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Algal Assemblage Distribution as Related to Seasonal Fluctuations of Selected Metal Concentrations

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ABSTRACT

Seasonal variations of phytoplankton assemblages have been observed in a mildly eutrophic lake in northwestern Arkansas for six years. The data indicated that certain metal concentrations also varied seasonally. Sodium, potassium, calcium and magnesium ion concentrations, and phytoplankton composition and abundances were examined spatially and temporally. Four major algal blooms characterized the lake: a spring, a summer and an autumnal cyanophycean assemblage and a winter diatom-chrysophyte dominated population. Each metal concentration was inversely proportional to the abundance of the cyanophytes. The presence of the winter assemblage was accompanied by decreases in sodium, calcium and magnesium and increased levels of potassium. First and second order linear regression models were developed for each assemblage.

INTRODUCTION

While certain alkali metal and alkaline earth elements are known to be required for the growth of algae, the relationship of the concentration variations of these metals and algal assemblage fluctuations *in situ* is largely uninvestigated. The purpose of this investigation was to examine relationships between variations of natural algal assemblages and fluctuations of ion cencentrations throughout the year in Lake Fayetteville, Arkansas.

Lake Fayetteville is approximately 420 ha in size, with a maximum depth of 10.5 m, a mean depth of 4.3 m and an average volume of 3 x 10^6 m^3 of water. The lake is of a limestone, chert bed, with primary water input from springs, two vernal streams, and a limited runoff (Meyer, 1971). The lake is shown to have a constant source of chemical input, with a slow, constant overflow at the dam area. This research site was selected due to the previous investigations of Meyer (1971) which indicated that distinct fluctuations of algal populations occurred with regularity both seasonally and spatially in this lake.

MATERIALS AND METHODS

A single representative site was chosen for the investigation. Samples were collected weekly, from March, 1973, to February, 1974, at 1 m depth intervals from the surface to 10 m with a nonmetallic Kemmerer water bottle. Temperature and oxygen data were obtained *in situ* by the use of a YSI Model 54 oxygen meter. Water samples were retained briefly in 1 liter polyethylene bottles.

Samples were filtered within one hour of collection through Whatman GF/A glass fiber filters, and the water was stored at room temperature. Sodium, potassium, calcium, and magnesium determinations on filtered water samples were made with the Jarrell Ash Model 82-270 Atomic Absorption Spectrophotometer. Sodium, potassium, and magnesium samples required no pre-treatment. Calcium samples were pre-treated with lanthanum nitrate and concentrated hydrochloric acid (Lee, 1967).

Sample aliquots were fixed at the collection site with M^3 fixative (Meyer, 1971) immediately upon collection. This preservative maintains cytological detail, does not alter cell dimensions and allows for long storage times of samples at room temperature. Phytoplankton were identified and enumerated from 5 ml aliquots with the inverted microscope technique (Utermohl, 1958).

Standard curves and concentration determinations were calculated with the use of a Monroe 1860 calculator. Each standard curve had a linear regression goodness of fit greater than $r = 0.9930$. A linear regression model for the data was determined by the use of the stepwise procedure of the SAS statistical package with an IBM 370 computer (Barr, et al., 1976).

OBSERVATIONS

Observations are based on 528 samples taken between March, 1973, and February, 1974. All of the temporal and spatial data for the phytoplankton species and sodium, potassium, calcium and magnesium concentrations and other simultaneously collected parameters have been reported, tabulated and summarized by Rice (1974).

Algal abundance reflected the development of four major blooms during the year. An assemblage developed in May which was composed of a cyanophycean association dominated by *Aphanizomenon flos-aquae* Ralfs ex Born. et Flah., 1888 and *Coelosphaerium nagelianum* (Lemm.) Ung., 1910. Levels during this assemblage ranged from 2.90 x 10^8 to 8.77 x 10^8 cells/1. Peak abundance levels for the year were reached in mid-May with 8.77 x 10^8 cells/1.

A second major assemblage developed within a range of 1.52 x 10^8 to 4.11 x 10^8 cells/1 during July. This blue-green assemblage was dominated by *Aph. flos-aquae, Anabaena flos-aquae* Breb. ex Born. et Flah., 1888, *C. nagelianum* and *Oscillatoria limosa* Lemm., 1900. Near the end of July *Merismopedia trolleri* Bach., 1920 was added to the assemblage.

In October a third bloom developed. *Aph. flos-aquae, An. flos-aquae* and *Coe. nagelianum*, with occasional appearances of *Microcystis flos-aquae* (Wittr.) Kirch., 1900 and *Mer. trolleri*, reached abundance levels of from 1.47 x 10^8 to 4.17 x 10^8 cells/1.

Abundance levels declined rapidly with the development of the fourth major assemblage in November. Levels fell to a range of 2.80 to 9.21 x 10^6 cells/1. This was characterized by the development of a chrysophyte-cryptomonad assemblage characterized by *Chroomonas acuta* Utermohl, 1925 and *Cryptomonas erosa* Ehrbg., 1838. In December *Melosira granulata* (Ehrenb.) Ralfs *in* Pritchard, 1861, *Mallomonas akrokomos* Ruttn. *in* Pascher, 1913 and *Mallomonas caudata* Iwanoff em. Kreiger, 1932 formed a secondary assemblage within this abundance range.

Sodium concentrations ranged from 1.88 to 4.60 mg/1 throughout the year. Depletion of sodium was noted in late May when the concentrations ranged between 1.88 and 2.77 mg/1. Following an accumulation, sodium concentrations again declined to 2.51 to 2.99 mg/1 during July. A second accumlation period was abbreviated by a decline of sodium concentrations during October. This minimum ranged from 3.84 to 3.97 mg/1. A rapid depletion of sodium occurred at the end of November throughout the lake. The resulting range of 2.56 to 3.93 mg/1 gradually declined to 2.42 to 2.54 mg/1, where the concentrations remained for the rest of the investigation.

Potassium concentrations were generally characterized as being stable with a trend toward increasing concentrations in the summer, followed by a decline in the autumn and an increase in the early winter. Levels ranged from a minimum of 1.00 to a maximum of 7.42 mg/1 throughout the year. In May a period of depletion developed with values from 1.60 to 1.92 mg/1. Homogeneous concentrations were from 2.02 to 2.68 mg/1 in July. Levels declined to between 1.69 and 1.94 mg/1 in October. Concentrations of potassium markedly increased to a range of 3.60 to 3.84 mg/1 in November. These levels persisted through the end of the year.

Calcium concentrations were generally higher in the spring, declined during the summer regime and returned to high levels in the autumnal bloom prior to a precipitous decline with the onset of winter. Concentraitons decreased to a range of 11.00 to 19.80 mg/1 in the epilimnion and a range of 20.40 to 25.50 mg/1 in the hypolimnion. A second decrease in calcium was observed in July resulting in a range of from 14.50 to 19.30 mg/1. October calcium levels were nearly homogeneous in a range of from 25.76 to 26.19 mg/1. A drastic reduction of this ion occurred, dropping levels to 15.10 mg/1 throughout the water column. Continued lowering of concentrations occurred through December to a range of 13.69 to 15.95 mg/1.

A trend of magnesium concentration accumulation with an autumnal decline of concentrations was noted. The annual spread was from 1.27 to 2.10 mg/1. A rapid accumulation of the ion occurred in May to a range of 1.82 to 1.90 mg/1. July concentrations were from 1.57 to 1.68 mg/1 and in October they were from 1.63 to 1.79 mg/1. Concentrations fell to an average of 1.44 mg/1 in November. These lower concentrations were characteristic of the winter conditions.

DISCUSSION

Similarities in the three cyanophycean blooms were evident. *Aph. flos-aquae* and *Coe. nagelianum* comprised the dominate algae in the spring bloom and were also important species in the July and October assemblages. *Ana. flos-aquae, Mer. trolleri,* and *Osc. limosa* were added to the July assemblage, but in the autumnal bloom *Osc. limosa* was absent, while *Mic. flos-aquae* was evident.

During the spring blue-green bloom, levels of all ions decreased in concentration. This trend was observed in association with the July assemblage with the exception of stable potassium concentrations. Trends of decreasing ion concentrations were again noted in conjunction with the autumnal assemblage. This indicated a definite requirement of all metals under investigation by the blue-green algae.

Utilizing a linear regression model developed for each assemblage, spring abundance levels were found to be best predicted by the calcium concentration, interactions of temperature with both sodium and calcium and the interactions of oxygen with sodium, calcium and magnesium ions. The summer assemblage abundance levels were predicted by the interactions of temperature and magnesium concentrations and the interaction of potassium and calcium levels. Abundance of autumnal algae was found to be the result of the interactions of temperature with potassium, interaction of oxygen and potassium and calcium ion interaction. Differences in the models were evident. These differences were associated with variations in assemblage composition. The addition of *Osc. limosa, Ana. flos-aquae* and *Mer. trolleri* to the summer assemblage caused a shift in ion requirements. The subsequent replacement of *Osc. limosa* by *Mic. flos-aquae* also appeared to cause a further change in the linear model. Of interest is that sodium is a major parameter associated with the spring *Aph. flos-aquae* and *Coe. nagelianum* assemblage but is less important in the summer and autumnal assemblages.

The winter assemblage consisted of *Chr. acuta, Cry. erosa, Mel. granulata* and *Mal. caudata* and was accompanied by lowered levels of sodium, calcium and magnesium concentrations and increased levels of potassium ions in the water column. The linear regression model developed for the chrysophyte-diatom assemblage indicated abundance levels to be a result of the interactions of temperature with potassium and calcium, interaction of oxygen with magnesium and the interaction of calcium with potassium and a second order interaction of calcium. This suggests that the changes in calcium, magnesium and potassium were associated with the development of the assemblage, but that sodium concentration decreases were due to other factors.

Removing the limitation of individual blooms, a first and second order regression model was developed for the site, without regard to depth or populational differences. The resulting model indicated that the annual cycle of algal abundance was influenced by the following parameters: oxygen, sodium, temperature and calcium; temperature and potassium interaction and a second order temperature interaction; oxygen interaction with sodium and magnesium and second order interactions of oxygen; calcium interaction with magnesium and second order interaction of calcium; and second order interaction of sodium. This model indicates that sodium, potassium, calcium, and magnesium ions are required nutrients for the algae present in Lake Fayetteville.

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