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Environmental Factors Contributing to the Disaggregation of a Colonial Cyanoprokaryote and Its Influence on Picoplankton Abundance within Lake Joyce, Virginia

Lewis F. Affronti Jr. and **B. Thomas Duquette**
Departments of Science and Math, Norfolk Academy
Norfolk, Virginia 234502-5591

ABSTRACT

A colonial cyanoprokaryote, *Aphanocapsa holsatica* and autotrophic picoplankton abundance were monitored weekly over a two year period in Lake Joyce, Virginia. Significant differences were observed in both the cyanoprokaryote and picoplankton abundance over the study period and an inverse relationship was observed between these two plankton groups. Disaggregation of colonies was shown to contribute to picoplankton populations where water temperature and precipitation input apparently trigger colony dispersion. This relationship is suggested to occur in other aquatic habitats. Results of this work and its implications for ecosystem dynamics are discussed.

INTRODUCTION

Picoplankton is defined as plankton between 0.2 and 2.0μm in size (Sieburth et al., 1978) and may include a variety of both heterotrophic and autotrophic organisms (Marshall, 2002). Numerous studies have shown picoplankton as an abundant and productive component within a variety of oceanic, estuarine and freshwater environments (Li, et al., 1983; Fahnensteil and Carrick, 1992; Marshall and Nesius, 1993; Affronti and Marshall, 1994). However, questions remain as to the relationship of picoplankton in aquatic food web dynamics (Stockner and Shortreed, 1989; Fogg, 1995; Marshall, 2002). To answer these questions, more detailed information is required on factors which influence picoplankton composition dynamics. With this information, a better understanding of the availability of picoplankton as a link or sink for nutrients can be determined.

The objectives of this study are: 1) identify variation in both autotrophic picoplankton and colonial cyanoprokaryotic abundance using a high frequency sampling regime and 2) identify the effects, if any that water temperature and storm water runoff have on colonial cyanoprokaryotic and autotrophic picoplankton population dynamics in Lake Joyce, Virginia.

Lake Joyce, Virginia (36° 54' 44'' Lat., 76° 7' 19'' Long.) is a 60ha freshwater lake whose overflow empties via Pleasure House Creek and the Lynnhaven River into the lower Chesapeake Bay. The Virginia Department of Environmental Quality (1994) has described this water body as an unstratified, hypereutrophic system whose average depth is 1.1m. The major nonpoint source input is from urban stormwater runoff. Lake Joyce is representative of other lakes in the Norfolk/Virginia Beach area where its general usage includes fishing, boating, and water skiing.

METHODS

During this study, three replicate surface grab samples (125 mL) were collected weekly at one station in Lake Joyce over a 24 month period (May 29, 2000 to May 20,

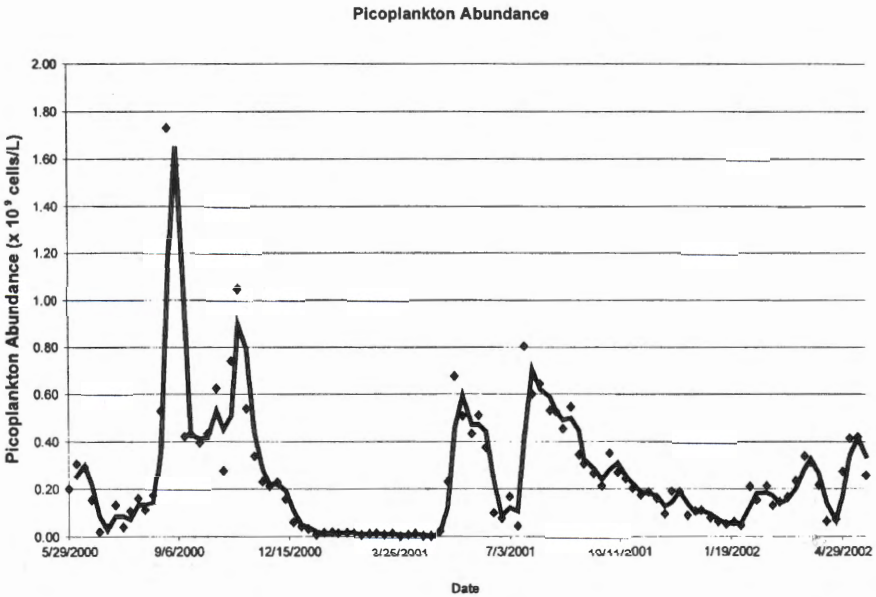

FIGURE 1. Average picoplankton abundance from three replicate samples. A moving average best fit line was used to fit data series.

2002) and preserved in 2% glutaraldehyde. Subsamples (5 mL) were drawn on to a 0.2μm Nucleopore filter stained in Irgalan Black using a mechanical pump at pressures less than 10cm of Hg to prevent cell rupture and colony disturbance. Both picoplankton and colonial cyanoprokaryotic abundance were determined from these filters using a Zeiss Epifluorescence Axiolab Microscope equipped with a 50 watt mercury bulb and a Zeiss 546 excitation filter, FT580 dichromatic mirror and 590 barrier filter. Picoplankton abundance was calculated from three replicate samples and colonial cyanoprokaryote abundance was calculated from two replicate samples. An ocular grid system (10 x 10 square grid, each square measured 10μm squared at 1000X) was used as a template to aid in the counting of both picoplankton and the colonial cyanoprokaryotic organism.

A one way Model I ANOVA with time as a treatment was performed on both picoplankton and colonial cyanoprokaryotic data to determine if significant changes in abundance occurred over the study period. Average picoplankton and colonial cyanoprokaryotic abundance was compared to both water temperature (October 23, 2000 to May 20, 2002) and weekly precipitation data (May 23, 2000 to April 1, 2002) (NOAA, 2000 – 2002).

RESULTS

The colonial cyanoprokaryote was tentatively identified as *Aphanocapsa holsatica*, according to Komarek (2000). Average picoplankton abundance data for the study period are given in Figure 1. Cell abundance ranged from 4.74×10^6 to 2.23×10^9 cells/L with peaks observed from late summer to early fall. Results of the one way Model I ANOVA indicated picoplankton abundance was affected by time ($P < 0.00001$). Abundance data for May 29, 2000 was not included in this analysis

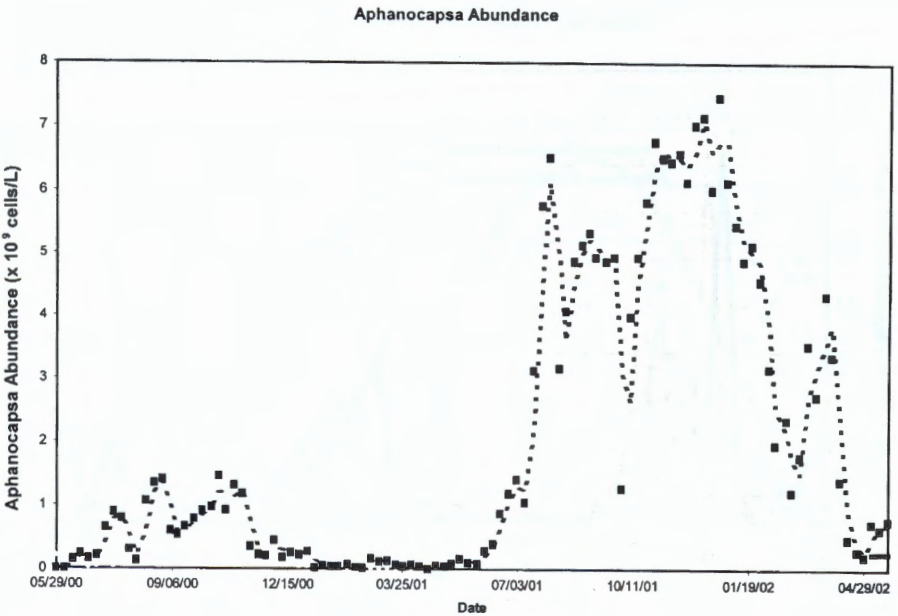

FIGURE 2. Average *Aphanocapsa holsatica* abundance from two replicate samples. A moving average best fit line was used to fit data series.

(missing replicate sample). Results of Tukey's a posteriori tests verified an overall decline in picoplankton abundance over the study period as picoplankton abundance on August 28, 2000 (peak value for 2000) was significantly higher than the maximum abundance observed during the following summer (July 16, 2001).

Average *Aphanocapsa holsatica* abundance data are given in Figure 2. Abundance peaks occurred in summer with a significant and extended growth pattern observed over the second year of the study. *Aphanocapsa holsatica* abundance ranged from 0 to 8.22 x 10^9 cells/L over this two year study. Results of the one way Model I ANOVA indicated *Aphanocapsa holsatica* cell abundance was affected over time ($P< 0.00001$). Tukey's multiple comparison tests suggests an overall increase in *Aphanocapsa holsatica* abundance over the study period. However, its maximum abundance on October 16, 2000 was significantly lower compared to the maximum the following year (December 23, 2001). In comparison, there was an inverse relationship between *Aphanocapsa holsatica* and picoplankton average abundance (Figure 3).

Water temperature taken over 19 months of the study is shown in Figure 4. Water temperature varied from 0.56°C (33.0°F) to 30.0°C (86.0°F). Average picoplankton abundance is in phase with water temperature (Figure 4) while average *Aphanocapsa holsatica* abundance is not (Figure 5). Weekly precipitation is shown in Figure 6. Precipitation ranged from 0cm to 11.20cm (4.41in) over the study period. Total rainfall for the first year of the study (115.77cm, 45.58in) was higher than the second year total (66.98cm, 26.37in). Average picoplankton abundance followed precipitation patterns with a slight lag time between their peaks (Figure 6). Average *Aphanocapsa holsatica* abundance had an inverse relationship with the amount of precipitation (Figure 7).

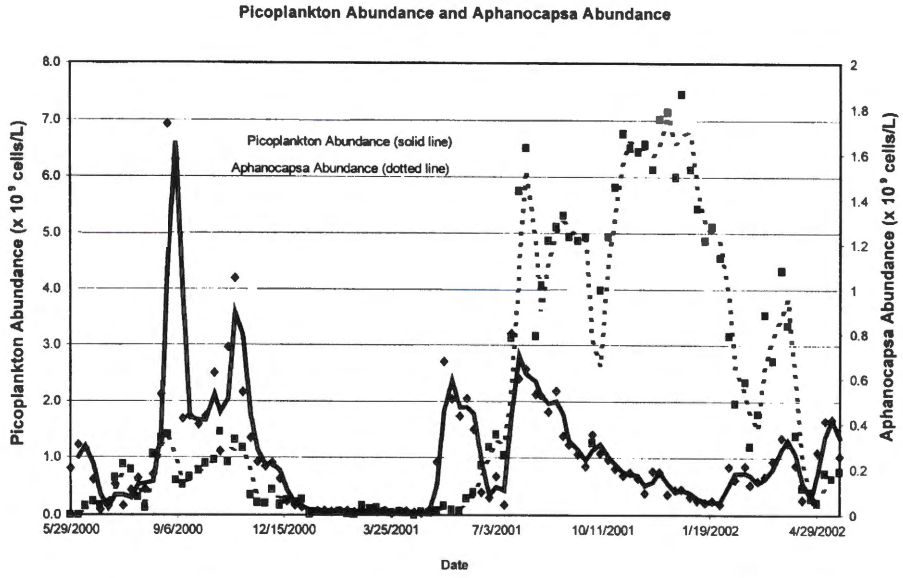

FIGURE 3. Comparison of picoplankton and *Aphanocapsa holsatica* abundance. Best fit lines are moving averages of each data series.

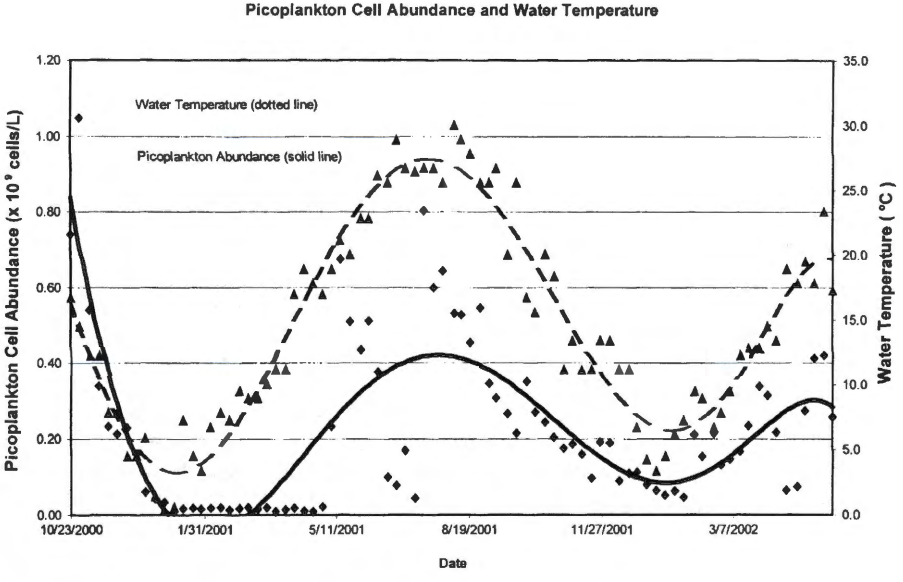

FIGURE 4. Comparison of picoplankton abundance and water temperature. Polynomial best fit lines are used for each data series.

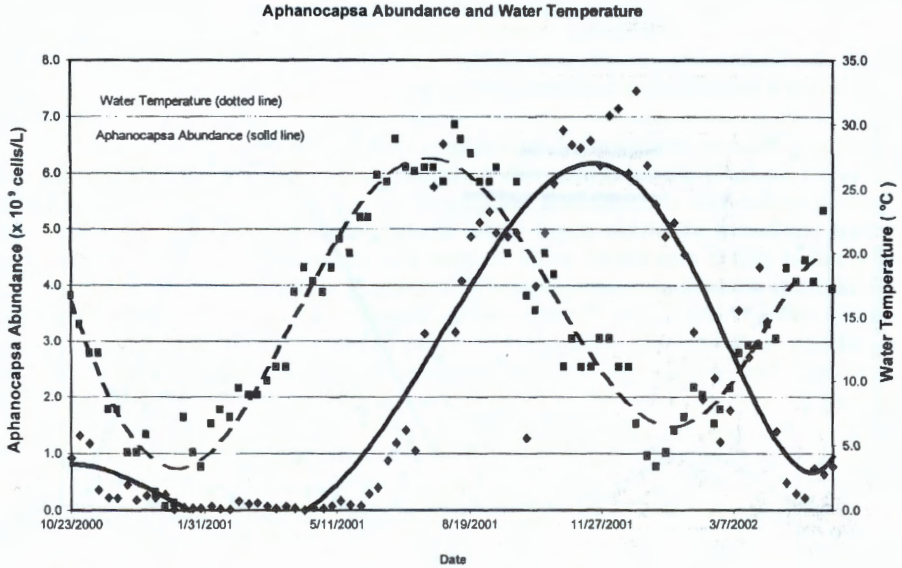

FIGURE 5. Comparison of *Aphanocapsa holsatica* and water temperature. Polynomial best fit lines are used for each data series.

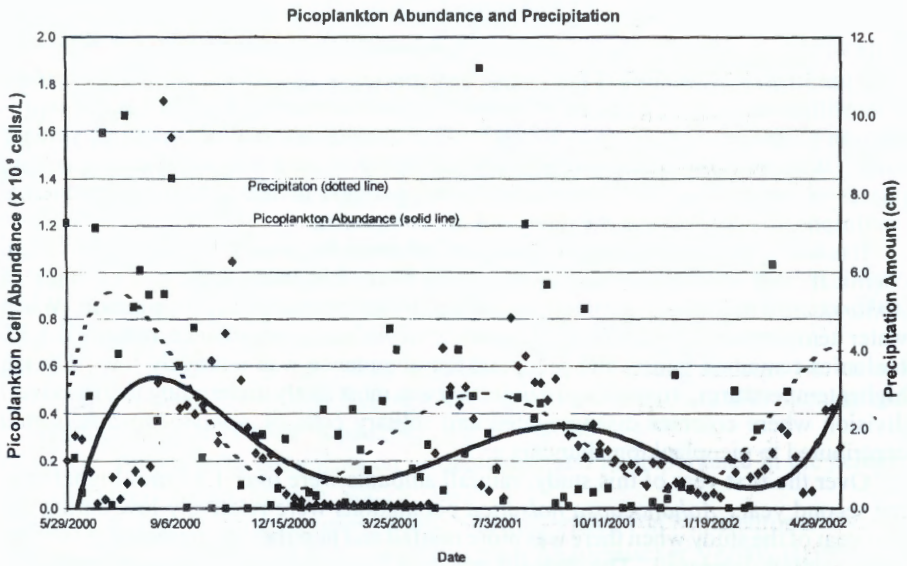

FIGURE 6. Comparison of picoplankton abundance and precipitation amount. Polynomial best fit lines are used for each data series.

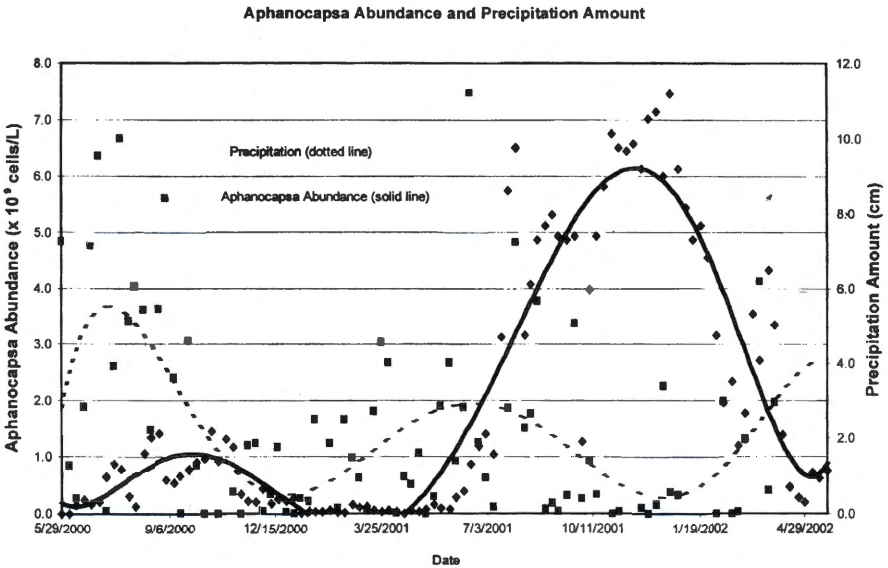

FIGURE 7. Comparison of *Aphanocapsa holsatica* and precipitation amounts. Polynomial best fit lines are used for each data series.

DISCUSSION

The inverse relationship of *Aphanocapsa holsatica* and picoplankton abundance (Figure 3) suggests these two plankton groups are interrelated. In his review of autotrophic picoplankton, Marshall (2002) stated there are numerous freshwater colonial cyanobacteria such as *Aphanothece*, *Aphanocapsa*, *Merismopedia*, etc. with cells <2.0 μm in size. Komárek (2000) describes species of *Aphanocapsa* with individual cells within the size range of picoplankton. Likewise, Komárek (2000) stated reproduction of *Aphanocapsa holsatica* involves the disintegration of colonies into solitary cells. With this information, it is likely for *Aphanocapsa holsatica*, during certain phases of its growth (i.e. reproduction) and perhaps under certain environmental conditions, to contribute to the picoplankton component.

It is widely understood that plankton are influenced by a variety of unique physical, chemical, and environmental factors. Data from this study indicated colonies of *Aphanocapsa holsatica* were being influenced by temperature and precipitation. When water temperatures were lower, *Aphanocapsa holsatica* abundance remained high (colonies remained intact) and picoplankton abundance was relatively low. During higher temperatures, *Aphanocapsa holsatica* was most likely undergoing increased cell division where colonies disaggregated and solitary cells of *Aphanocapsa holsatica* contributed to picoplankton abundance.

Over the first year of this study, rainfall amounts were over 1.5 times higher than the second year. *Aphanocapsa holsatica* populations were relatively low during the first year of the study when there was more rainfall and populations increased in number when rainfall decreased. The opposite was true for picoplankton abundance where a decrease in abundance was observed over the two year study. The fact that picoplankton abundance patterns mimicked precipitation amounts, suggests this freshwater input has a direct influence on *Aphanocapsa holsatica* colony disaggregation. There is

support for this suggestion from culture studies on other colonial cyanoprokaryotes by Parker (1982). She observed *Microcystis* sp. colonies dispersing into unicells when distilled water was added to the colonies. Furthermore, she suggested because of this occurrence *Microcystis* cells could be mistakenly identified in the field as a unicellular organism.

The degree to which this dispersion response of *Aphanocapsa holsatica* to freshwater input is evolutionary in nature, simply a chemical response (Parker, 1982), or some reproductive strategy to increase population abundance is difficult to discern. However, colony dispersion during storm water input would be beneficial to the survival of *Aphanocapsa holsatica*, and nutrient input during rain events is likely to increase the chance for species propagation. When picoplankton diversity is modified, microbial food web dynamics that include carbon trophodyanmics and microzooplankton grazing rates are also expected to vary. These changes may result in significant shifts at higher trophic levels, thus influencing overall lake productivity and efficiency.

CONCLUSION

Data from this study suggests a major contributor to picoplankton abundance in Lake Joyce is from the disaggregation of *Aphanocapsa holsatica* colonies. The cosmopolitan nature of *Aphanocapsa holsatica* infers this association may also occur in other aquatic habitats. To verify species specific relationships of picoplankton and *Aphanocapsa holsatica*, DNA techniques (Krienitz et al., 1999; Moon-van der Staay et al., 2000; Lopez-Garcia et al., 2001 and Moon-van-der Staay et al., 2001) would be required and should be the focus of further research. Two environmental factors appear to trigger the release of individual cells of *Aphanocapsa holsatica*; these included temperature and rainwater input. This study emphasizes the importance of long term, high frequency studies on time scales that more accurately correspond with picoplankton and *Aphanocapsa holsatica* growth patterns under changing environmental conditions.

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LITERATURE CITED

Affronti, L.F. and H.G. Marshall. 1994. Using frequency of dividing cells in estimating autotrophic picoplankton growth and productivity in the Chesapeake Bay. Hydrobiologia 284: 193-203.

Fahnenstiel, G. and H. Carrick. 1992. Phototrophic picoplankton in Lakes Huron and Michigan: Abundance, distribution, composition, and contribution to biomass and production. Can. J. Fish. Aquat. Sci., 49: 379-388.

Fogg, G. 1995. Some comments on picoplankton and its importance in the pelagic ecosystem. Aquat. Microb. Soc., 9: 33-39.

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

Krienitz, L., H. Takeda, and D. Hepperle. 1999. Ultrastructure, cell wall composition, and phylogenetic position of *Pseudodictyosphaerium jurisii* (Chlorococcales,

Chlorophyta) including a comparison with other picoplanktonic green algae. Phycologia 38: 100-107.

Li, W.K., S. Subba Rao, W. Harrison, J. Smith, J. Cullen, B. Irwin, and T. Platt. 1983. Autotrophic picoplankton in the tropical ocean. Science 219: 292-295.

Lopez-Garcia, P., F. Rodriguez-Valera, C. Pedros-Alio, and D. Moreira. 2001. Unexpected diversity of small eukaryotes in deep-sea Antarctic plankton. Nature 409: 603-607.

Marshall, H.G. 2002. Autotrophic picoplankton: Their presence and significance in marine and freshwater ecosystems. Va. J. Sci. 53(1): 13-33.

Marshall, H.G. and K.K. Nesius. 1993. Seasonal relationships between phytoplankton composition, abundance, and primary productivity in three tidal rivers of the lower Chesapeake Bay. J. Elisha Mitchell Sci. Soc. 109(3): 141-151.

Moon-van der Staay , S., G. van der Staay, L. Guillou, and D. Vaulot. 2000. Abundance and diversity of prymnesiophytes in the picoplankton community from the equatorial Pacific Ocean inferred from 18S rDNA sequences. Limnol. Oceanogr. 45:98-109.

Moon-van der Staay, S., R. DeWatcher and D. Vaulot. 2001. Oceanic 18S rDNA sequences from picoplankton reveal unsuspected eukaryotic diversity. Nature 409:607-610.

National Oceanic and Atmospheric Administration. 2000 - 2002. Local climatological data, weekly summary Norfolk International Airport, Norfolk, VA.

Parker, D. L. 1982. Improved procedures for the cloning and purification of *Microcystis* cultures (Cyanophyta). J. Phycol. 18: 471-477.

Sieburth, J. McN., V. Smetacek, and J. Lenz. 1978. Pelagic ecosystem structure: Heterotrophic components of the plankton and their relationship to plankton size-fractions. Limnol. Oceanogr. 23: 1256-1263.

Stockner, J. and K. Shortreed. 1989. Algal picoplankton production and contribution to food-webs in oligotrophic British Columbia lakes. Hydrobiologia 173: 151-166.

Virginia Department of Environmental Quality 1994. Targeted Lake and Reservoir Monitoring Program, Lake Joyce, Virgina. (August 22, 1994).