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MODELING THE PLANKTON DIVERSITY AND DYNAMICS IN A POLLUTED EUTROPHIC LAKE AT RANCHI

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ABSTRACT: Modeling plankton diversity and dynamics in a polluted eutrophic lake is quite complex especially with a constant influx of detergents and sewage material which continually changes the state variables and interferes with the assessment of the chemical rhythm occurring in polluted conditions as compared to unpolluted systems. Studies were conducted at Ranchi lake to understand the altered environmental dynamics in hyper-eutrophic conditions, and its impact on the plankton community. The lake was monitored regularly for ten years (2010 – 2020) and the data collected on the carbon flux, nitrates, phosphates and silicates was used to design a mass balance model for evaluating and predicting the system. The model was then used to correlate the chemical rhythm with that of the phytoplankton dynamics and diversity. Nitrates and phosphates were not limiting (mean nitrate and phosphate concentrations were 1.74 and 0.83 mgl-1 respectively). Free carbon dioxide was found to control the system and, interacting with other parameters determined the diversity and dynamics of the plankton community. N/P ratio determined which group of phytoplankton dominated the community, above 5 it favoured the growth of chlorophyceae while below 5 cyanobacteria dominates. TOC/TIC ratio determined the abundance. The overall system was controlled by the availability of free carbon dioxide which served as a limiting factor.

Key words: - plankton, modeling, diversity, total inorganic carbon, eutrophication

INTRODUCTION :

In our study we addressed the question how cultural eutrophication modifies the lake environment, and the diversity and dynamics of the plankton population. Studies were therefore conducted on a culturally eutrophicated lake, Ranchi lake, in order to assess the deterioration of water quality and the characteristics of the planktonic community with high nutrient regime.

Cultural eutrophication relates to the rapidly increasing amount of phosphorus and nitrogen normally present at relatively low concentrations (Vollenweider, 1968; Harper, 1992; Biggs, 2000; Wetzel, 2006). Phosphorus is considered to be the major cause of eutrophication, as it is a growth-limiting factor for algae in freshwaters.

At Ranchi lake the entry of nutrients was due to the daily input of detergents, and the influx of sewage water which includes organic content from surrounding areas. Our studies were concentrated on the estimation of the increase of nutrients due to the influx and its impact on the planktonic community. We studied the plankton community of the lake and its rhythm in this regime. Ranchi lake is a predominantly eutrophic lake with high nutrient content. We observed mean values concentration of various parameters at Ranchi lake, Ranchi.

MATERIAL AND METHODS:

Ranchi lake (Fig. 1) has an area of about 0.157km^2, a depth of about 6 metres. Unfortunately the lake has been accumulating a wide range of daily inputs (especially detergents), such that the water has become unfit for any reasonable use. Samples were collected once every month and were preserved in neutralized formalin and Lugol's iodine. Preserved samples were used for species identification and counting on a Sedgwick-Rafter cell at 10x and 45x magnification.

We used three types of indices for the study of the plankton community: the Shannon – Weaver diversity index (Shanon *et al.*, 1963; Azeiteiro *et al.*, 1999, 2000; Morgado *et al.*, 2003), the Bray – Curtis dissimilarity index (Bray et al., 1957; Curtis *et al.*, 1950), and the 'Importance Value Index' (IVI) (Jayatissa *et al.*, 2006).

Parameters such as temperature, light, pH, oxygen, carbon dioxde, inorganic carbon, nitrates, sulphates, phosphates, dissolved organic matter and BOD were monitored at regular monthly intervals. Chemical analysis of phosphates, nitrates, sulphates, DOM, BOD and COD was done using standard methods (APHA, 2006), (Table: 1).

RESULT:

There was an increase in the concentration of phosphates, nitrates, and total carbon as compared to the desirable levels. The values were 0.95mg l^{-1}, 1.75 mg l^{-1} and 7.59 mg l^{-1} respectively. Therefore there was an increase in all the nutrients. An analysis of the plankton constituents and its relationship with the chemical environment was studied in this regime.

Phytoplankton population:

The mean annual percentage of various classes of phytoplankters in descending order was as follows: Cyanobacteria 38% > Bacillariophyceae 27% > Chlorophyceae 22% > Chrysophyceae 9% and > Euglenophyceae 4%. Among these the cyanobacteria and bacillariophyceae forms the dominant members in these culturally eutrophic waters, indicating organic pollution (Fig. 2).

In general a bimodal peak is the usual pattern with a spring peak and an autumn peak occurring in February – March, and October – November respectively coinciding with peak nutrient availability. In our study we found the lake to be in constant bloom and shoots up thrice forming three peaks, one in the month of Jan-Feb, the second in the month of May and the third in Nov-Dec (Fig. 3).

An inverse relation was found between abundance and diversity; this is due to the fact that most of the abundance is related to the sudden profuse growth of a single species of either Cyanobacteria or Bacillariophyceae or chrysophyceae. At times a positive correlation between the concentration of nitrates and phosphates and the abundance of phytoplankton is exhibited instead of a negative relation because of the continuous entry of phosphates and inorganic carbon through the use of detergents, and nitrates and organic carbon from sewage material.

A close relation is found only in May and December. Species diversity calculated by the Shannon – Weaver diversity index. The graph shows the species diversity and annual abundance of the phytoplankton population. The maximum diversity attainable is 2.9 (Fig. 4). A significant negative relation occurs between abundance and diversity (Fig. 5).

The importance value index of various phytoplankton species was calculated at Ranchi lake, Ranchi. The IVI is maximum for *Gloeocapsa* and is minimum for *Chlorella* (Fig. 6). The phytoplankton communities of the three peaks were analyzed to assess the relative contribution of the various phytoplankters towards the bloom. Bray – Curtis community similarity analysis showed that each peak had four clusters (Fig. 7).

Zooplankton population:

The percentage of the various classes in a descending order are as follows Rotifera > Copepoda > Ostracoda > Branchiopoda. In comparison to the phytoplankton, the zooplankton population is lower by a factor of 1.77×10^2 (Fig. 8). The zooplankton population shows two peaks in the months of February and July, with a small peak in October. The abundance of zooplankton during the annual cycle oscillated with that of the phytoplankton but with a time lag (Fig. 9). There is a time lag of about a month between the phytoplankton and zootoplankton peaks. Interestingly, this time lag of 30-45 days represents the time taken by the zooplankton to develop from their eggs.

The regression calculated between the zooplankton and phytoplankton population with the introduction of a time lag gives a significant negative correlation ($r = -0.81; p < 0.01$) and is shown in Fig. 10. The correlation equation can be expressed as follows:.

$$\text{Phytoplankton (log nos } l^{-1}) = 0.884 \text{ zooplankton (log nos } l^{-1}) + 6.17 \quad \text{Eq. 1}$$

That is, the zooplankton peak alternates with the phytoplankton peak using a time lag sequence of about 30 to 45 days. The phytoplankton does not show any relation with nutrient availability but, the zooplankton shows a moderately significant negative correlation with phosphates ($r = -0.87; p < 0.01$), (Jeppesen et al. 2005). The correlation equation can be expressed as follows:

$$PO_4 \text{ (log mg } l^{-1}) = -0.6324 \text{ zooplankton (log nos } l^{-1}) + 1.8377 \quad \text{Eq. 2}$$

Species diversity is high in March and August. Maximum dominance is in July when *Brachionus* is found in great numbers and the minimum in June and September. Calculation of the Importance value index showed that the most dominant genera of zooplankton within the community were *Brachionus* and *Mesocyclops*, Cluster analysis of the zooplankton was done for the two peaks, February and July to assess the relative contribution of the various genera.

DISCUSSION:

Plankton species composition and abundance are functions of interactions with environmental conditions including salinity, temperature, light, nutrients, turbulence, and water depth in addition to grazing, competition, and disease. (Hutchinson *et al.*, 1947) stated that it is a well known fact that the total quantity of plankton present in the waters of a lake may undergo marked and rapid variation, so that in the course of a year a number of pulses may succeed each other.

The planktonic community rhythm at Ranchi lake shows a wide displacement from those occurring in natural unpolluted water bodies. Reports of annual planktonic rhythm and peak concentration for Indian fresh waters have been given by (Ganpati *et al.*, 1951; Chacko *et al.*, 1954; Das *et al.*, 1956; Das *et al.*, 1957 & 1959; and Michael, 1968). In general a bimodal peak (spring peak and monsoon peak) occurring in February – March and July – August respectively is the usual pattern in India. The spring peak is usually greater than the monsoon peak. However small scale departures usually occur due to specific changes. Michael (1968) reported a single but prolonged peak lasting from January to April. Similarly, (Mukherjee *et al.*, 1993) in their studies of a polluted pond reported a single peak of phytoplankton (other than cyanobacteria) from February to April while the cyanobacteria exhibited two peaks: one in June and the other in October – November.

The phytoplankton community at Ranchi lake shows a complete departure from normal conditions. The first three peaks in March, May and August are relatively small while, the November bloom is the highest and is contributed by all the phytoplankton groups. This is in contrast to normal conditions where the spring bloom is more important. *Microcystis* blooms are primarily warm-water phenomenon and the range for optimum growth is 28.8–30.5°C (Kruger *et al.*, 1978) especially in organically polluted waters. However in Ranchi lake the species shows peak abundance during November at a temperature of 22.8 °C. Ranchi lake with high concentration of organic matter thus show an abundance of *Microcystis and Gleocapsa* while the elevated concentrations of nitrates and phosphates favour the development of diatoms.

Juday et al., 1931 noted that such rises in the phytoplankton might occur without reducing the phosphate content of the water and that on occasions both phosphate and plankton might rise together. Statistical analysis of our data shows that there is little if any correlation between phytoplankton abundance and the concentration of phosphates and nitrates. Similarly, the bloom of cyanobacteria as well as the other plankters during November cannot be explained both on the basis of chemical and biotic analysis. Nutrients such as nitrates, phosphates, inorganic and organic carbon are comparatively high creating a discordant note in the normal planktonic rhythm and what combination of environmental parameters triggers this abnormal bloom is a matter of further research.

Berthon *et al.* (1966) states that the threshold level of N/P ratio for algae is greater than 7. When, the ratio falls below 5 the algae collapse giving way to the cyanobacteria. At Ranchi lake the N/P ratio remains above 5 from January to March, throughout the rest of the year it remains below 5. Thus from January to March we have a moderate abundance of chlorophyceae, chrysophyceae, bacillariophyceae and euglenophyceae but throughout the rest of the year cyanobacteria dominates when the N/P ratio is below 4.

Fig. 11 shows the N/P ratio and growth of phytoplankton at Ranchi lake. The N/P ratio controls the type of phytoplankton (low N/P ratio favors the growth of blue green algae i.e. Cyanobacteria and high N/P ratio favors the growth of green algae i.e. Chlorophyceae). This usually starts in the month of October.

Although the pattern is consistent with the boom-bust ecological characteristic (Sheil *et al.*, 2006) but, the timing of peaks in zooplankton diversity does not coincide with peaks in phytoplankton diversity as reported by Costelloe et al. (2005), rather it occurs with a time lag. This may be due to the grazing intensities of both the zooplankton and fishes and the time that most of the zooplankters require to develop.

CONCLUSION:

Thus we can build a model showing the annual planktonic rhythm of the lake and the lake can be considered to be eutrophic. An increase in the nutrient factor (nitrates & phosphates) favors the growth of the phytoplankton. The N/P ratio controls the type of phytoplankton; low N/P ratio favors the growth of blue green algae i.e. Cyanobacteria and high N/P ratio favors the growth of green algae i.e. Chlorophyceae. With the growth of the phytoplankton and their subsequent death the DOM increases and so does the BOD and COD load of the water body. The decomposition of organic matter releases free carbon dioxide and decreases the pH of the system. The increase in free carbon dioxide triggers a phytoplankton peak while its decrease initiates a trough giving rise to an annual rhythm. This is in turn modulated by the TIC/TOC ratio. As the phytoplankton concentration increases, free CO_2 decreases, followed by a decrease in the phytoplankton and the cycle continues. This is followed closely by the zooplankton with a time lag and shows a positive correlation with that of the phytoplankton.

A final aspect of the successional process in these eutrophic waters is the development of *Eichhornia crassipes* which started developing rapidly close to the completion of our study. When not controlled, water hyacinth covers lakes and ponds entirely; this dramatically impacts water flow, blocks sunlight from reaching native aquatic plants, and starves the water of oxygen, often killing fishes. The endpoint is generally the death of the lake or pond, being converted into a marshy habitat.

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