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Influence of Phosphorus on Phytoplankton Diversity in a Shallow Eutrophic Reservoir

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Abstract

Seasonal changes in the algal diversity with respect to phosphorus load from sewage and dyeing effluent in a small eutrophic reservoir was investigated for a year with monthly samplings. An increase in phytoplankton count was observed (R^2 = 0. 6) with rise in Phosphate concentrations. Maximum algal diversity (Shannon & Simpsons diversity indices, richness, and evenness) was observed during summer, April to July, when phosphate concentrations were at moderate level (0.074-0.163 mgL^{-1}). Excessive phosphate influx (1.060-1.170 mgL^{-1}) during rainy season, September to November, caused blooms of nonheterocystous assemblage of desmids, particularly of *Cosmarium sp* and myxophycean species, and a general decrease in algal diversity indices was observed.

Introduction

The importance of phosphorus (P) availability for phytoplankton growth is well established in many freshwater reservoirs and lakes (Jordan & Bender 1973; Schelske et al. 1974; Habib et al. 1997; Calijuri & Dos Santos 2001). Seasonal changes in phytoplankton community and numerical abundance in relation to the physicochemical parameters, particularly with P, occur in fresh water bodies, which signal the quality of the water. Hence, a study was made in Sulur tank with an area of 33.2 ha and volume of 0.506 m.cu.m, which is fed by Noyyal river originating from the Western ghats of South India, to observe the phytoplankton community as a bioindicator of the trophic status and health. In addition, to determine the seasonal succession of phytoplankton for the effective application of culture based fisheries. This tank is under the control of the town panchayat and regularly stocked by fingerlings of Indian major carps by the Sulur Fishermen Cooperative Society, Coimbatore (Tamil Nadu).

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Materials and Methods

Noyyal river receives large quantity of sewage effluent from Coimbatore city, having population of more than 30 lakh people, and the discharges from 180 dyeing and processing units located in the city (Fig. 1). It is reported that approximately 600 Megatonnes of garbage is being generated daily in Coimbatore Corporation. The river is also massively polluted by municipal wastes, soaps, and detergents from the Sulur town panchayat, which forms the chief sources of P to this tank. Frequent fish mortalities were observed during algal bloom season.

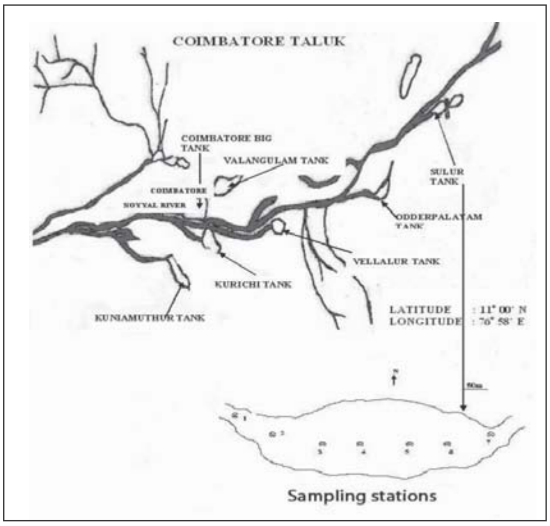

Figure 1. Map showing the Sulur tank location and sampling stations

Water samples were collected from surface waters at seven different places keeping equal distances. They were analyzed for available P as per the ascorbic acid method. Water, pH, alkalinity, and hardness were measured to observe major changes (APHA 1989).

Univariate analysis

The raw numerical abundance data for phytoplankton were collected from the samples. Analysis was performed to calculate species richness, diversity, and evenness index values using the PRIMER FIVE (Plymouth Routines in multivariate Ecological research) software package developed at the Plymouth laboratory, UK (Clarke & Warwick, 1994). Species richness was determined using Margaleff's index (d) that provides a measure of the number of species (S) present for a given number of individuals (N) according to the following equation:

$D = (S-1)/\log_2 N.$

Diversity index was calculated using the Shannon-Weiner (H') index:

$H' = \Sigma\, i\, pi\, (\log_2 pi)$, where pi is the proportion of the total count arising from the i^{th} species. Equitability, the evenness of the species distribution was determined using the Pielou's evenness index (J'):

J' = H' (observed) / H' max where H' max is the maximum possible diversity that could be achieved if all the species were equally abundant $= \log_2 (S)$

Simpsons diversity in the form of Δ° = 1-Σ I (Xi (Xi-10 N9N-1)
All above indices were determined using the diverse routine within the PRIMER software package.

Results

The total algal cells increased with the increase in P concentration considering all the sites combined (Fig.2).

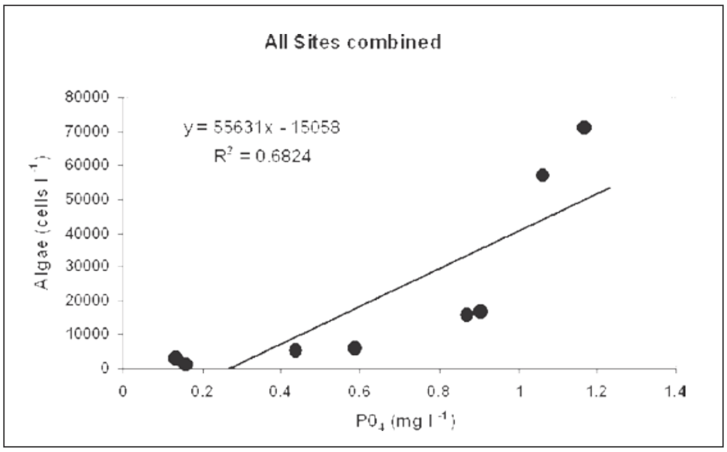

Figure 2. Correlation between phosphorus concentration and algal cells

The average concentration of available P increased from 0.159 mg L^{-1} (July) to 0.588 mg L^{-1} after a brief spell of rain in August. In proportion, plankton count raised from 1183 to 6046 Nos L^{-1}. During July and August only species of Chlorophyceae and Bacillariophyceae were present with scanty presence of *Microcystis sp*. A phenomenal increase in phytoplankton abundance comprising *Cosmarium sp* of Desmidaceae contributing 90% was observed, with little occurrence of other genera consequent to heavy rain, raising the P input to 1.06 mg L^{-1} during September (Fig. 3). In association with *Microcystis*, *Anabaena* and *Polycystis* also occurred. An apparent reduction in Bacillariophyceae and Chlorophyceae was also observed with the rise of desmidacean species *Cosmarium*, which eventually caused the bloom. When monsoon again brought a large quantity of sewage, the P level remained high (> 1.0 mg L^{-1}) even after dilution in October, November, and December. However, the highest record of plankton population (70884 Nos L^{-1}), of which the major count was represented by *Cosmarium sp*, induced dense algal bloom, covering the larger surface of the water during early monsoon in October, discolored the water and smelled obnoxious.

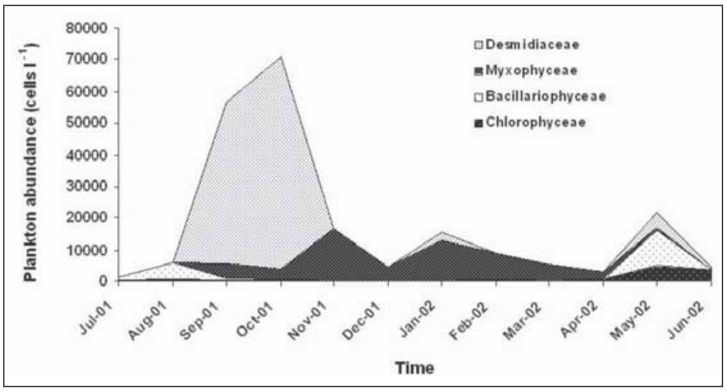

Figure 3. Plankton dynamics of Sulur tank.

A slight decrease in P shifted the algal diversity to *Spirulina sp* dominance in November, which persisted till March 2002 inspite of the P decline. However, with decreasing P concentration, the *Closterium sp* of Desmidiaceae and species of *Scenedesmus*, *Selenastrum*, and *Crucigenia* of Chlorophyceae appeared with declining total count. The P content registered 0.870 mg L^{-1} (January), 0.824 mg L^{-1} (February), and 0.437 mg L^{-1} (March) with corresponding plankton count of 10972, 7912, and 4712 NosL^{-1}, respectively. A further drop in P level (0.074 - 0.134 mg L^{-1}) during summer (April to June) reproduced algal spectrum, with representative species of Chlorophyceae and Bacillariophyceae. During June 2002, *Protococcus* sp appeared in the sample and were dominant (2596 Nos L^{-1}).

Water quality and algal indices

The entire period of study recorded alkaline pH (> 8.21). Surface temperature ranged from 25.9 to 30.5 ^{o}C. The highest conductivity value recorded was 5630 µmhos cm^{-1} in August before the monsoon set in and subsequently declined to 538 µmhos cm^{-1} immediately after monsoon by water dilution (Fig.4). The dissolved oxygen (D.O.) depleted to 2.26 mg L^{-1} at surface when *Spirulina* sp bloom occurred, and there was increase in D.O. in the subsequent months (January to March) and again

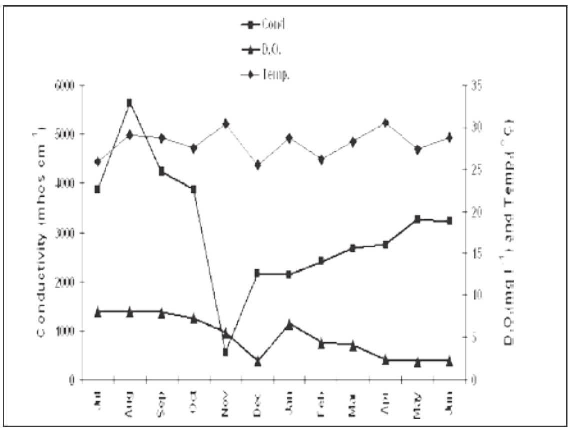

Figure 4. Physico-chemical qualities of water.

lowered to approximately 2.00 mgL^{-1} in summer.

The algal indices (Fig.5) (Shannon, Margalef and Simpson indices) were higher during summer and pre-monsoon (March to July) and during other periods they were lower indicating the later periods comprised of monospecies of Myxophyceae, which outcompeted other algae during that time when the water was in lentic condition.

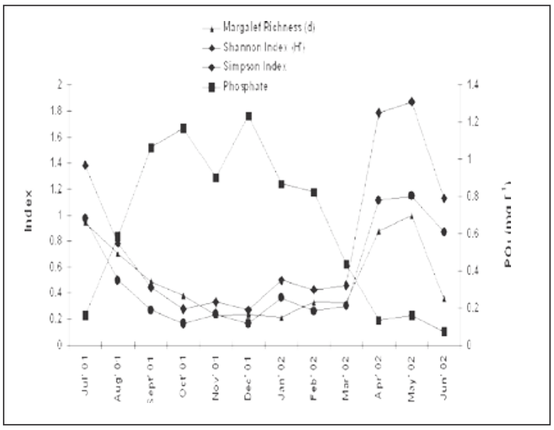

Figure 5. Algal indices and Phosphate concentration.

Discussion

Phosphorus supply is the principal determinant of phytoplankton standing crop and primary productivity in most lakes, a function modified by lake morphometry, light, lake depth, and other influences (Oglesby 1977; Ishida & Mitamura 1988). When it is further accompanied with high pH, increase in light, temperature, and stable water column, the blooms of blue green algae develop and it outcompetes other algae. It stimulated desmid assemblage and myxophycean blooms frequently and has been reported in P limiting freshwater systems (Schindler 1977; Habib et al 1997) and episodes of obnoxious blooms consequent to eutrophication have been recorded by many authors (Hecky & Kilham 1988; Anneville & Pelletier 2000; Bittencourt & Nascimento Moura 2001). The phytoplankton community of the fertilized lake was dominated by desmids, cryptophytes, and at times filamentous nonheterocystous cyanobacteria, *Lyngbya*, *Oscillatoria*, and *Pseudoanabaena* (Levine & Schindler 1989) indicating the role of phosphates in structuring phytoplankton communities in large mesocosms.

Pollution of the Sulur reservoir with anthropogenic phosphate input is the major problem, which caused desmids bloom during rainy season (September, October, & November). The continuous supply of P through sewage subsequently for three months has supported the Myxophyceae bloom and reduction of phosphate concentration during summer altered algal floristic composition. This clearly indicated that the phosphate flux was the principal factor forcing species change in this tank. In a hypertrophic water body due to fertilization recorded the Margalef index value ranging from 0.2 to 2.0 (Sigee 2005), whereas the index values of the present study also showed similar range. However, the intervention of nongovernmental organization based at Coimbatore reclaimed the reservoir from pollution by various management measures such as solid waste management by Effective Microbial technology, removal of encroachment in the river stretch, desilting, and removal of water hyacinth.

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