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Stormwater Influence on Phytoplankton Composition and Dynamics in Lake Joyce, Virginia

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ABSTRACT

A three year study of Lake Joyce, Virginia revealed relationships between the timing, duration, and amount of stormwater runoff and phytoplankton abundance and composition. Major phytoplankton taxa were identified and cyanophytes dominanted during periods of decreased rainwater input and increased lake water retention times. Increased freshwater input was associated with the growth of a diverse assemblage of both chlorophytes and diatoms. Phytoplankton dynamics as a result of significant rain events (i.e., hurricanes Floyd and Irene, 1999) were documented and specific taxa involved in nuisance algal blooms were identified.

INTRODUCTION

Lake Joyce, located in Virginia Beach, Virginia (36° 54' 44" Lat., 76° 7' 19" Long.) is a 60.7 hectare freshwater lake with an average depth of 1.1meters. Lake overflow empties to the lower Chesapeake Bay via Pleasure House Creek and the Lynnhaven River. Because the lake is surrounded by residential housing, a major nutrient nonpoint source results from urban stormwater runoff (United States Environmental Protection Agency 1983). Local changes in the seasonal periods of precipitation will influence the amount of this surface runoff that will enter Lake Joyce. The lake is an unstratified, hyper-eutrophic system with reports of nuisance algal blooms documented since 1978 (Roger K. Everton, Virginia Department of Environmental Quality, Tidewater Region, personal communication). While once a water reservoir for the City of Norfolk, Virginia, its current use is now recreational and includes boating, fishing and water skiing.

The objectives of this study were: 1) identify phytoplankton composition and abundance within Lake Joyce, and 2) compare phytoplankton population dynamics to precipitation data over the three year study period.

METHODS

Three replicate surface grab samples (125 milliliters (ml)) were collected weekly from a pier in Lake Joyce over a 36 month period (May 4, 1999 to May 20, 2002). All samples were preserved with buffered glutaraldehyde to yield a final concentration of 2% (American Public Health Association 1998). Phytoplankton abundance was determined using the mean cell concentrations from two replicate samples and mean autotrophic picoplankton abundance from all three replicate samples. Five to ten ml subsamples were drawn on to a 0.2 micrometer (µm) Nucleopore filter stained in Irgalan Black using a mechanical pump at pressures less than 10 centimeters (cm) of Hg to prevent cell rupture. A Zeiss Axiolab Microscope equipped with a 50 watt mercury bulb and a Zeiss 450–490 excitation filter, 510 dichromatic mirror and 520 barrier filter and Zeiss 546 excitation filter, FT580 dichromatic mirror and 590 barrier filter were used to identify the autotrophic picoplankton, colonial cyanoprokaryotes and the presence of dominant nanoplankton and microplankton forms (at 1000X). Identification of dominant nanoplankton and microplankton species was verified using light and phase contrast microscopy (at 400X). For consistency, autotrophic picoplankton abundance was measured using the Zeiss 450-490 excitation filter set. For each replicate sample, four randomly chosen fields were examined for the representative nanoplankton, microplankton and autotrophic picoplankton components (Affronti and Duquette, 2002). A full filter scan was performed to identify other non dominant phytoplankton species present in the sample. A one way Model I ANOVA was performed on total phytoplankton abundance data with year as a treatment (1st year – May 4, 1999 to May 1, 2000, 2nd year – May 8, 2000 to May 7, 2001 and 3rd year – May 14, 2001 to May 20, 2002) to determine if there were significant differences in phytoplankton abundance. Average phytoplankton abundance was compared to weekly precipitation data (National Oceanic and Atmospheric Administration/National Climatic Data Center 1999-2002).

RESULTS

Average total phytoplankton and autotrophic picoplankton abundance over the three year period is shown in Figure 1. Cell abundance ranged from 3.70×10^7 to 7.75×10^9 cells per Liter (L) with onset growth occurring in late spring and early summer. Seasonal maximum abundance varied the three years with numbers generally decreasing into winter. Results of the one way Model I ANOVA indicated total phytoplankton abundance was affected by year ($P<0.0001$). Tukey's *a posteriori* tests verified all pair- wise comparisons of abundance by year were significantly different (1st and 2nd years; $P<0.05$, 1st and 3rd years: $P<0.05$, 2nd and 3rd years; $P<0.05$). Phytoplankton abundance for the second year was less than the first and third years of the study where an extended and greater growth period was observed from May 14, 2001 to May 20, 2002 (Figure 1).

Throughout the study, Lake Joyce flora consisted primarily of cyanophytes, chlorophytes and diatoms. Cyanophytes dominated total phytoplankton abundance and ranged from 0.00 to 7.71×10^9 cells L^{-1}. Peak abundance occurred in late summer to early autumn and often associated with bloom events (Figure 2). Three dominant cyanophyte groups were observed. These included filamentous forms (*Anabaena* sp. and *Lyngbya* sp.) colonial taxa that included the temporarily identified *Aphanocapsa holsatica* (Affronti and Duquette 2002) as described by Komárek and Anagnostidisk (2000), plus *Gloeocapsa* sp., *Gomphosphaeria* sp., and *Merismopedia* sp. Unicellular forms included *Synechococcus* sp. and individual cells of *Aphanocapsa holsatica*, both of which dominated the autotrophic picoplankton component which ranged from 1.98×10^6 to 2.14×10^8 cells L^{-1}.

Chlorophytes were the most diverse phytoplankton group observed and ranged in abundance from 3.16×10^6 to 6.06×10^8 cells L^{-1}. Growth periods varied over the study with peak abundance occurring in late autumn and an increase in numbers beginning each spring (Figure 2). Representative forms were *Ankistrodesmus* sp., *Closterium* sp., *Cosmarium* sp., *Crucigenia rectangularis*, *Crucigenia tetrapedia*, *Desmidium* sp., *Kirchneriella* sp., *Oocystis* sp., *Pediastrum duplex*, *Pediastrum simplex*, *Quadrigula*

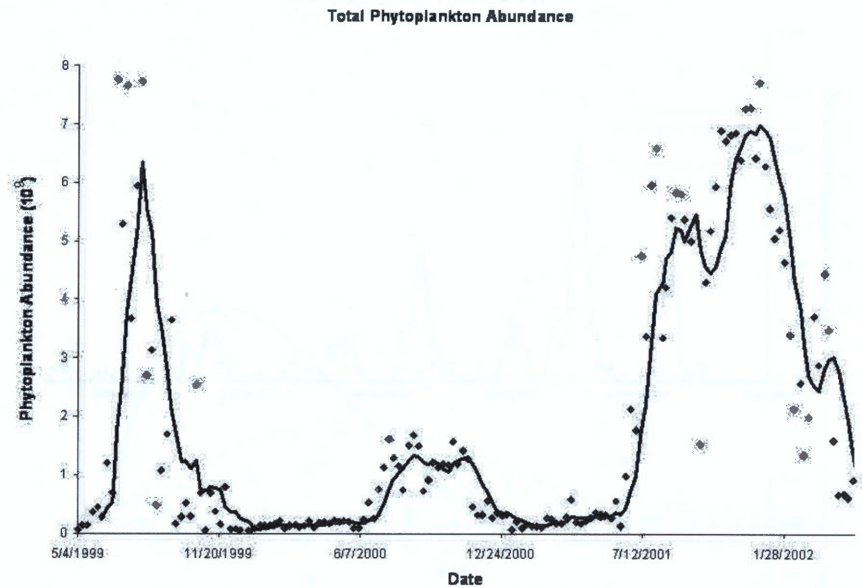

FIGURE 1. Average total phytoplankton abundance from two replicate samples. A moving average best fit line was used to fit data series.

sp., *Scenedesmus alternans*, *Scenedesmus dimorphus*, *Desmodesmus quadricauda*, *Staurastrum* sp., and *Tetraedron* sp.. Unidentified chlorophyte cells <2µm also contributed to autotrophic picoplankton abundance.

The diatoms consisted of centric and pennate forms that included *Asterionella* sp., Cyclotella sp., *Leptocylindricus minimus*, *Navicula* sp., and *Skeletonema potamos*. Increased abundance occurred during early spring and again in late autumn, with reduced concentrations during winter (Figure 2). Diatom abundance varied from 0.00 to 2.69×10^7 cells L^{-1}. Additional phytoplankton groups were observed, but did not contribute significantly to overall abundance. These included dinoflagellates (e.g. *Amphidinium* sp., *Ceratium hirundianella*), euglenoids and chrysophytes (*Synura* sp. and *Dinobryon* sp.).

Weekly rainfall for this region ranged from 0.00 to 18.64cm over the three years (Figures 3-5). Precipitation and phytoplankton data were compared for each year. Two significant rain events occurred in September and October 1999 (16.66cm and 18.64cm, respectively) resulting in substantial freshwater input to the lake. Also, there were significant periods (i.e., 12 consecutive weeks from February to May 2000) without rain. Average phytoplankton abundance the first year had a single peak in June/July, then decreased with an increase in precipitation during autumn and remained low into winter and early spring (Figure 3). The opposite was true the second year as maximum precipitation occurred during summer and phytoplankton abundance remained low in summer and during a second rainfall peak the following spring (Figure

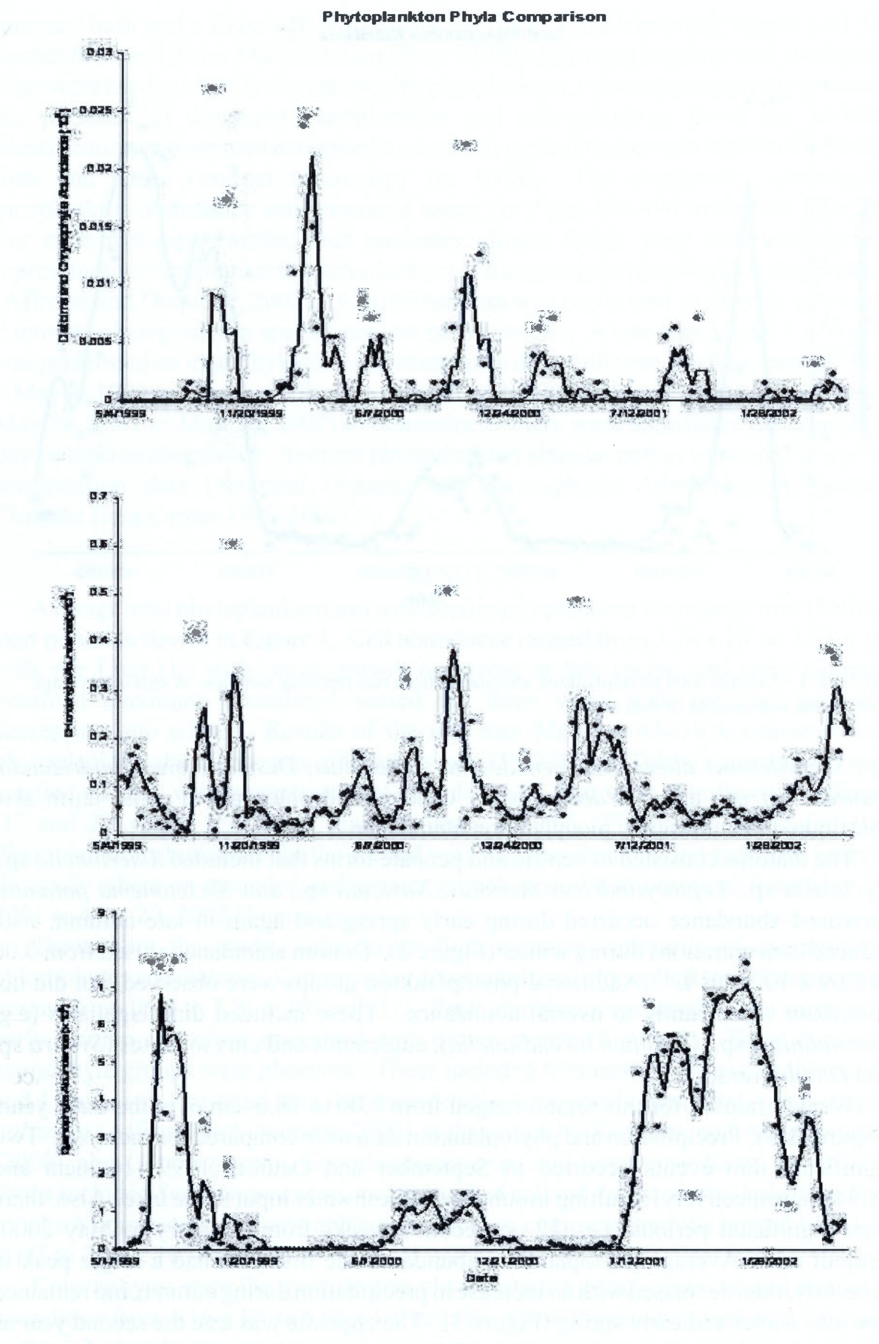

FIGURE 2. Comparison of phytoplankton phyla patterns. Patterns are a result of moving average best fit trend lines of representative data series.

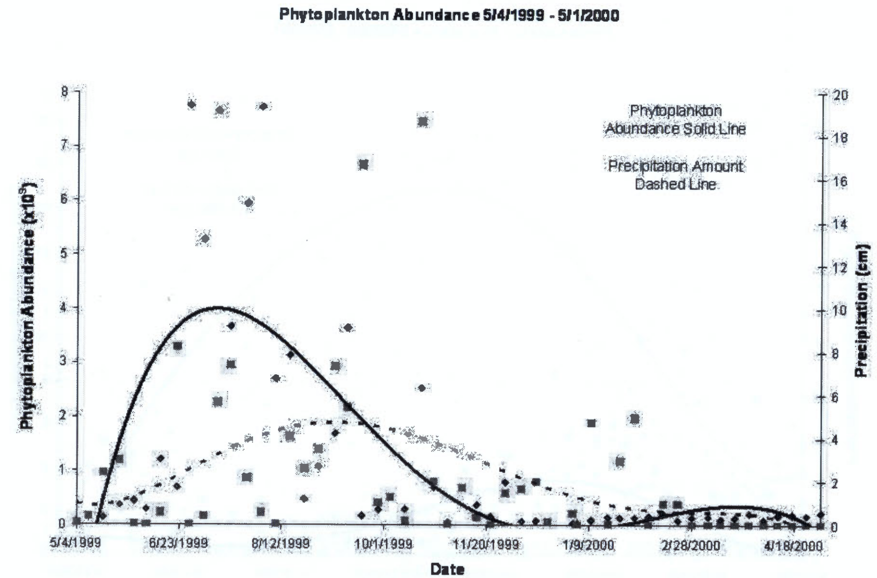

FIGURE 3. Comparison of total phytoplankton abundance (diamond) and precipitation (square) for first year of study. Polynomial best fit lines are used for each data series.

4). The third year of the study was the driest with total precipitation 19.05cm lower than year two, which was the wettest year (118.95cm). Maximum phytoplankton growth occurred during this period of reduced precipitation and surface runoff, and was dominated by *Aphanocapsa holsatica* and *Anabaena* sp. into late autumn.

DISCUSSION

Numerous studies have implicated phytoplankton abundance and diversity being influenced by the complex interaction of many variables that include physical, chemical and environmental factors (Harris 1986; Padisák et al. 1988; Ochs et al. 1995 and Chen et al. 2003). Because a major source of freshwater input to Lake Joyce includes stormwater runoff, rain events also have an important influence on lake dynamics. Timing, duration, and amount of rainwater input for Lake Joyce not only influenced lake depth and nutrient input, but influenced phytoplankton abundance and composition. Total phytoplankton abundance during the second year of the study was significantly lower than years one and three when total rainfall during this period was high. Likewise, the inverse relationship between phytoplankton abundance and rainwater input during autumn of the first year implied periods of increased freshwater input influenced phytoplankton abundance and composition. As a result of rain events, increased flushing rates and simple dilution of organism abundance would be expected. Over 35.3cm of rain as a result of hurricanes Floyd and Irene provided these conditions during September and October of 1999 which decreased phytoplankton abundance.

Timing of freshwater input to Lake Joyce also influenced phytoplankton dynamics. Most rainfall during the first year occurred from late summer into autumn and resulted in a decline of established phytoplankton growth. However, the major rain events

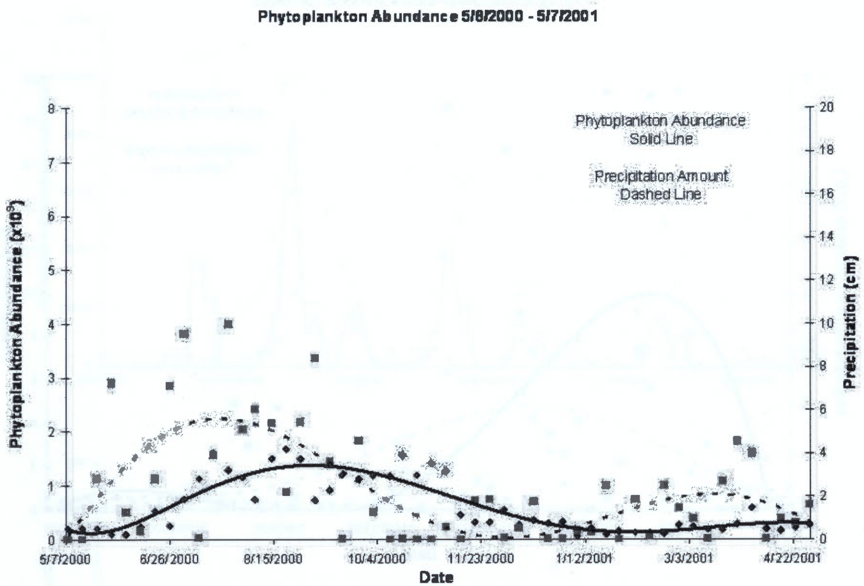

FIGURE 4. Comparison of total phytoplankton abundance (diamond) and precipitation (square) for second year of study. Polynomial best fit lines are used for each data series.

during the second year occurred from late spring into summer where phytoplankton growth responded to this input. Most likely, this response was related to nutrient input which in conjunction with other environmental factors promoted phytoplankton growth (United States Environmental Protection Agency 1983). During periods of reduced precipitation and runoff, residency time within the lake was increased allowing for greater phytoplankton development (Figure 5).

Over the study period, changes in phytoplankton composition were associated with the amount of precipitation. During the second year, high rainfall in late spring resulted in more chlorophyte and diatom growth compared to years one and three where cyanophytes dominated phytoplankton composition. The third year was the driest of the study, with only 99.90cm of rainfall measured. During this year, the lake became stagnant, resulting in increased residency time and favorable conditions for cyanophyte growth. The dominant phytoplankton species during this period were *Aphanocapsa holsatica* and *Anabaena* sp. Both are common forms that thrive in nutrient rich warm waters and have been involved in bloom development (Edson and Jones 1988; Tsujimura and Okubo 2003). Humphries and Lyne (1988) report cyanophytes are able to out-compete other phytoplankton in part because of their increased nutrient uptake kinetics and ability to control cell buoyancy.

Prior to the hurricane events, rainwater input in spring and early summer of 1999 was minimal when phytoplankton composition was dominated by cyanophytes. After the hurricanes and resulting input of a significant amounts of freshwater, cyanophyte abundance decreased and conditions were more favorable for diatom growth, especially during cooler temperatures. The third year followed a similar onset growth of

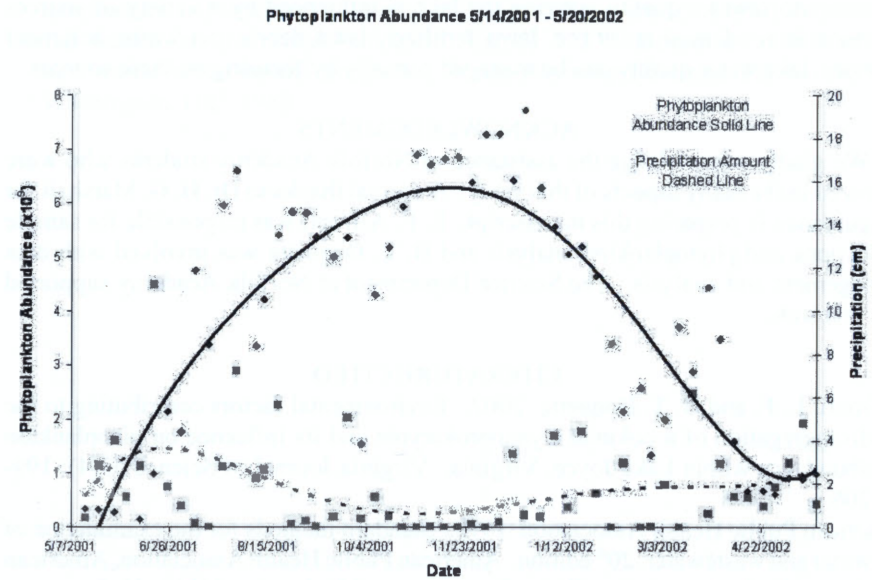

FIGURE 5. Comparison of total phytoplankton abundance (diamond) and precipitation (square) for third year of study. Polynomial best fit lines are used for each data series.

cyanophytes as the first year, but without significant rain events. In this case, cyanophytes continued to thrive and bloom conditions resulted. In a study of urban lakes, reservoirs and ponds, Olding et al. (2000) reported cyanophytes dominating phytoplankton abundance as a result of high water retention times.

The autotrophic picoplankton abundance reported in this study is conservative compared to those values reported by Affronti and Duquette (2002) where a different filter set was used (Zeiss 546 excitation filter). However, the patterns of autotrophic picoplankton abundance are similar and followed precipitaton patterns. In their study, Affronti and Duquette (2002) suggested the composition of autotrophic picoplankton in Lake Joyce was influenced by freshwater input as the colonial cyanophyte, *Aphanocapsa holsatica* disaggregated into individual cells within the picoplankton size range (0.2 – 2.0μm).

CONCLUSION

Lake Joyce is an enclosed natural resource with restricted outflow where rainfall events have a significant impact on lake dynamics. Rainwater is not the only factor influencing phytoplankton growth, but data from this study indicated their abundance and composition were affected by the timing and duration of freshwater input. Similar results were reported by Edson and Jones (1988) in a study of Lake Fairfax, Virginia where differences in stormwater runoff influenced phytoplankton community structure. Phytoplankton composition and abundance was more diverse with increased freshwater input that resulted in lower water retention times and less nuisance bloom conditions.

Because stormwater quality entering the lake is influenced by a variety of sources common in residential areas (i.e. lawn fertilizer, lawn debris, pet waste, sediment erosion), lake water quality can be managed partially by focusing on these sources.

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LITERATURE CITED

Affronti, L. F. and B. T. Duquette 2002. Environmental factors contributing to the disaggregation of a colonial Cyanoprokaryote and its influence on picoplankton abundance within Lake Joyce, Virginia. Virginia Journal of Science 53(4): 199-206.

American Public Health Association 1998. Standard methods for the examination of water and wastewater, 20th edition. American Public Health Association, American Water Works Association, Water Environmental Federation 10200: 10-5.

Chen, Y., B. Qin, K. Teubner, and M. T. Dokulil 2003. Long-term dynamics of phytoplankton assemblages: *Microcystis*-domination in Lake Taihu, a large shallow lake in China. Journal of Plankton Research 25: 445-453.

Edson, J. J., and C. Jones 1988. Spatial, temporal and storm runoff-related variations in phytoplankton community structure in a small suburban reservoir. Hydrobiologia169(3): 353-362.

Harris G. P. 1986. Phytoplankton Ecology, Structure, Function and Fluctuation. Chapman and Hall, New York. 384pp.

Humphries, S. E., and V. D. Lyne 1988. Cyanophyte blooms: the role of cell buoyancy. Limnology and Oceangraphy 33(1) 79-91.

Komárek, J. and K. Anagnostidisk 2000. Süßwasserflora von Mitteleuropa. Cyanoprokaryota 1. Teil: Chroococcales. Spektrum Akademischer Verlag, Heidelberg. 548 pp.

National Oceanic and Atmospheric Administration/National Climatic Data Center 1999-2002. Hourly precipitation data for Norfolk International Airport, Norfolk, VA DS 3240.

Ochs, C. A., J. J. Cole, and G. E. Likens 1995. Population dynamics of bacterioplankton in an oligotrophic lake. Journal of Plankton Research 17: 365-391.

Olding, D., J. Helleburst, and M. Douglas 2000. Phytoplankton community and composition in relation to water quality and water body morphometry in urban lakes, reservoirs and ponds. Canadian Journal of Fisheries and Aquatic Sciences 57: 2163-2174.

Padisák, J., L.G. Toth, and M.Rajczy 1988. The role of storms in the summer succession of the phytoplankton community in a shallow lake (Lake Balaton, Hungary). Journal of Plankton Research 10: 249-265.

Tsujimura, S. and T. Okubo 2003. Development of *Anabaena* blooms in a small reservoir with dense sediment akinete population, with special reference to temperature and irradiance. Journal of Plankton Research 25: 1059-1067.

United States Environmental Protection Agency 1983. December results of the nationwide urban runoff program. Water Planning Division, PB 84-185552, Washington, D.C. 1983.