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Phytoplankton Biomass and Water Column Temperature Dynamics of Lake James, NC USA

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Abstract: Phytoplankton biomass and water column temperature dynamics of Lake James, NC were studied between 1997 and 1999. Continuous water temperature data showed that thermal stratification starts in late March and breakdowns in early November in Lake James. At 2 m phytoplankton biomass dynamics were mostly seasonal, being high in the fall and spring and low in the summer. The hypolimnetic biomass was the lowest and the least influenced by the temperature dynamics. The only layer in which the biomass responded to the oscillations of the water temperature was metalimnion. The biomass in this layer usually increased after periodic oscillations of the water temperature.

Key words: Lake James, epilimnion, metalimnion, hypolimnion, temperature oscillation

INTRODUCTION

Aquatic systems are subject to high spatial and temporal variability in terms of physical and chemical environmental factors. As a result of this variability the relative abundance and species composition of planktonic organisms are frequently reorganized[1].

Phytoplankton community structure dynamics driven by turbulence and environmental variability have been emphasized by many authors[2-4]. In general, research on phytoplankton community dynamics considers the physical instability of the water column to be the main factor controlling the changes in species composition and abundance.

Most temperate lakes are very sensitive to wind induced mixing in the early spring when temperature-density structure is poorly established. As the season progresses, resistance to mixing increases and wind becomes a less effective external force because of greater density gradients[5]. However, partial non-seasonal mixing can occur in poorly stratified lakes. Partial mixing may not extend to the bottom, but usually includes plankton habitat in most lakes[6].

The severity of a disturbance on the plankton habitat and the time elapsed since the last major disturbance can play a primary role in establishing, at any given time, the species composition, biomass and productivity of a lake[7,8].

The time series of vertical temperature profiles can be used to summarize both the stability and the turbulent mixing of the water column in lakes and reservoirs. Abrupt changes of thermal stratification cut downs the successional processes by entraining the nutrient-rich water from the deeper layers. This in turn may result in higher primary production because under stable conditions the growth of certain species can be limited by the scarcity of nutrients[2].

There has been enormous amount of research on phytoplankton biomass in lakes and reservoirs[4,9,10], but there still exists the need for studies dealing with the dynamics of physical factors that control the vertical distribution of phytoplankton in deep lakes. The purpose of this study was to determine the relationships between the vertical distribution of phytoplankton biomass and the dynamics of water column temperature in Lake James, NC USA.

MATERIALS AND METHODS

Lake James (Fig. 1) is located in North Carolina at latitude 35°44' and longitude 81°55'. The lake is formed by the impoundment of three-headwater streams. These streams are Catawba River, Paddy's Creek and Linville River, each being separately dammed to form one interconnected lake. The lake has an average depth of 25 m and the maximum depth of the lake is 35 m. The lake has a total area of 26 square km. The lake is 21 km long and has a width varying from 0.4 to 3.2 km.

Daily average temperature profiles were collected using Onset@ Tidbit thermistors at deepest point of the

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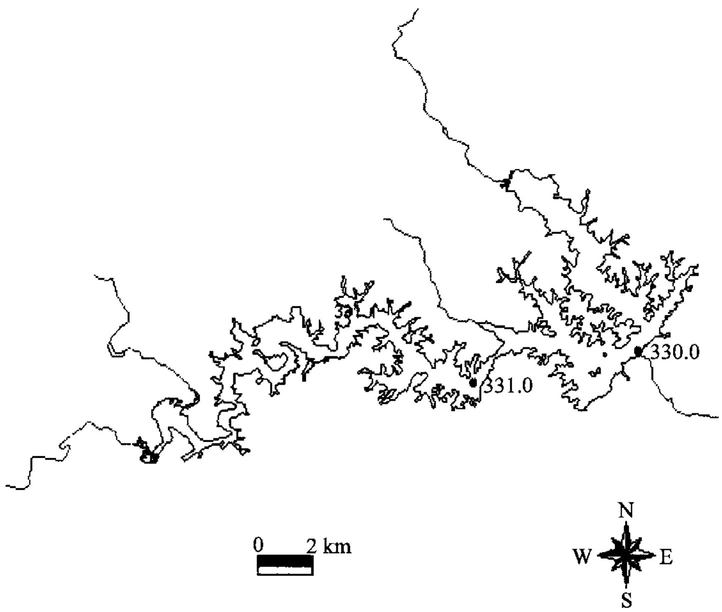

Fig. 1: The Map of Lake James, NC

lake (Fig. 1). Three thermistors were deployed at 2, 10 and 30 m depths between 1997 and 1999.

Phytoplankton samples were taken from the same station and the same depths using a Kemmerer bottle. Samples were placed in 250 mL dark bottles and fixed with M3 solution[11]. Samples were analyzed using Palmer-Maloney plankton counting cell with phase-contrast illumination and a water immersion lens on a compound microscope. Algal cells were identified and counted by making horizontal transects across the slide at predetermined intervals on the slide stage.

Cell volume of each species was calculated by measuring average dimensions and approximating the geometric shapes that most closely resemble the species[12]. All individuals in a sub sample were sized using an ocular micrometer and their volume was calculated in cubic microns per liter. Biovolume was converted to biomass, assuming specific gravity of one[13].

A data set of 30 was used to determine the correlation coefficients between the number of oscillations and the biomass dynamics using SAS statistical software[14].

RESULTS

Continuous water temperature data showed that thermal stratification starts in late March and breakdowns in early November in Lake James. The lake is isothermal between December and early March.

At 2 m there were frequent oscillations in the water temperature throughout the study period showing that this layer was mixing continuously. At 30 m there were no apparent oscillations in the water temperature, except when the lake was isothermal (Fig. 2a-c).

At 10 m temperature oscillated several times in April and August 1997 (Fig. 2a). In 1998 there were few oscillations in April, May, June and August at the same depth (Fig. 2b). In 1999 10 m temperature oscillated a number of times in March and May then no abrupt changes were observed until August (Fig. 2c).

Phytoplankton biomass at 2 m was quite low (about 0.5 mg L^{-1}) in the summer, but was relatively high (about 1 mg L^{-1}) in the spring and fall of 1997. At 10 m the biomass had two peaks of 2.4 and 2.7 mg L^{-1} in April and August 1997, respectively (Fig. 2d). At 30 m the biomass was quite low (about 0.2 mg L^{-1}) throughout the study period. In 1998, phytoplankton biomass at 2 m decreased from 1 mg L^{-1} in January to 0.5 mg L^{-1} in August then went up to 1.2 mg L^{-1} in December. At 10 m the biomass increased from 0.8 mg L^{-1} in January to 2.4 mg L^{-1} in April then dropped to 1.5 mg L^{-1} in May and then reached 3.5 mg L^{-1} in August, gradually decreasing to 0.9 mg L^{-1} thereafter (Fig. 2e). In 1999 at 2 m, the biomass decreased from 1.4 mg L^{-1} in February to 0.6 mg L^{-1} in August. At 10 m, the biomass increased from 0.7 mg L^{-1} in January to 2.9 mg L^{-1} in April then gradually decreased to 2 mg L^{-1} in August (Fig. 2f).

The correlation coefficients (R) between the number of oscillations in water temperature and biomass were 0.15 for 2 m, 0.49 for 10 m and 0.02 for 30 m, respectively during the summer stratification. The same coefficients were 0.1 for 2 m, 0.08 for 10 m and 0.04 for 30 m, respectively when the lake was not thermally stratified.

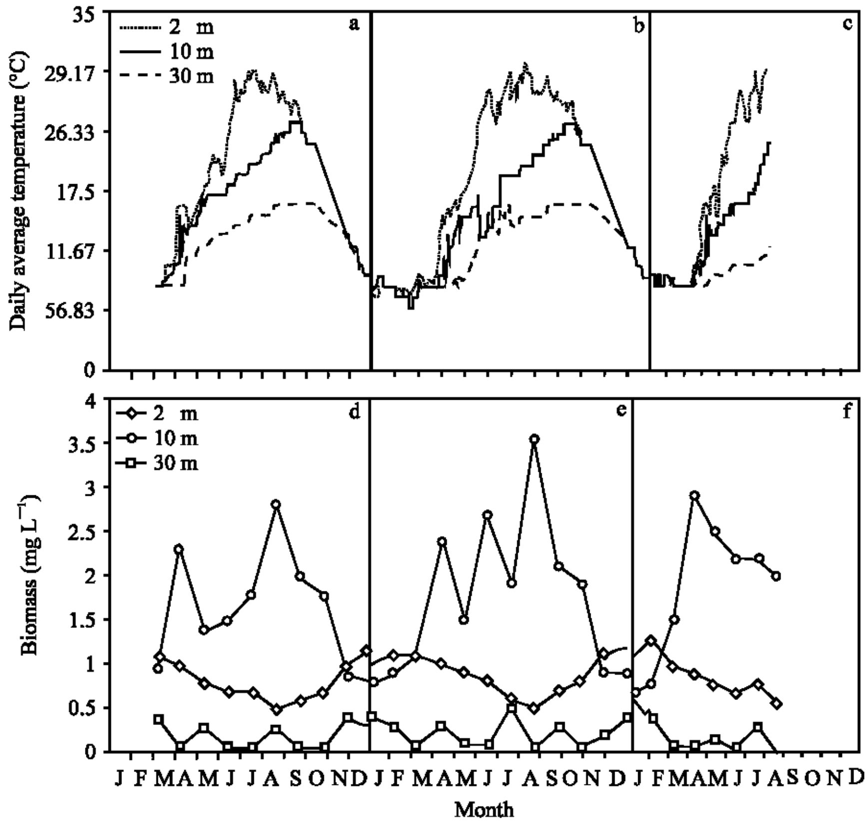

Fig. 2a: Daily average temperature at 2, 10 and 30 m in 1997
b: Daily average temperature at 2, 10 and 30 m in 1998
c: Daily average temperature at 2, 10 and 30 m in 1999
d: Phytoplankton biomass at 2, 10 and 30 m in 1997
e: Phytoplankton biomass at 2, 10 and 30 m in 1998
f: Phytoplankton biomass at 2, 10 and 30 m in 1999

DISCUSSION

The phytoplankton biomass dynamics at 2 m of Lake James seemed to be rather seasonal, being relatively high in the spring and fall and low in the summer between 1997 and 1999. The oscillations of the water temperature did not seem to be effective at controlling the biomass dynamics in this layer (R=0.15 during stratification and 0.1 during the winter). This might be due to the fact that this layer is usually quite dynamic and mixes almost constantly. The biomass dynamics in this layer is probably controlled by the seasonal variations of environmental factors rather than being controlled by the non-seasonal stochastic perturbations.

The biomass at 30 m seemed to be affected the least by the thermal structure dynamics (R=0.02 during the stratification and 0.04 during the winter mixing). This was probably because there were no oscillations in the water temperature at this depth when the lake was stratified throughout the study period. Water temperature at this depth oscillated only in the wintertime when the lake was isothermal. The phytoplankton biomass at bottom of Lake James is more likely to be light limited rather than being controlled by physical perturbations. Goldman[15] reported that the ability of most phytoplankton to grow was dependent on adequate light intensity. The average Secchi Disc depth for Lake James lake is about 4 m, which means that there is either very little or no light at 30 m.

The only layer in which the biomass was responsive to the periodic oscillations of the water temperature was metalimnion (R=0.49 during thermal stratification and 0.08 during the winter mixing period). If the individual oscillation periods of the metalimnetic temperature and the biomass patterns are examined closely, it can be clearly seen that nearly after each of the oscillation event that was either strong or perpetuated longer, the biomass somehow increased either in the same or the following month.

Harris[16] states that when large environmental changes occur rapidly, community changes are likewise large, but there may be a considerable lag (up to 2 weeks) before total biomass returns to its capacity and characteristic assemblages establish. Lake James phytoplankton biomass and water column temperature dynamics seem to validate the above statement. For instance, in April and August 1997 there were several oscillations at 10 m in the temperature and the biomass peaked in the same month. Similar cases were common during the study period, such as in April, May and June 1998 and 1999.

When temperature did not oscillate for a month or longer, the biomass tended to decline. For example, from June to July 1997 temperature did not oscillate and the biomass declined during that time.

In conclusion, present data show that during summer stratification if the thermal structure of the deeper layers is perturbed, phytoplankton biomass usually increases. If the stable conditions persist for a couple of weeks or longer, phytoplankton biomass tends to decline.

Finally, further research in this direction is needed to elucidate the relationships between water temperature oscillations and phytoplankton biomass dynamics in stratified deep lakes. Phytoplankton should be sampled at finer intervals (ranging from daily to weekly) to match temperature oscillations and the response of plankton. Longer sampling intervals are likely to miss the response of planktonic assemblages to the periodic oscillation events due to their short life cycle.

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REFERENCES

1. Richerson, P., R. Armstrong and C.R. Goldman, 1970. Contemporaneous disequilibrium, a new hypothesis to explain the Paradox of Plankton. Proceedings of Natl. Acad. Sci., 67: 1710-1714.
2. Harris, G.P., 1983. Mixed layer physics and phytoplankton populations: Studies in equilibrium and non-equilibrium ecology. Progress in Phycol. Res., 2: 1-52.
3. Fee, E.J., J.A. Shearer, E.R. DeBruyn and E.U. Schindler, 1992. Effects of lake size of phytoplankton photosynthesis. Canadian J. Fisheries and Aquatic Sci., 49: 2445-2459.
4. Gaedeke, A. and U. Sommer, 1986. The influence of the frequency of periodic disturbances on the maintenance of phytoplankton diversity. Oecologia, 71: 25-28.
5. Monismith, S.G., 1985. Wind-forced motions in stratified lakes and their effect on mixed-layer shear. Limnology and Oceanography, 30: 771-783.
6. Lewis, W.M., 1978. The thermal regime of Lake Lanao (Phillippines) and its theoretical implications for tropical lakes. Limnology and Oceanography, 18: 200-217.
7. Carpenter, S.L., J.F. Kitchell and J.R. Hodgoson, 1987. Regulation of lake primary productivity by food web structure. Ecology, 68: 1863-1876.
8. Reynolds, C.S., 1984. Phytoplankton periodicity: The interactions of form, function and environmental variablility. Freshwater Biol., 14: 111-142.
9. Sommer, U., 1991. Phytoplankton: Directional Succession and Forced Cycles. Springer Verlag: Berlin.
10. Reynolds, C.S. 1994. The long, the short and the stalled: on the attributes of phytoplankton selected by physical mixing in lakes and rivers. Hydrobiologia, 289: 9-21.
11. APHA., 1995. American Public Health Association: Standard Methods for the Examination of Water and Wastewater (19th Edn.), Washington, D.C.
12. Wetzel, R.G. and G.E. Likens, 1991. Limnological Analyses. Springer-Verlag: Berlin.
13. Edmondson, W.T., 1971. Productivity in Freshwaters. Blackwell Scientific Publications: Oxford.
14. SAS Institute Inc., 1987. SAS Institute Inc., 1987. SAS/STAT User's Guide: Cary, NC.
15. Goldman, C.R., 1981. Lake Tahoe: Two decades of change in a nitrogen deficient oligotrophic lake. Verh. Intl. Ver. Limnol., 21: 45-70.
16. Harris, G.P., 1980. Temporal and spatial scales in phytoplankton ecology. Mechanisms, methods, models and management. Canadian J. Fisheries and Aquatic Sci., 37: 877-900.