of specific conductivity during summer could be attributed to rise in temperature and decrease in water level due to evaporation. The significant correlation between

Table 5. Seasonal abundance of the zoo- and phyto-plankton collected from a pond at Central Inland Fisheries Research Institute, Karnal.

Planktons	Abundant	Common	Rare	Accidental
Cynophyceae				
Agmenellurin	—	—	—	×
Holopedia	—	—	×	—
Gomphosphaeria	—	×	—	—
Anacystis	—	—	—	×
Spirulina	—	×	—	—
Coccochloris	—	—	×	—
Anabaena	—	—	×	—
Oscillatoria	—	—	×	—
Bacillariaceae				
Cyclotella	—	—	—	×
Coscinodiscus	—	—	—	×
Helosira	—	—	—	×
Synedra	—	—	×	—
Diatoma	—	—	×	—
Pleurosigma	—	×	—	—
Navicula	—	×	—	—
Amphora	—	×	—	—
Chlorophyceae				
Netrium	—	×	—	—
Closterium	—	×	—	—
Closteridium	—	×	—	—
Cosmerium	—	×	—	—
Micrasterias	—	—	×	—
Spirogyra	—	—	×	—
Scenedesmus	—	—	—	×
Selenastrum	—	—	×	—
Pediastrum	—	×	—	—
Actinastrum	—	—	×	—
Tetraedron	—	—	×	—
Mastigophora				
Chlamydomonas	×	—	—	—
Trachelomonas	—	×	—	—
Euglena	—	×	—	—
Chlorogonium	×	—	—	—
Phacus	—	—	—	×
Dinoflagellates				
Peridinium	×	—	—	—
Rotifers				
Trichocerca	—	—	×	—
Synchaeta	—	—	×	—
Brachionus	—	×	—	—
Pedalion	—	×	—	—
Filinia	—	×	—	—
Asplanchna	—	×	—	—
Keratella	—	×	—	—
Cladocera				
Ceriodaphnia	—	—	×	—
Copepoda				
Cyclops	—	—	×	—
Liaptomus	—	×	—	—
Nauplius	—	×	—	—
Ostracoda	—	—	×	—

alkalinity, specific conductivity and temperature further confirms this finding. Increases in alkalinity due to evaporation of water have been recorded previously (Hazelwood and Parker 1961) but the marked decline during the rainy months in the ponds at Karnal were probably due to dilution. Similar observation of decrease in methyl orange alkalinity (bicarbonate) and electrical conductivity due to rain water or the influx of flood water has also been reported elsewhere (Sreenivasan *et al* 1964) who also reported a positive correlation between the electric conductivity and the bicarbonate alkalinity of hypolimnetic water. Moreover, the specific conductance which also indicates ion concentration has been reported to be closely related to total alkalinity (Hem 1959).

Dunn (1962) while differentiating the trophic levels of Danish lakes classified the lakes having conductivity greater than 200 μmm/cm as clearly eutrophic and those with values less than 200 μmmh/cm as oligotrophic. If Dunn's criterion is applied to the ponds at Karnal their conductivity values which range between 451 and 1560 μmmh/cm falls would categorize them as highly eutrophic. Moyle (1946) suggested 40 ppm of alkalinity as a natural separation point between soft and hard water in which case the water in the ponds at Karnal would be classified as hard.

Very few reports on the occurrence of plankton from ponds in Haryana are available for comparison. Sharma (1981) recorded the abundance of Cladocera, Copepoda and Rotifera from unmanaged ponds in Kurukshetra during the winter months of November through March. Vasisht and Sharma (1978) only recorded the abundance of the Rotifera from ponds in Ambala for two months (February, March). These authors also found Cyanophyceae, Chlorophyceae, Protozoa, Rotifera, Cladocera and Copepoda commonly present in managed ponds at Karnal throughout the year except for January but only *Chlamydomonas*, *Chlorogonium* and *Peridinium* were abundant from November through March.

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