178
1

Phytoplankton Colonization and Seasonal Succession in New Experimental Ponds

by

Michael S. Rosenzweig

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Biology

APPROVED:

A.L. Buikema, Jr./Chairman

B. C. Parker

B.C. Parker

J R. Voshell, Jr.

J.R. Voshell, Jr.

April 1990

Blacksburg, Virginia

Phytoplankton Colonization and Seasonal Succession in New Experimental Ponds

by

Michael S. Rosenzweig

Committee Chairman: A.L. Buikema, Jr.
Biology

(Abstract)

Following the U.S. Environmental Protection Agency's specifications for pesticide registration tests, 12 experimental ponds were constructed in Blackstone, VA at VPI&SU Southern Piedmont Agricultural Experiment Station. Colonization and succession of the ponds' phytoplankton communities were investigated during the first year after filling. Taxa richness and densities, biomass as chlorophyll a, and primary productivity (*in situ* oxygen method) were measured. In addition, water quality data were collected and analyzed. The dominant taxonomic groups were the Cyanophyceae, Chlorophyceae (with Desmidaceae dominating), Dinobryon (in the Chrysophyceae), Dinophyceae, and Bacillariophyceae. Similar successional patterns in all 12 ponds occurred, however, the community structure between ponds was not similar at any given time. Although the ponds had statistically similar environmental characteristics, they varied in their community structure indicating that, after one year, they were not mature enough for use as replicate test systems. No structural parameter could be measured with reasonable precision using a three replicate pond scheme recommended by the USEPA. Taxa richness could be measured with a precision of approximately 25% over the year; and was ≤11% during the peak growing months. Taxa densities could usually be measured with a precision of <100% during these months. The *in situ* oxygen method for measuring primary productivity was found to be to insensitive during early colonization. The heterogeneity of the ponds' phytoplankton communities indicate that mesocosms will need to be managed to produce replicate experimental units.

Key Words

mesocosms, experimental ponds, phytoplankton, biovolume, chlorophyll a, primary productivity, hazard evaluation, risk assessment.

Acknowledgments

In appreciation for the opportunity to work on this project, I would like to thank Dr. A.L. Buikema, Jr. His advice and support was much appreciated throughout this project. My committee, Dr. J.R. Voshell, and Dr. B.C. Parker deserve special thanks for their extra time during Dr. Buikema's two year extended sabbatical. I am especially grateful to Dr. Parker, who shows special care for all students. He gave me the friendship and special attention that a young apprentice such as myself so badly needs at times.

I am also grateful to my associates on this project. For laboratory assistance I thank Messers. Tim Morgan and Scott Smedley; Dr. Ray Layton and Mr. Van Christman for scientific and technical advice. Special thanks go to my colleague Dave Jenkins, his wife Mary, and their children Amy and Sarah. The 13 months associated with field collection was made humanly possible by their friendship and support. To my friends and family, you know who you are, thanks. Your smiles and support are worth one million bad days.

This project was supported by Virginia Tech. and the USEPA. No opinion in this study necessarily reflects the views of or bears the official endorsement of the USEPA.

Table Of Contents

page

List Of Tables

List Of Figures

List Of Figures, continued

Introduction

Theoretical Background

"The principles of ecological succession bear importantly on the relationships between man and nature (Odum 1969)." Odum believed that it was time to test many of the untested, yet generally accepted ecological theories such as succession theory. McIntosh (1980) described succession as "one of the oldest, most basic, yet still in some ways, most confounded of ecological concepts." Succession is essential to the scientific study and understanding of the natural environment. Experimentation on succession theory has been set back by disagreement among investigators. Odum (1969) believed that the lack of experimental work on testing succession theory was due to ecologists' tendency to regard succession as a single, linear progression; Odum believed it was an "interacting complex of processes, some of which counteract one another." This was further complicated by the nature of succession theory development. Succession theory developed in two schools, hidden schools, as McIntosh referred to them: Clement's (holistic, super-organism) school and Gleason's (individualistic, reductionist) school.

Clements (1916) proposed that succession was a universal, orderly process of progressive change. That an ecosystem's development could be predicted was key to Clement's idea of a "climax community." Clements' basic premise, that the development of an ecosystem occurs in a deductive, deterministic fashion, continues to be the foundation for many ecological discussions (Odum 1977).

Gleason (1926), proposed that succession was determined by random interactions between populations within an ecosystem. Gleason viewed succession not as an orderly and predictable phenomenon, but as a random process with each successional change depending entirely on the chance interaction between populations in an ecosystem.

Two approaches for studying ecosystems developed from these early schools of succession theory. The Clements approach emphasized function, and the focus was on a holistic view of energy flow between the communities of an ecosystem. The Gleason approach focused on the structure of an ecosystem. This view emphasized the assessment of individual populations within an ecosystem. These different philosophies have caused extensive debate among ecologists. At least some have recognized the value of both philosophies as a unified concept (Odum 1968, 1977). However, the points that unify these ecological philosophies should be clarified for ecologists to resolve current environmental problems such as water and air pollution (Conway 1988, Norton 1988, Leopold 1949).

In 1901, Cowles spoke of ecology as a study in dynamics. He said "we are trying to hit a moving target" (cited in McIntosh 1980). McIntosh (1980) has clarified many of the differences between Clement's functional philosophy and Gleason's structural philosophy by referring to Cowles' idea of a dynamic ecosystem. The common ground between the two philosophies was the dynamic character of ecosystems. Structure and function together give us a broader perspective of the dynamic character of an ecosystem. As the dynamic character of ecosystems is better understood (through continued experimentation) the various "schools of thought" should converge to form common goals.

In order to subject succession theory to experimentation, appropriate models and designs must be utilized. Phytoplankton have been used extensively as models to investigate succession and colonization (Reynolds 1980,1984, Goldman 1974, 1977, Harris 1984, 1986, Lack and Lund 1974). Phytoplankton may have many generations in one year and cycles in these communities can be observed in a relatively short period of time (Harris 1986). By manipulating the physical and chemical environment, phytoplankton communities can be adjusted or managed to the needs of our studies (Harris 1986). The ability to validate field observations of algal communities has been facilitated by the success of culturing and observing algae in the laboratory (Goldman 1974, 1977).

A variety of experimental designs have incorporated algae to monitor changes in environmental conditions of aquatic systems, e.g., the experiments of Lack and Lund (1974), and Lund (1972) in the English Lake District. They utilized plastic enclosures (isolation tubes) to separate and observe changes in the phytoplankton communities over a 2.5-yr period. The isolation tubes enclosed an entire column of water from the surface down to and including the benthos. These tubes were useful for manipulating isolated communities within a larger system (in this case a small temperate lake). Parker et al. (1971) utilized similar acrylic plastic cylinders and 1-L polyethylene bags suspended by a polystyrene grid for assaying enzyme concentration effects on *in situ* phytoplankton communities. In this case, small field enclosures were successful in testing a range of dose effects of two commercial alkaline protease preparations in a cost-effective fashion. In addition, Parsons and Parker (1989) have used algae to monitor stress in Mountain Lake, an oligotrophic lake in the Allegheny mountains of southwestern Virginia. Kuhn et al. (1981) examined diatom communities that colonized artificial substrates in relation to prevailing environmental conditions along a eutrophic gradient of Smith Mountain Lake, Va. A model was derived from this latter study to provide a framework for describing complex aquatic habitats and interpreting successional changes occurring on the substrates.

Experiments conducted in systems that more closely represent a natural ecosystem can provide information with either increasing precision or accuracy (Lundgren 1985, Smith 1988, Dudzik 1979). In toxicity testing, the multispecies test has been discussed as a replacement for the single species test (e.g., Cairns 1985). An advantage to the multispecies test is the use of important ecological rate processes rather than lethality as end points (Cairns 1985). Recently there also has been a variety of studies that used enclosures or artificial impoundments in both ecological studies and toxicity testing (e.g., Giddings 1978, Eppley 1978, Bryfogle 1979, Dudzik 1979, Elliott 1983, Solomon 1986, Vanni 1987, Kerfoot 1987). Some of these studies date back to the 1960's (Goldman 1962, Beyers 1963) and the idea of investigation at the ecosystem level dates back as early as 1887 (Forbes 1887). While plankton (and specifically phytoplankton) communities have been observed or manipulated in many of the above mentioned studies, it is important for investigators to combine data from various trophic levels to understand the emergent properties of ecosystems (Odum 1984).

Experimental mesocosms provide a means to integrate studies on various components of an ecosystem (Lundgren 1985, Odum 1984). In addition, mesocosms offer the advantage of a design that can simulate natural systems in both structure and function. deNoyelles and Kettle (1985) used a field and lab study to validate the use of experimental ponds as test systems for prediction of effects of the herbicide atrazine in aquatic ecosystems. Their results were useful for assessing the safety of this chemical for public use. Structural and functional features of test systems have been found to become less variable over time. This was true for enclosures (Lack and Lund 1974) and with experimental ponds (deNoyelles et al. 1982, 1985, Hill 1985). In addition, the temporal variations of algae in experimental freshwater systems has been found to follow patterns associated with seasonal conditions and water quality (Reynolds 1980, 1984, Wetzel 1983). The goal of this study was to investigate the role of phytoplankton in the maturation of mesocosms and evaluate its use in ecological and risk assessment studies.

Risk Assessment

The use of mesocosms as test systems in ecological risk assessment is the state of the art (Jenkins et al. 1989). Experiments conducted in systems that more closely represent natural ecosystems can provide information with either increased precision or accuracy (Lundgren 1985, Smith and Mercante 1988, Dudzik 1979). The use of aquatic field studies is now required by the USEPA for registering pesticides that trigger concern (e.g., 40 CFR 158). These studies include the use of farm ponds (single or multiple impoundments) or replicated mesocosms (Touart 1988). Phytoplankton have been used extensively as experimental organisms in ecological studies because of their importance in trophic dynamics, as well as for their ease of manipulation (Harris 1986). Consequently, this parameter has been included in mesocosm studies.

Considerable gaps exist in our knowledge about the performance of mesocosms (Voshell 1989). While the USEPA has not written a specific protocol for these systems, protocols are reviewed and adapted for specific situations (Buikema pers. comm.). A generic guide has been provided (Touart 1988); this document, while providing information on the design of the ponds and the general experimental design of a test, does not provide specific information on the age or maturity of ponds that should be used in an official data requirement test. No information is available as to the number of replicate units needed to measure significant differences in taxa richness and density, chlorophyll a, and primary productivity. While there have been studies which examine the effects of various hazardous chemicals on phytoplankton in mesocosms (Hill 1985, deNoyelles and Kettle 1985), none have investigated the precision of measurements in mesocosms during their early colonization period to evaluate their usefulness in hazard assessment. Jenkins (unpublished PhD dissertation) has used multivariate techniques (Green 1980) to analyze the degree of similarity between ponds. Among his findings, he found that pond placement and date of completion had no effect on the chemical or physical characteristics of the ponds.

Objectives

As part of a multi-disciplinary study, this research was intended to answer questions about the biota that colonize new experimental ponds. For the first year, phytoplankton colonization and periodicity was monitored. The data were used to evaluate the future use of the ponds as replicate test units. Assuming that the 12 experimental ponds have statistically similar physical and chemical characteristics, the colonization and succession of phytoplankton in the ponds should be similar. Specifically, the objectives were:

1. To describe initial phytoplankton colonization and seasonal succession over a one year period after filling the ponds.
2. To analyze various parameters of the phytoplankton community that could be used for testing the effects of hazardous chemicals.

Materials and Methods

Design

To meet the above objectives, information was collected on the following parameters: taxa richness, taxa and total density, biomass (chlorophyll a), primary productivity, and physico-chemical analysis. This study ran from February 5, 1988 through February 10, 1989. Samples were collected bimonthly except from March 30 through October 10 when the water temperature >10°C; then weekly samples were collected. Subsamples were collected and pooled for each pond at each collection time; each pond was treated as an experimental unit for analyses. A record book was kept on site to record amounts of water added to the ponds as well as general notes about the site which included weather information.

Study Site

A mesocosm facility was constructed according to USEPA guidelines (Touart 1988, Touart and Slimak 1989) at the VPI&SU Southern Piedmont Agricultural Experiment Station near Blackstone VA (long. 77°57' 30" W lat. 37°5'30" N). The facility was located within the Piedmont Physiographic Province. Elevation was 128 m (above MSL), mean annual temperature was 14.4°C, and mean annual precipitation was 105.8 cm. Several impoundments were located near the site ranging in size from 0.04 to 2 ha. Among the largest was an irrigation pond (1.5 ha) located on the station grounds 0.5 km north-east of the mesocosms and separated from the mesocosms by pine forests (Layton 1989).

The facility was constructed during Summer and Autumn 1987 and consisted of 12 square 0.04 ha ponds and a 0.36 ha reservoir. Each pond was 2.1 m deep with sides sloping at 2.5:1 and contained a volume of 517 m^3. The ponds were lined with a 15-cm layer of compacted clay (from excavation) and topped with a 15-cm layer of the sandy-loam top soil, which was initially scraped off of the site. The mesocosms were filled between January 25 - 31, 1988 from the local municipal water supply; the municipal water had no toxic effects based on a chronic 7-d Ceriodaphnia toxicity study. Pond levels were maintained with well water. The ponds were immediately colonized by zooplankton (Jenkins, pers. comm.).

Sediments in the ponds were analyzed before the ponds were filled and again one year later by the Soil Testing and Plant Analysis Laboratory, Dept. of Agronomy, VPI&SU (Table 1). Sediments were collected from the bottom and sides of each pond, mixed and subsampled. Before the ponds were filled, soil and water used were analyzed for pesticide residues by the Pesticide Analysis Laboratory, Dept. of Biochemistry and Nutrition, VPI&SU. Results were negative for both a general pesticide scan as well as for specific chemicals known to have been used in the area.

Sampling and Analyses

A Weather Measure® pyreheliometer was set up just prior to dawn at the site to record photosynthetically active radiation. Data on precipitation and air temperature were obtained from the agricultural station's weather monitoring records. Dissolved oxygen and temperature were measured with a YSI® meter (model 54A) and probe at 15 cm, 1 and 2 meters. Light penetration was measured with a Secchi disk. An integrated depth sample of water was collected with a .04 m x 2 m transparent acrylic plastic tube sampler (Ganf

1974; Appendix 1). Subsamples were collected in equal proportions from the middle and two sides of a pond chosen at random. The subsamples were then pooled and mixed. The pH was measured on the pooled sample using an Orion® model 407A meter with a Fisher® model SN8057164 probe. Four 600-ml aliquots from each pond were stored on ice for transport to Blacksburg for analysis of alkalinity, hardness, conductivity, ammonia, and organic phosphorus according to Standard Methods (APHA et al. 1985). Nitrate and nitrite were also measured from these aliquots with a Dionex® model 14 ion chromatograph. An additional 200-ml. aliquot was preserved with 2% acid Lugol's solution for subsequent phytoplankton identification and enumeration (APHA et al. 1985).

In the laboratory, each 200-ml aliquot of preserved phytoplankton was stirred and poured into a 7.7 cm x 14.4 cm (outside measurement) glass settling jar. Jars were stored in the dark for at least 1 wk, after which the supernatant was decanted and the remaining sample was thoroughly mixed and poured into a 5.3 cm x 7.0 cm (outside measurement) glass jar for further settling. After at least 2 wk, the supernatant of each sample was siphoned leaving approximately 20 ml to be transferred for final settling. The final volume of sample was recorded for later calculations. Final settling occurred for at least 1 mo in a 2.7 x 9.5 cm (outside measurement) glass settling vial. The final volume was brought down to 5 ml, from which three 0.1-ml aliquots were examined at 500 X magnification in a Palmer-Maloney phytoplankton counting cell (APHA et al., 1985) for taxa identification. For taxa density, an entire Whipple counting grid field was counted.

An 800-ml aliquot was taken for two 400-ml filtrations on Whatman® GF/C filters to collect phytoplankton for chlorophyll a determinations (Ganf 1974, APHA et al. 1985). Filters were stored in sealed test tubes and were placed on dry ice for transport back to the laboratory. In the laboratory they were stored in a freezer (< -20°C) until analyzed. Samples were stored for a maximum of 72 hr when pH<7.00 and for 1 wk when pH>7.00 (Parker, pers. comm.). Samples were extracted by grinding in a 90:10 acetone: $MgCO_3$ mixture (APHA et al. 1985) and analyzed on a Perkin-Elmer® spectrophotometer (Model 552, Norwalk CT).

Dissolved oxygen was used to measure primary productivity (Harris 1984, APHA et al. 1985). Two light and two dark BOD bottles were filled for primary productivity measurements. Dissolved oxygen was measured from one of these bottles with a YSI® meter (model 54A) and a BOD bottle probe for the zero time dissolved oxygen measurement. Bottles were suspended in each pond at one-half the Secchi depth for a 3 - 5 hr incubation period. At the end of incubation, dissolved oxygen was recorded from each bottle using the dissolved oxygen meter and probe described above. Calculations of primary productivity were made (APHA et al. 1985).

Data were stored as Microsoft® Excell spreadsheets on a Apple™ Macintosh SE/30 computer. Statistical analysis was performed using Statworks™ software for the Macintosh. Linear regressions were performed to test for dependant relationships. ANOVA was performed on data to test for relationships and variability between ponds.

Results

Environmental Characteristics

Dissolved oxygen, temperature, pH, hardness, and alkalinity were similar between ponds (Table 2). As expected, dissolved oxygen concentrations were inversely associated with water temperature during the study period (Fig. 1). The pH and alkalinity increased over the year (Fig's. 2 and 3). This was expected with increases in biological activity in the ponds. The aberration in hardness measurements (Fig. 4) during October, November, and December was due to an analytical error because the buffer was defective, therefore, an approximate line was drawn between September and January. This was justified as other chemical parameters did not differ significantly during that period.

Secchi depth was variable between ponds during the study period (Table 2). An inverse relationship between chlorophyll a and Secchi depth was seen during the summer months (Fig. 5). Conductivity was similar during the year, but the standard deviation was high at any given date (Fig. 6). Employment of Tukey's multiple comparison test identified differences in conductivity among ponds (Table 3). Group 3 received the most well water during the year, and group 1 received the least; group 2 received an intermediate amount of well water.

Although the air temperature dropped below freezing during January and February of 1989, the ponds did not freeze (Figs. 7 and 8). During the coldest periods a thin layer of ice formed overnight on some ponds, however, this melted after sunrise. There was no thermal stratification during the study period.

Concentrations of NH_3, NO_3, NO_2, and PO_4 were usually at or below detection (Table 2). Levels of NH_3 and NO_3 dropped over the year (Fig's. 9 and 10). The peak in NO_2 during May and June may be due to the cycling of nitrogen (Fig. 11). Except for

November, PO4 concentrations were near the lowest limit of detection (Fig. 12).

Macrophytes were first observed in the ponds during June, 1988. By late summer, dominant emergent genera included Carex, Cyperus, Eliochorus, Hypericum, Juncus, Ludwigia, and Typha. There was no submerged or floating vegetation.

Phytoplankton Colonization

Table 4 lists the phytoplankton that occurred in the ponds. Only 7 out of 40 taxa were observed in all 12 ponds. Of these seven, only Chlorococcales sp1, Dinobryon, and Peridinium, were observed consistently from May 1988 through Feb. 1989. The total number of taxa that accrued in the ponds increased during the year and peaked during the Fall (Fig. 13). However, the number of taxa found in any one pond on a given date varied among ponds and over time (Fig. 14). Phytoplankton periodicity also varied among major taxa (Figs. 15 - 20). While algal densities varied among ponds throughout the year, the data indicate similar successional patterns among ponds. Algal biomass, measured as chlorophyll a, was also variable among ponds (Fig. 21). The coefficients of variation for group densities and biomass were high throughout the year (Table 5).

Phytoplankton Periodicity

Seasonal periodicity in the major taxonomic groups occurred (Figs. 15 - 20). Densities were converted into biovolume using geometric conversions as described by Rice (1936). While Dinobryon, Chlorophyceae, and Desmidaceae density dominated at various times of the year (Table 6), Dinobryon and the Dinophyceae dominated in biovolume (Table 7). There were no positive or negative associations between chlorophyll a and biovolume.

Phytoplankton Function

Fig. 21 depicts the trends and variation associated with algal biomass in the ponds as they colonized. Algal biomass was undetectable for February 1988 (Fig. 21). Algal biomass increased through August 1988. Calculated values for primary productivity averaged 5.5 mg carbon fixed/m^3 throughout the year except for June - July (Fig. 22). Changes in primary productivity could not be detected using the *in situ* oxygen method due to the low biomass of phytoplankton and the oligotrophic nature of the ponds.

Precision of Community Structure Parameters

Levels of precision for four commonly reported parameters were calculated (Figs. 23-28) using the equation of Elliot 1977 (cited in Layton 1989):

$$n = (t^2 s^2)/(D^2 x^2)$$

where n = the number of ponds needed at a given level of precision; D = precision as relative error in terms of 95% confidence limits of the mean; x = the mean; s^2 = the sample variance; and t^2 = the students t-distribution value corresponding to n-1 degrees of freedom (Zar 1984). Data from May 1988 to February 1989 were used for these calculations because the ponds were well colonized by this time. The level of precision increases as the number of replicate ponds increases (Figs. 23-30). Increased precision appears to diminish after six replicate ponds.

Discussion

Environmental Characteristics

The issues of importance in the USEPA design of mesocosms are the precision of the measurements that can be obtained and the cost effectiveness (practicality) of the facility (Touart 1988, Touart and Slimak 1989). The mesocosms investigated in this project were quite similar in terms of physical/chemical parameters. Coefficients of variation for dissolved oxygen, temperature, pH, hardness, and alkalinity rarely exceeded 10 percent. Although conductivity varied, those ponds with the lowest conductivity had the largest amount of well water added to correct for differential evaporation or leakage; the well water was softer than the water originally used to fill the ponds.

The variation in Secchi depth can be attributed to changes in planktonic communities during the year. Mazumder et al. (1989) showed that Secchi depth was largely a function of size distribution and biomass of algae; usually high densities of smaller phytoplankton were associated with a more shallow Secchi depth measurement. There was an inverse relationship between Secchi depth and chlorophyll a in this study (using mean Secchi depth and mean chlorophyll a, Fig. 5); this relationship departed during the last two months of the study. During this time the desmids were the dominant taxa. All other taxa (except the dinoflagellates and Dinobryon) were declining in density. This rise in desmid density probably contributed to the increase in chlorophyll a during these months, but did not affect Secchi depth. This scenario is different than that observed by Mazumder et al. (1989). The desmids observed during the last three months of this study were among the smallest phytoplankton measured. The decrease in zooplankton densities during this time (especially rotifers) may be a factor in this discrepancy (Jenkins, pers. comm.). The desmids' thick cellulose cell walls make them difficult for most zooplankton to consume, thus, contributing to lower zooplankton densities and deeper Secchi depth measurements.

Phytoplankton Colonization

The colonizing algal taxa (taxa accrued over time) in the experimental ponds were similar to taxa expected in small, soft-water impoundments (Harris 1986, Wetzel 1983). The taxa were *Dinobryon* , Dinophyceae (especially *Peridinium* and *Glenodinium*), Cyanophyceae, and Desmidaceae. In addition, the seasonal periodicity of these taxa was also similar to expected trends (Harris 1986, Wetzel 1983). Chlorophyceae were dominant during the summer and the desmids increased during the cooler Fall months.

The significant variation in taxa densities between ponds presents a problem in using the USEPA's mesocosm guidelines when the ponds have had only one year to colonize (Touart 1988). In addition to the variation in densities, biomass (as chlorophyll *a*) was also highly variable. With these high variations, the ponds should mature longer or be managed. Touart (1988) recommended augmenting the biota of mesocosms with organisms from another established pond. Other options to reduce variability include mixing of the water among ponds or filling all ponds from a source pond (reservoir). However, these options may not be appropriate for newly constructed mesocosms before they can be used in a toxicity study. Premature homogenizing efforts may be confounded by natural biological and chemical maturation processes and may not decrease the variability due to the rapidly reproducing populations of phytoplankton.

Phytoplankton Periodicity

Algae have been found to recover and establish early successional stages rapidly after a catastrophe (Harris et al. 1984, Rushforth et al. 1986). The phytoplankton colonizing the ponds established expected periodicity patterns both as densities and biovolumes (Harris 1986, Wetzel 1983). However, Dinobryon, which was the dominant taxon in terms of biovolume, exhibited no seasonal periodicity compared to the other groups. This may be due to the ability of Dinobryon to shift between autotrophy and phagotrophy. Bird and Kalff (1986, 1989) have documented the role of Dinobryon as a phagotroph. The use of ^{14}C-labeled bacteria enabled them to calculate Dinobryon's contribution to secondary production. They found that under low light conditions, Dinobryon "switched" into phagotrophic mode. The data collected in the experimental ponds suggests that Dinobryon may be phagotrophic even if light was not limiting. Low nutrients and high bacterial cell numbers may also be factors affecting the trophic state of Dinobryon.

Phytoplankton Function

The issue of phytoplankton function has not been addressed in previous mesocosm studies. The importance of phytoplankton as carbon fixers has been well documented (Harris 1986). An inverse relationship between phytoplankton productivity and biomass has been documented in many studies e.g., Harris 1986, Vollenweider and Nauwerck 1971). No expected relationships such as an inverse correlation between biomass and primary productivity (Amezaga et al. 1973) were detected. While primary productivity may be valuable as an end-point rate measurement, the oxygen method failed to detect carbon fixation in this study because the amount of oxygen produced could not be detected with the oxygen probe. The *in situ* oxygen method is a practical and reliable method (APHA et al. 1985) and may be useful in mesocosms with more mature communities and higher concentrations of nutrients: in this study the ^{14}C method would have been a more useful technique. High densities of zooplankton, through respiratory O_2 uptake, might also interfere with measurements of primary productivity in mesocosms. A more intensive study to determine phytoplankton function in mesocosms is necessary.

Precision of Community Structure Parameters

To determine a statistically significant impact of a chemical on an ecological measurement, there are two parameters which must be considered: variability of the measurement itself and the number of replicate units. The standard value of precision of measurements to obtain a significant difference is 10% (Zar, 1984). It is clear from this mesocosm study that 10% precision can only be achieved under controlled laboratory conditions. Lundgren (1985) states that "experiments in large-scale model ecosystems can provide valuable information on the fate and effects of pollutants in natural ecosystems." He also concedes that while these systems are more environmentally realistic, they are more difficult to replicate; i.e. variability is high between systems. None of the measured environmental parameters comes close to a 10% level of precision.

With the ANOVA design suggested by the USEPA (Touart 1988) there would be three replicate control ponds and three replicate ponds of three different treatment concentrations. Using three ponds per treatment, the level of precision for yearly data would be ±22% for total number of taxa accrued (Fig. 23) and ±67% for chlorophyll a (Fig. 24). Table 5 demonstrates the decrease in variation between ponds for number of taxa accrued during the year. For phytoplankton density over the season, the three most commonly observed taxa in all ponds were analyzed (Fig. 25). Levels of precision for 3 ponds were ±172% for Chlorococcales sp1 (Chlorophyceae), ±102% for both Dinobryon (Chrysophyceae) and Peridinium (Dinophyceae). Precision for group densities over the season were as follows: ±88% for the Cyanophyceae (bluegreens), ±140% for the Desmidaceae (desmids), ±109% for the Chlorophyceae (greens), ±104% for Dinobryon (in the Chrysophyceae), ±132% for the Dinophyceae (dinoflagellates), and ±296% for the Bacillariophyceae (diatoms) (Fig. 26). The high values described above were expected. Phytoplankton have short generation times and variation in densities among ponds was high. Furthermore, seasonal succession of phytoplankton also contributes to this variability because major taxa change due to temperature and availability of nutrients.

The procedure was repeated for July and October to look at data at specific points in time. Precision for three ponds improved for number of taxa, ±11% for July and ±7% for October (Fig. 27). Precision was improved for chlorophyll a in July, ±34%, but not in October, ±84% (Fig. 28). Precision was only slightly improved for group densities in July as follows: ±143% for the Cyanophyceae (bluegreens), ±91% for the Desmidaceae (desmids), ±68% for the Chlorophyceae (greens), ±72% for Dinobryon (in the Chrysophyceae), ±75% for the Dinophyceae (dinoflagellates), and ±111% for the Bacillariophyceae (diatoms) (Fig. 29). Dominant taxa precision improved in July (Fig. 30). Levels of precision were ±59% for Chlorococcales sp1 (Chlorophyceae), ±73% for Dinobryon (Chrysophyceae) and ±82% for Peridinium (Dinophyceae). October values were similar to those observed for the entire season (Fig. 25).

Precision also increased as the number of replicate ponds increased, but a large number of replicate ponds per treatment is not practical. Precision increased 1.5 fold with three ponds, 2.5 fold with six ponds, and 3.5 fold with 12 ponds. Despite the variability in ecological measurements, it appears that to maximize the detection of an effect at least six ponds per treatment are necessary. Further, variability can be reduced by longer term natural colonization or by more intensive management of ponds.

Conclusions

The mesocosms were statistically similar for most of their environmental conditions. They were colonized by expected groups of organisms and had typical seasonal fluctuations in group densities. The ponds were quite variable during the first year for algal biomass and taxa densities. Primary productivity measured by oxygen was not useful.

The colonizing algal taxa (taxa accrued over time) in the experimental ponds were similar to taxa expected in small, soft-water impoundments. The taxa were Dinobryon , Dinophyceae (especially Peridinium and Glenodinium), Cyanophyceae, and Desmidaceae. In addition, the seasonal periodicity of these taxa was also similar to expected trends . Chlorophyceae were dominant during the summer and the desmids increased during the cooler Fall months. The data indicate that a longer maturation time or management may be necessary to achieve the densities necessary to monitor both community structure and function.

The conversion to biovolume elicited some interesting aspects of Dinobryon which may otherwise have been "hidden" in the data. Because Dinobryon biovolume had no relationship to Secchi depth, then Dinobryon's trophic state may depend not only on light as has been suggested in previous studies, but may also depend on available nutrients. Dinobryon also may be able to detect bacteria in the water column.

Precision (defined as relative error in terms of 95% confidence limits of the mean) sharply increased when six ponds per group (e.g., 6 controls and 6 treatments) was used. Precision may also be a function of pond maturity and needs to be investigated further in these ponds. Simply increasing the number of ponds may not be appropriate for a set of new, colonizing and maturing ponds. Increasing the number of ponds will not decrease the importance of natural colonization and seasonal succession. The use of mesocosms as a realistic approach for studying effects of chemicals on structural and functional parameters of natural aquatic ecosystems remains an intriguing possibility. However, more assessments will be needed to thoroughly understand the limitations of this approach.

Literature Cited

American Public Health Association, American Water Works Association, and Water Pollution Control Federation [APHA et al.}. 1985, Standard methods for the examination of water and wastewater. 16th ed. American Public Health Association, Washington, D.C. 1268 pp.

Amezaga, E. De.; Goldman, C. R.; and Stull, E. A. 1973. Primary productivity and rate of change of biomass of various species of phytoplankton in Castle Lake California.. Verh. Int. Verein. Limnol. 18:1768-1775.

Beyers, R. J. 1963. The metabolism of twelve aquatic laboratory microecosystems. Ecol. Monogr. 33:281-306.

Bird, D. F.; and Kalff, J. 1986. Bacterial grazing by planktonic lake algae. Science 231:493-494.

Bird, D. F.; and Kalff, J. 1989. Phagotrophic sustenance of a metalimnetic phytoplankton peak. Limnol. Oceanogr. 34:155-162.

Bryfogle, B. M.; and McDiffett, W. F. 1979. Algal succession in laboratory microcosms as affected by an herbicide stress. Amer. Midl. Nat. 101:344-354.

Cairns, J. Jr.; Pratt, J. R.; and Niederlehner, B. R. 1985. A provisional multispecies toxicity test using indigenous organisms. J. Test. Eval. 13:316-319.

Clements, F. E. 1916. Plant Succession: An analysis of the development of vegetation. Publ. No. 242 (Washington, DC: Carnegie Institution)

Conway, H. C. 1988. Letter to the editor. Cons. Biol. 2:236-237.

deNoyelles, F. Jr.; and Kettle, W. Dean; and Sinn D.E. 1982. The responses of plankton communities in experimental ponds to atrazine, the most heavily used pesticide in the United States. Ecology 63:1285-1293.

deNoyelles, F. Jr.; and Kettle, W. Dean 1985. Experimental ponds for evaluating bioassay predictions. pp 91-103. In T.P. Boyle [ed.] Validation and Predictability of Laboratory Methods for Assessing the Fate and Effects of Contaminants in Aquatic Ecosystems. STP No. 865. American Society for Testing and Materials. Philadelphia, PA.

Dudzik, M.; Harte, J.; Jassby, A.; Lapan, E.; Levy, D.; Rees, J. 1979. Some considerations in the design of aquatic microcosms for plankton studies. Intern. J. Environ. Studies 13:125-130.

Elliott, E. T.; Castañares, L. G.; Perlmutter, D.; and Porter, K. G. 1983. Trophic-level control of production and nutrient dynamics in experimental planktonic community. Oikos 41:7-16

Eppley, R. W.; Koeller, P.; and Wallace, G. T. Jr. 1978, Stirring influences on the phytoplankton species composition within enclosed columns of coastal sea water. J. Exp. Mar. Biol. Ecol. 32:219-239.

Forbes, S. A. 1887. The lake as a microcosm. Bull. Peoria Sci. Assoc. pp 77-87.

Ganf, G. G. 1974. Phytoplankton biomass and distribution in a shallow eutrophic lake (Lake George, Uganda). Oecologia 16: 9-29.

Giddings, J.; and Eddlemon, G. 1978. Photosynthesis/Respiration ratios in aquatic microcosms under arsenic stress. J. Wat. Air Soil Pollut. 9:207-212.

Gleason, H. A. 1926. The individualistic concept of the plant association. Bull. Torrey Bot. Club 44:463-481.

Goldman, C. R. 1962. A method of studying nutrient limiting factors in situ in water columns isolated by polyethylene film. Limnol. Oceanogr. 7:99-101.

Goldman, J. C.; and Carpenter E. J. 1974. Temperature influenced species competition in mass cultures of marine phytoplankton. Biotechnol. Bioeng. 18:1125-1144.

Goldman, J. C. 1977. Temperature effects on phytoplankton growth in continuous culture. Limnol. Oceanogr., 22:932-936.

Green, R. H. 1980. Multivariate Approaches in Ecology: The assessment of ecologic similarity. Ann. Rev. Ecol. Syst. 11:1-14.

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

Harris, G. P. 1984. Phytoplankton productivity and growth measurements: past, present, and future. J. Plank. Res. 6:219-237.

Harris, L.; Ebeling, A. W.; Rowley, R .J. 1984. Community recovery after storm drainage: A case of facilitation in primary succession.. Science 224:1336-1338.

Hill, I. 1985. Effects on non-target organisms in terrestrial and aquatic environments. pp. 151-262. In J.P. Leahey [ed.]. The Pyrethroid Insecticides. Taylor and Francis, Philadelphia PA.

Jenkins, D. G.; Layton, R. J.; and Buikema, A. L., Jr. 1989. State-of-the-art in aquatic ecological risk assessment. pp.18-32. In J.R. Voshell, Jr. [ed.], Using mesocosms to assess the aquatic ecological risk of pesticides: theory and practice. Entomological Society of America Miscellaneous Publication, Lanham MD.

Kerfoot, W. C. 1987. Bosmina responses to Copepod predation. Ecology 68:596-610.

Kuhn, D. L.; Plafkin, J. L.; Cairns, J., Jr.; and Lowe, R. L. 1981. Qualitative characteristics of aquatic environments using diatom life-form strategies. Trans. Amer. Microsc. Soc. 100:165-182.

Lack, T. J.; and Lund, J. W. G. 1974. Observations and experiments on the phytoplankton of Blelham Tarn, English Lake District. I. The experimental tubes. Freshwater Biol.4:399-415.

Layton, R. J. 1989. Macroinvertebrate colonization and production in new experimental ponds. PhD dissertation, Dept. of Entomology, Virginia Polytechnic Institute and State University, Blacksburg. 196 pp.

Leopold, A. 1949. A Sand County Almanac. And Sketches Here and There. Oxford University Press, New York. 228 pp.

Lund, J. W. G. 1972. Preliminary observations on the use of large experimental tubes in lakes. Verh. Int. Verein. Limnol. 18:71-76.

Lundgren, A. 1985. Model ecosystems as a tool in freshwater and marine research. Arch. Hydrobiol./Suppl. 70:157-196.

Mazumder, A.; Taylor, W. D.; McQueen, D. J.; and Lean, D. R. S. 1989. Effects of fish and plankton on lake temperature and mixing depth. Science 247:312-315.

McIntosh, R. P. 1980. The relationship between succession and the recovery process in ecosystems. pp. 11-64. In: Cairns, J.,Jr. [ed.] The Recovery Process in Damaged Ecosystems. Ann Arbor Science. Ann Arbor MI.

Norton, B. G. 1988. What is a Conservation Biologist? Cons. Biol. 2:237-238.

Odum, E.P. 1969. The strategy of ecosystem development. Science 164:262-270.

Odum, E. P. 1977. The emergence of ecology as a new integrative discipline. Science 195:1289-1293.

Odum, E. P. 1984. The mesocosm. BioScience 34:558-562.

Reynolds, C.S. 1980. Phytoplankton assemblages and their periodicity in stratifying lake systems. Holarctic Ecol. 3:141-159.

Reynolds, C. S. 1984. Phytoplankton periodicity: the interactions of form, function and environmental variability. Freshwater Biol. 14:111-142.

Rice, J. M. 1936. Geometry. pp32-53. In O.W. Eshbach. [ed.] Handbook of Engineering Fundamentals. Wiley Engineering Handbook Series 2. J. Wiley and Sons, Inc. New York NY.

Parker, B. C.; Samsel, G. L.; and Obeng-Asamoa, E. K. 1971. Effects of detergent protease enzymes on sewage oxidation pond phytoplankton. BioScience 21:1035-1039.

Parsons, M. J.; and Parker, B.C. 1989. Mountain Lake, Virginia: an oligotrophic lake under increasing stress. Cur. Pract. Environ. Sci. Eng. 4:1-20.

Platt, T.; Subba Rao, D.V.; and Irwin, B. 1983. Photosynthesis of picoplankton in the oligotrophic ocean. Nature 189:702-704.

Rushforth, S. R.; Squires, L.E.; Cushing, C.E. 1986. Algal communities of springs and streams in the Mt. St. Helens region, Washington, U.S.A. following the May 1980 eruption.. J. Phycol. 22:129-137.

Smith, E. P.; and Mercante, D. 1988. Statistical concerns in the design and analysis of multispecies microcosm and mesocosm experiments. Technical Report # 88-9, Dept. of Statistics, Virginia Polytechnic Institute and State University, Blacksburg. 28 pp.

Solomon, K. R.; Yoo, J.Y.; Lean, D.; Kaushik, N.K. 1986. Methoxychlor distribution, dissipation and effects in freshwater limnocorrals. Env. Tox. Chem. 5:577-586.

Sommer, U. 1985. Seasonal succession of phytoplankton in lake Constance, Switzerland. Bioscience 35:351-357.

Touart, L.W. 1988. Aquatic mesocosm tests to support pesticide registration. Hazard Evaluation Division, U.S. Environmental Protection Agency, Washington, D.C. EPA 540/09-88-035.

Touart, L.W.; and Slimak, M.W. 1989. Mesocosm approach for assessing the ecological risk of pesticides. pp.33-40. . In J.R. Voshell, Jr. [ed.], Using mesocosms to assess the aquatic ecological risk of pesticides: theory and practice. Entomological Society of America Miscellaneous Publication, Lanham MD.

Vanni, M. J. 1987. Effects of nutrients and zooplankton size on the structure of a phytoplankton community. Ecology 68:624.

Vollenweider, R. A.; and Nauwerck, A. 1971. Some observations on the ^{14}C method for measuring primary production. Verh. Int. Verein. Limnol. 14:134-139.

Voshell, J. R., Jr. 1989. Introduction. pp.1-3. In J.R. Voshell, Jr. [ed.], Using mesocosms to assess the aquatic ecological risk of pesticides: theory and practice. Entomological Society of America Miscellaneous Publication, Lanham MD.

Wetzel, R. G. 1983. Limnology. Saunders College Publishing, New York, NY 767 pp.

Zar, J. H. 1984. Biostatistical Analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, N.J. 718 pp.

Table 1. Pond sediment characteristics as measured by the Soil Testing and Plant Analysis Laboratory, Dept. of Agronomy, Virginia Tech Detection ranges are specified within parentheses.

parameter	Dec. 1987	Feb. 1989
pH (units)	5.5 (5.2-5.7)	5.6 (5.2-6.1)
Phosphorus (ppm)	1.3 (1-2)	1.0 (1-1)
Potassium (ppm)	33.9 (25-40)	36.6 (31-39)
Calcium (ppm)	308.0 (168-396)	519.0 (468-588)
Magnesium (ppm)	56.8 (41-63)	53.3 (41-59)
Soluble Salts (ppm)	1.0 (1-1)	3.1 (1-26)
NO_3,N (ppm)	5.3 (3-8)	3.3 (3-5)
Manganese (ppm)	1.0 (0.6-1.4)	7.2 (5.5-8.6)
Zinc (ppm)	1.0 (0.6-1.4)	1.3 (1.2-2.0)
Organic Matter (%)	2.1 (1.4-2.8)	2.3 (2.0-2.7)

Table 2. Summary statistics for physical & chemical parameters for all twelve Ponds

Date	Value	D.O. mg/L	Temp °C	pH units	Secchi m	NH_3* mg/L	NO_3* mg/L	NO_2* mg/L	PO_4* mg/L	Hard. mg/L	Alk. mg/L	Cond. µmho
5	Min	9.0	5.0	6.8	0.6	0	0	0	0.0	70.0	28.6	163.4
Feb	Max	12.2	7.4	6.9	1.2	0.04	4.0	0.2	0.2	75.0	31.2	233.9
88	Mean	10.3	6.2	6.9	0.8	0.02	1.1	0.1	0.04	72.9	30.1	199.0
	S.D.	0.8	0.7	0	0.2	0.02	1.0	0.1	0.1	2.6	1.2	23.9
	C.V.	7.9	11.8	0.7	27.5	105.0	87.6	110.	124.	3.5	4.1	12.0
4	Min	10.4	8.0	6.7	0.8	0.02	0.6	0	0	65.0	28.6	159.5
Mar	Max	11.6	9.0	7.0	1.1	0.2	2.7	0.2	0.1	75.0	36.4	235.5
88	Mean	11.2	8.5	6.8	0.9	0.1	1.3	0.04	0.02	73.3	32.7	202.0
	S.D.	0.3	0.4	0.1	0.1	0.1	0.5	0.1	0.04	3.3	2.3	24.7
	C.V.	2.8	5.0	1.1	12.6	75.1	39.5	171.	170.1	4.4	7.2	12.2
1	Min	9.6	14.0	6.8	0.6	0	0.3	0.01	0	70.0	26.0	178.8
Apr	Max	10.6	17.0	7.1	1.2	0.2	1.7	0.1	0.1	75.0	33.8	237.6
88	Mean	10.1	16.2	6.9	0.9	0.1	0.9	0.03	0.02	71.3	30.3	203.7
	S.D.	0.4	0.8	0.1	0.2	0.1	0.4	0.02	0.03	2.3	2.6	20.9
	C.V.	3.5	4.8	1.6	20.2	93.4	39.4	66.2	145.9	3.2	8.4	10.3
13	Min	7.4	20.0	7.0	0.5	0	0	0.2	0	70.0	28.6	169.5
May	Max	10.8	21.0	7.6	1.5	0.1	1.5	0.6	0.1	80.0	44.2	235.8
88	Mean	9.0	20.9	7.2	0.8	0.1	0.4	0.4	0.1	75.0	35.6	205.7
	S.D.	1.0	0.3	0.2	0.3	0.4	0.4	0.1	0.1	4.3	5.1	22.6
	C.V.	10.7	1.5	2.4	39.7	85.5	110.	27.6	76.6	5.7	14.4	10.9
10	Min	6.6	20.0	7.0	0.5	0.03	0.01	0.7	0	65.0	33.8	175.0
Jun	Max	10.1	22.0	7.3	1.1	0.1	0.3	1.7	0.01	80.0	46.8	238.0
88	Mean	8.3	20.9	7.2	0.8	0.1	0.1	0.9	0.001	72.5	40.3	207.3
	S.D.	1.2	0.6	0.1	0.2	0.03	0.1	0.3	0.002	4.5	4.4	20.4
	C.V.	13.5	3.1	1.4	20.6	42.1	83.7	27.6	200.9	6.2	10.8	9.9
8	Min	7.3	27.0	7.0	0.9	0.0	0	0	0.008	65.0	38.0	163.2
Jul	Max	9.6	29.5	7.5	1.8	0.1	0.2	0	0.03	80.0	51.3	239.7
88	Mean	8.3	27.8	7.3	1.2	0.02	0.1	0	0.02	73.8	44.0	205.4
	S.D.	0.8	0.8	0.2	0.3	0.02	0.1	0	0.01	4.3	3.9	22.0
	C.V.	9.1	2.9	2.3	20.9	101.	77.6	0	29.6	5.9	8.8	10.7

Table 2. Continued

Date	Value	D.O. mg/L	Temp °C	pH units	Secchi m	NH_3* mg/L	NO_3* mg/L	NO_2* mg/L	PO_4* mg/L	Hard. mg/L	Alk. mg/L	Cond. µmho
5	Min	6.6	29.0	7.0	0.9	0	0	0	0	55.0	39.9	148.7
Aug	Max	8.4	30.0	7.7	2.1	0.04	0.5	0.05	0.03	75.0	53.2	236.6
88	Mean	7.4	29.6	7.3	1.4	0.003	0.06	0.01	0.01	65.4	47.3	206.1
	S.D.	0.5	0.3	0.2	0.4	0.01	0.15	0.01	0.01	7.3	4.3	28.6
	C.V.	6.9	1.1	3.2	29.0	346.4	272	228	64.1	11.2	9.0	13.9
16	Min	7.7	23.0	7.4	1.1	0	0	0	0	60.0	38.0	149.6
Sept	Max	11.0	24.0	8.6	2.2	0.1	0.09	0.01	0	80.0	49.4	246.9
88	Mean	8.7	23.5	7.7	1.7	0.02	0.02	.001	0	66.7	47.0	205.1
	S.D.	0.8	0.5	0.3	0.4	0.02	0.03	.002	0	7.8	3.6	26.4
	C.V.	9.3	1.9	4.0	26.0	94.8	167	346	0	11.7	7.7	12.9
14	Min	9.6	13.0	7.4	0.9	0	0	0	0	30.0	41.8	139.3
Oct	Max	11.2	14.0	8.2	2.1	0.1	0.1	0	0	50.0	55.1	252.5
88	Mean	10.0	13.5	7.9	1.7	0.03	0.02	0	0	44.2	48.6	205.6
	S.D.	0.4	0.3	0.2	0.5	0.02	0.02	0	0	6.7	4.5	32.8
	C.V.	4.1	2.4	2.5	27.7	65.3	98.8	0	0	15.1	9.2	15.9
18	Min	10.0	10.2	7.4	0.6	0	0	0	0	30.0	45.6	150.6
Nov	Max	11.2	11.5	7.8	1.7	0.1	0.03	0.02	0.7	40.0	51.3	241.9
88	Mean	10.6	10.9	7.6	0.8	0.02	0.004	0.001	0.2	35.0	47.7	202.5
	S.D.	0.4	0.4	0.1	0.4	0.02	0.01	0.01	0.2	5.2	2.1	34.3
	C.V.	3.6	3.8	1.9	44.6	96.1	216	346	127.6	14.9	4.3	16.9
16	Min	11.6	3.5	7.4	0.8	0	0	0	0.001	38.0	38.0	160.1
Dec	Max	12.6	4.0	7.8	2.1	0.01	0.05	0.02	0.004	40.0	49.4	244.0
88	Mean	12.1	3.9	7.6	1.4	0.002	0.01	.001	0.003	30.0	45.9	197.7
	S.D.	0.4	0.2	0.1	0.5	0.004	0.02	0.01	0.001	4.3	3.52	29.9
	C.V.	3.2	3.8	1.6	35.1	233.6	142	346	42.6	14.2	7.66	15.1
13	Min	11.4	5.5	7.5	0.8	0	0	0	0.001	50.0	36.1	146.4
Jan	Max	12.2	7.8	8.7	2.0	0.04	0	0	0.02	70.0	43.7	245.4
89	Mean	11.7	6.6	7.8	1.3	0.01	0	0	0.01	56.7	41.6	197.6
	S.D.	0.2	0.8	0.4	0.4	0.01	0	0	0.01	6.5	2.4	30.7
	C.V.	1.8	12.7	4.6	29.7	199.6	0	0	82.2	11.5	5.7	15.5

Table 2. Continued

Date	Value	D.O. mg/L	Temp °C	pH units	Secchi m	NH_3* mg/L	NO_3* mg/L	NO_2* mg/L	PO_4* mg/L	Hard. mg/L	Alk. mg/L	Cond. µmho
10	Min	11.4	3.8	7.4	0.8	0	0	0	0.02	50.0	34.2	159.1
Feb	Max	12.8	4.8	7.8	2.1	0.03	0	0	0.03	70.0	49.8	230.2
89	Mean	11.9	4.3	7.6	1.4	0.01	0	0	0.02	60.0	43.6	198.5
	S.D.	0.4	0.4	0.1	0.4	0.01	0	0	0	6.0	4.2	26.9
	C.V.	3.3	8.8	1.5	31.0	71.6	0	0	6.2	10.1	9.7	13.5
Grand	Min	9.1	14.0	7.1	0.8	0.0	0.1	0.1	0.0	55.2	44.1	158.7
Means	Max	11.1	15.5	7.7	1.7	0.1	0.8	0.2	0.1	68.5	45.8	239.8
	Mean	10.0	14.8	7.4	1.2	0.0	0.3	0.1	0.0	61.3	41.1	202.8
	S.D.	0.6	0.5	0.2	0.3	0.1	0.2	0.0	0.0	5.0	3.4	26.5
	C.V.	6.1	4.9	2.2	28.0	123.9	103	128	82.4	9.0	8.2	13.1

* Detection limits:

NH_3 (0.02-5.00 mg/L)
NO_2 (By Ion Chromatography)
NO_3 (By Ion Chromatography)
PO_4 (0.02-2.00 mg/L)

Table 3. Variation of conductivity between ponds. Significantly different groups defined by Tukey's analysis of multiple comparisons.

Group 1 ponds	Group 2 ponds	Group 3 ponds
1	10	6
2	9	8
3	5	
4		
7		
11		
12		

Table 4. Phytoplankton collected in the experimental ponds between Feb. 5, 1988 and Feb. 10, 1989.

Genus	Class/Family	Date/Pond first observed @	Date/Pnd lastObserved	All 12 Ponds
Chroococcus	Cyanophyceae	4-Mar-88 P08	16-Sep-88 P11	***
Anabaena	Cyanophyceae	4-Mar-88 P08	10-Jan-89 P12,11,7,6,4,2	***
Chlorococcales sp1	Chlorophyceae	01-Apr-88 all Exc P04	10-Jan-89 P06	10Jun88
Chlorococcales sp2	Chlorophyceae	01-Apr-88 P5,6,10,11	10-Feb-89 P5,10,11,12	***
Dinobryon	Chrysophyceae	01-Apr-88 ALL	10-Jan-89 Exc. 3,6	1Apr88
Staurastrum sp1	Desmidaceae	01-Apr-88 P3	13-Jan-89 P9	***
Cosmarium sp1	Desmidaceae	01-Apr-88 P9	18-Nov-88 P3,5	***
Gymnodinium	Dinophyceae	13-May-88 ALL Exc 7	10-Feb-89 P5,6,9,10,12	***
Closteriopsis	Chlorophyceae	13-May-88 P2,6	10-Feb-89 ALL Exc 7,9	14Oct88
Cosmarium sp2	Desmidaceae	13-May-88 ALL Exc 7	10-Feb-89 ALL Exc 5,8	***
Cosmarium sp3	Desmidaceae	13-May-88 P3,6	16-Sep-88 P1,2,4	***
C.panamense (sp4)	Desmidaceae	13-May-88 P4,8	18-Nov-88 P9	***
Peridinium	Dynophyceae	13-May-88 ALL Exc 10	10-Feb-89 ALL	10Feb89
Pennate Diatom sp1	Bacillariophyceae	13-May-88 P1,3,4,6,11,12	10-Feb-89 P12	***
Cosmarium sp5	Desmidaceae	13-May-88 P1,2,3,5,7,9	5-Aug-88 P4,10	***
Oscillatoria	Cyanophyceae	4-May-88 P9	13-Jan-89 P3,9	***
Desmidium type	Desmidaceae	13-May-88 P2,3,9	10-Jun-88 P3	***
Dactylotheca	Chlorophyceae	13-May-88 P2,11	13-May-88 P2,11	***
Coccomyxaceae sp1	Chlorophyceae	13-May-88 P2,7,11	13-Jan-89 P12	***
Coccomyxaceae sp2	Chlorophyceae	13-May-88 P2,11	16-Dec-88 P7,10,12	***
Palmellaceae sp1	Chlorophyceae	10-Jun-88 P5,10,12	10-Jan-89 P12	5Aug88
Coelastrum	Chlorophyceae	10-Jun-88 ALL Exc 4,6,9	10-Feb-89 P12	***
Kirchneriella	Chlorophyceae	10-Jun-88 ALL Exc 9	16-Dec-88 P1	8Jul88
Pennate diatom sp2	Bacillariophyceae	10-Jun-88 P1,5,8,12	13-Jan-89 P3,5,8	***
Ankistrodesmus	Chlorophyceae	10-Jun-88 ALL	10-Feb-89 ALL Exc 4,5,7	10Jun88
Coccomyxaceae sp3	Chlorophyceae	10-Jun-88 ALL Exc 1,12	10-Feb-89 P12	***
Ulothrix type	Chlorophyceae	10-Jun-88 P6	10-Jun-88 P6	***
Chlorococcales sp3	Chlorophyceae	10-Jun-88 P5,7,9,11	10-Feb-89 P12	***
Chlamydom. * sp1	Chlorophyceae	10-Jun-88 P4,7	18-Nov-88 P7	***
Unkno. Chloro.	Chlorophyceae	10-Jun-88 P5	18-Nov-88 P9	***
Cosmarium sp6	Desmidaceae	10-Jun-88 P1,2,3,4,5,7	13-Jan-89 P12	***
Penium	Desmidaceae	10-Jun-88 P9	10-Jun-88 P9	***
Sphaerocystis	Cyanophyceae	10-Jun-88 P2,3	10-Feb-89 P2,3	***
Dimorphococcus *	Chlorophyceae	8-Jul-88 P5	5-Aug-88 P2	***
Glenodinium	Dynophyceae	8-Aug-88 P1,2,4,11	10-Feb-89 P1,3,6,9	***
Merismopedia	Cyanophyceae	5-Aug-88 P1,2,4,6	18-Nov-88 P2	***
Scenedesmus *	Chlorophyceae	5-Aug-88 P9	18-Nov-88 P1	***
Staurastrum sp2	Desmidaceae	16-Sep-88 P2	16-Sep-88 P2	***
Unknown Chloro.	Chlorophyceae	14-Oct-88 P8	10-Feb-89 P8	***
Spinocosmarium	Desmidaceae	10-Feb-89 P12	10-Feb-89 P3	***

* Dimorphococcus lunatus, Scenedesmus opooliensis, Chlamydomonas

@ P stands for Pond.

Table 5. Coefficient of variation for group densities and biomass (Chl. a) in experimental ponds.

	Coef. Var.						
Date	Cyanophy.	Desmid.	Chlorophyceae	Dinobryon	Dinophy.	Bacillario.	Biomass
5-Feb-88	0	0	0	0	0	0	245.4
4-Mar-88	280.6	0	0	0	0	0	195.1
1-Apr-88	79.0	250.9	69.7	104.9	0	0	112.8
13-May-88	346.4	114.6	120.8	189.8	101.2	256.6	66.7
10-Jun-88	162.7	66.2	86.4	94.3	96.1	307.4	53.6
8-Jul-88	167.4	105.9	79.2	84.1	88.0	129.8	39.0
5-Aug-88	205.3	161.4	72.8	146.9	80.7	182.8	57.0
16-Sep-88	107.1	194.9	104.4	160.8	97.5	65.0	71.9
14-Oct-88	123.9	115.1	75.2	108.5	84.0	99.2	97.6
18-Nov-88	124.1	136.5	120.2	81.3	99.5	142.5	71.2
16-Dec-88	116.2	107.8	178.8	140.5	71.8	234.2	87.2
13-Jan-89	114.1	104.9	138.4	87.5	74.6	121.6	81.6
10-Feb-89	125.8	105.5	250.9	89.0	51.9	346.4	67.7

Table 6. Proportion of density of each taxonomic group in each sample, 1988-1989.

Date	% Cyanophy.	%Desmid.	%Chlorophy.	%Dinobryon	%Dinophy.	%Bacillario.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	100.0	0	0	0	0	0
1-Apr-88	23.2	0.9	18.1	57.9	0.0	0.0
13-May-88	7.7	70.6	6.1	5.3	8.3	1.9
10-Jun-88	0.3	4.5	74.6	15.6	3.4	1.7
8-Jul-88	0.4	4.9	84.7	7.7	1.8	0.5
5-Aug-88	0.5	45.0	47.4	5.7	0.9	0.5
16-Sep-88	0.5	78.5	18.3	2.4	0.2	0.2
14-Oct-88	0.2	93.7	5.0	0.8	0.2	0.1
18-Nov-88	0.4	92.1	6.2	1.0	0.2	0.0
16-Dec-88	0.5	92.7	4.1	2.4	0.2	0.0
13-Jan-89	0.4	93.5	1.9	3.7	0.3	0.1
10-Feb-89	0.2	94.2	3.6	1.4	0.5	0

Table 7. Proportion of biovolume (cells/cm^3) of each taxonomic group in each sample, 1988-1989.

Date	% Cyanophy.	%Desmid.	%Chlorophy.	%Dinobryon	%Dinophy.	%Bacillario.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	100.0	0	0	0	0	0
1-Apr-88	0	0	0	100.0	0	0
13-May-88	0	0.1	0.1	76.4	23.4	0
10-Jun-88	0	0	0.2	99.8	0	0
8-Jul-88	0	0	0.3	90.7	9.0	0
5-Aug-88	0	0	0.4	95.1	4.5	0
16-Sep-88	0	0.1	0.4	96.5	3.1	0
14-Oct-88	0	0.3	0.4	91.6	7.7	0
18-Nov-88	0	0.2	0.5	90.2	9.1	0
16-Dec-88	0	0.1	0.1	96.7	3.1	0
13-Jan-89	0	0.1	0	95.8	4.1	0
10-Feb-89	0	0.2	0.1	89.0	10.7	0

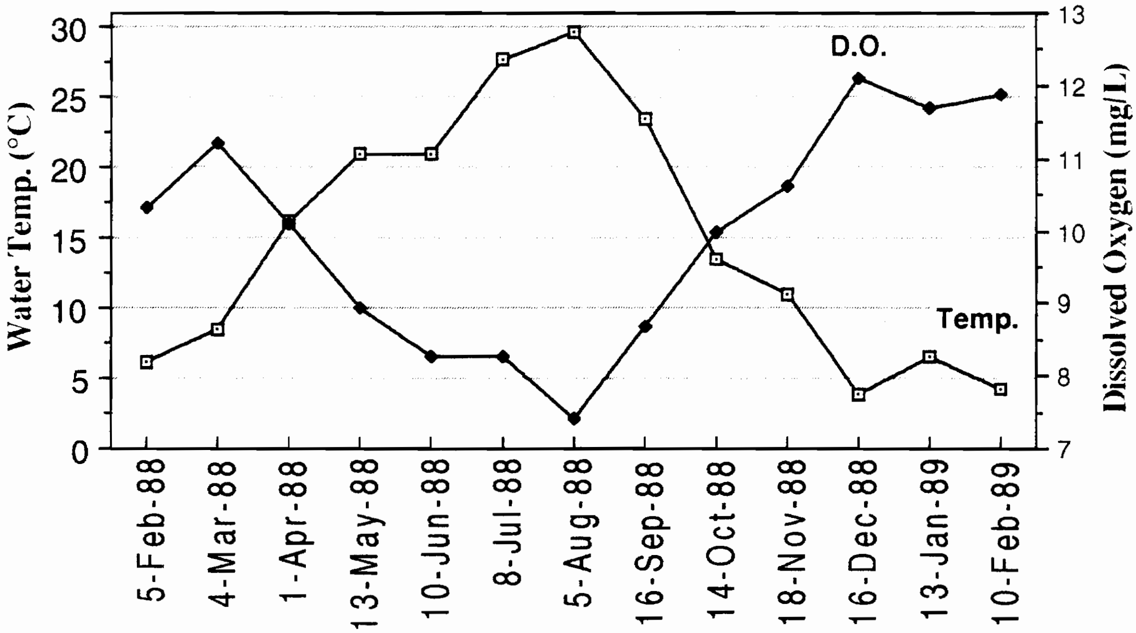


Fig. 1 Relationship between mean water temperature (°C) and dissolved oxygen (mg/L) for all ponds, 1988-89.

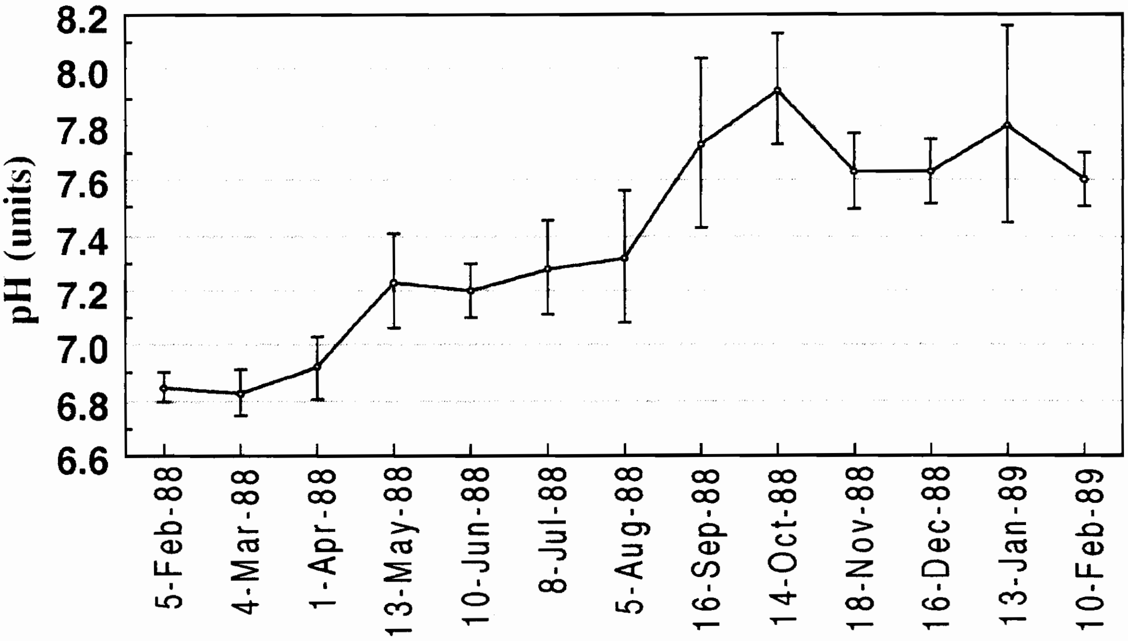


Fig. 2 Mean pH (units) of all ponds, 1988-89. Error bars represent standard deviation.

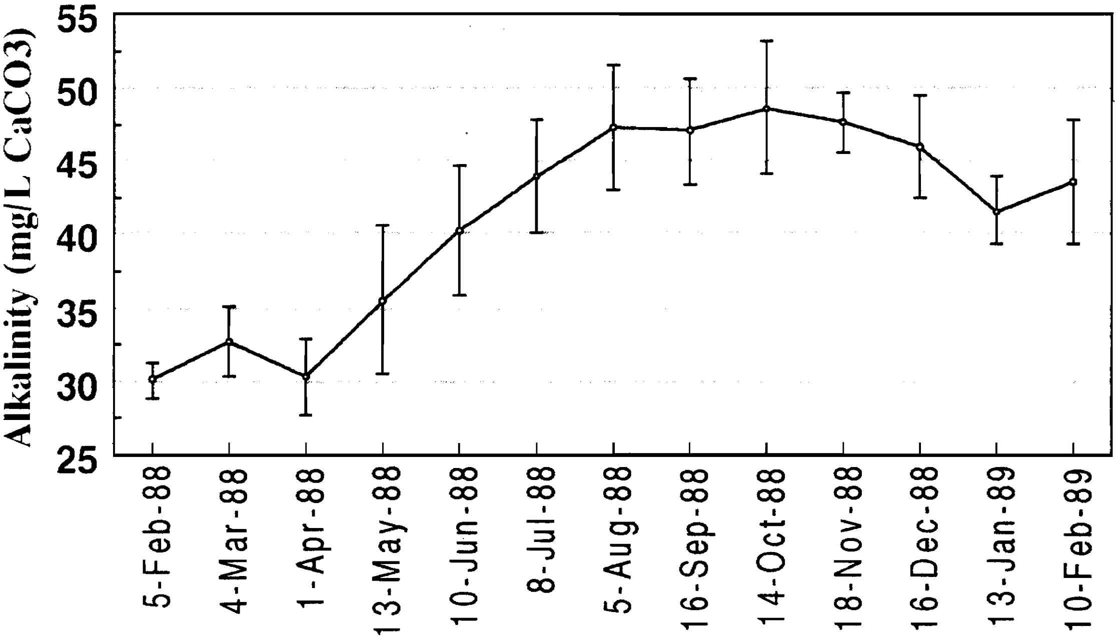


Fig. 3 Mean alkalinity as mg/L $CaCO_3$ for all ponds, 1988-89. Error bars represent standard deviation.

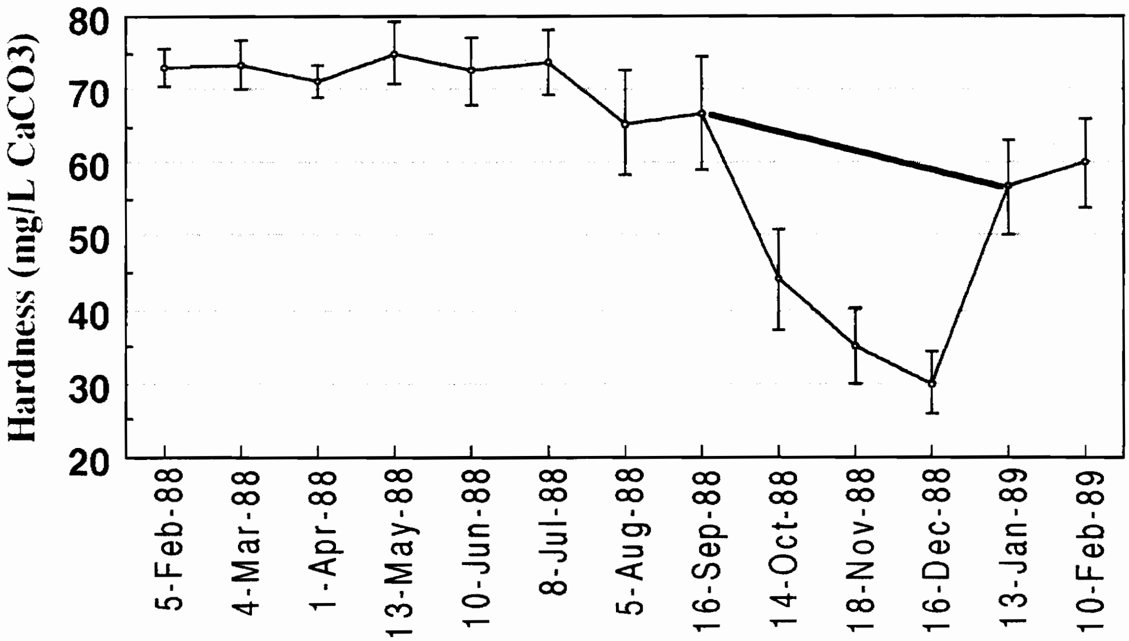


Fig. 4 Mean hardness as mg/L CaCO3 for all ponds, 1988-89. Error bars represent standard deviation.

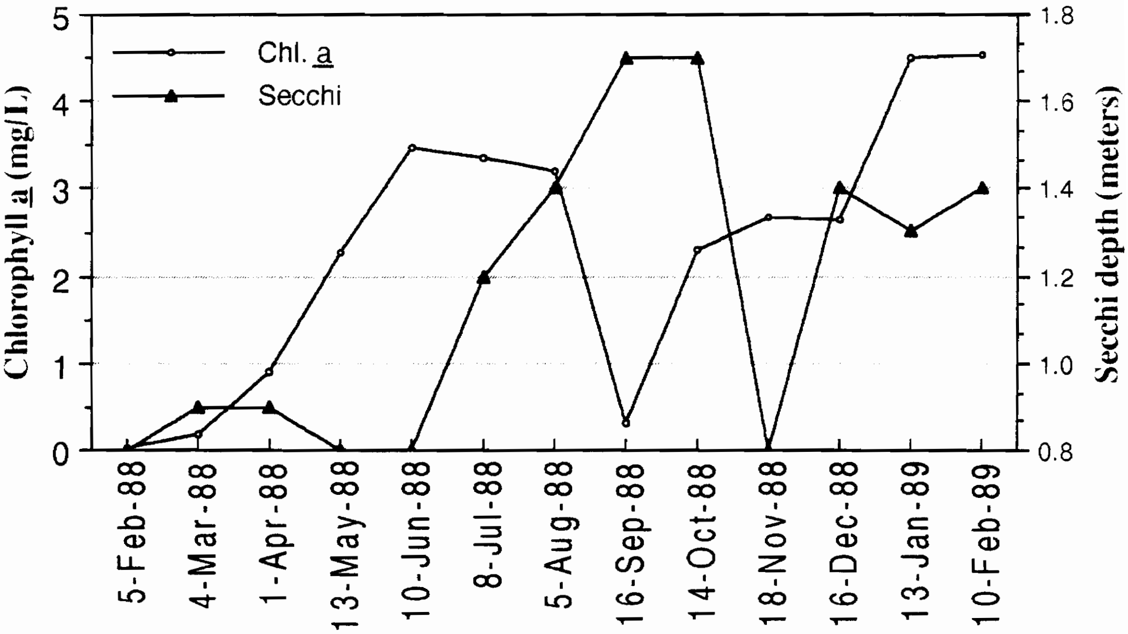


Fig. 5 Comparison of chlorophyll a (mg/L) and Secchi depth (m) in experimental ponds, 1988-89.

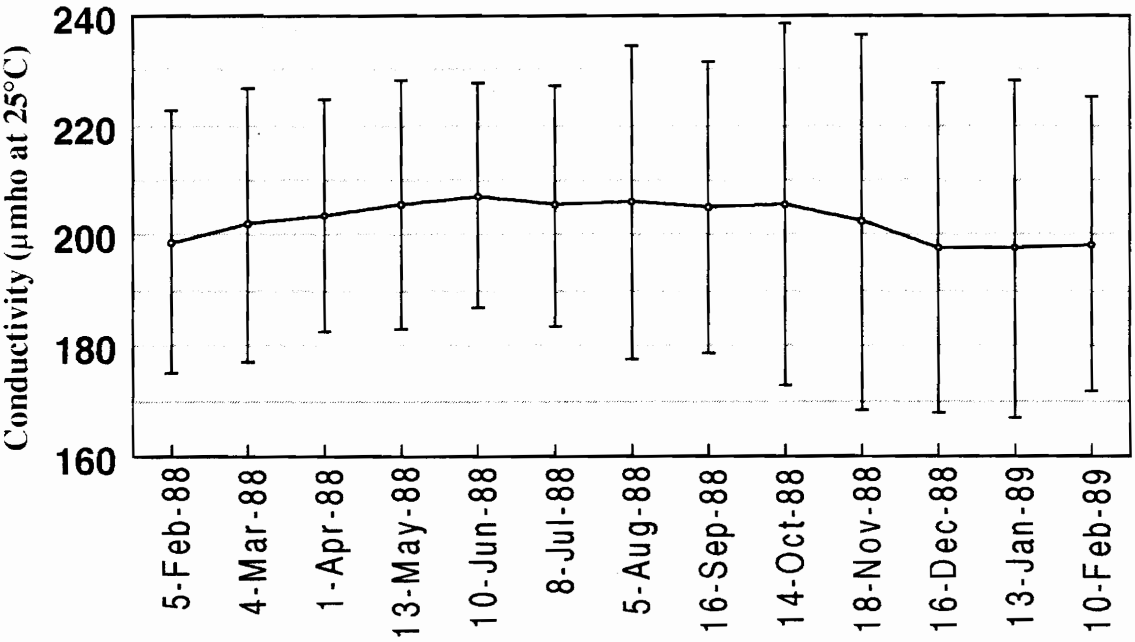


Fig. 6 Mean conductivity (µmhos/cm^2/sec at 25°C) for all ponds, 1988-89. Error bars represent standard deviation.

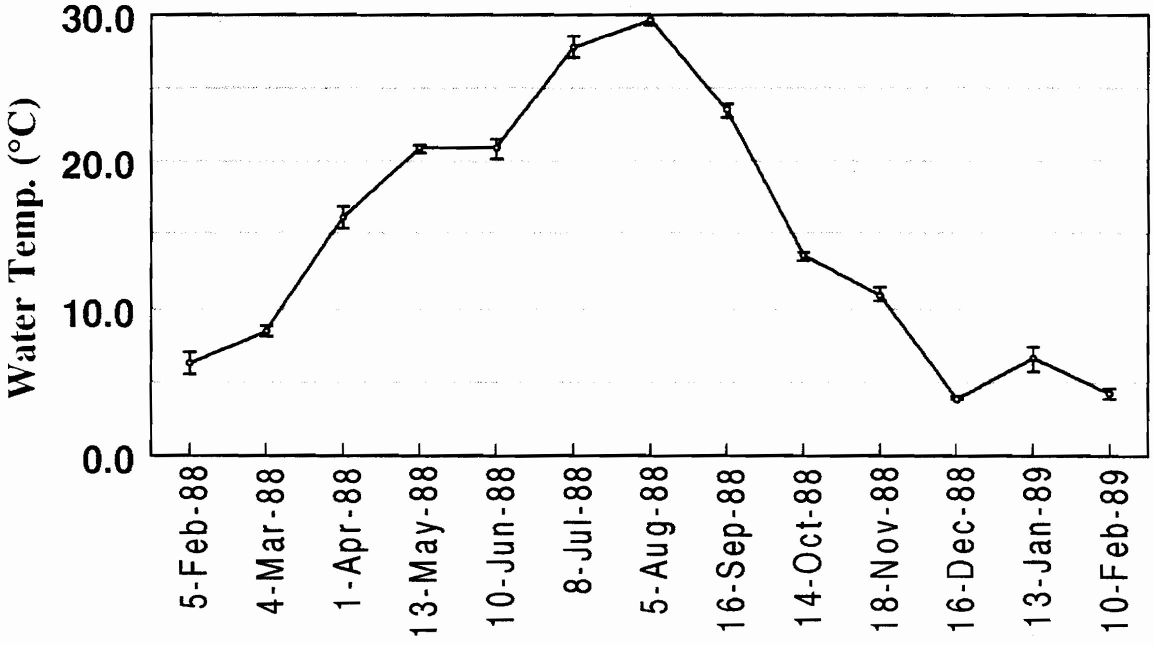


Fig. 7 Mean water temperature (°C) of all ponds, 1988-89. Error bars represent standard deviation.

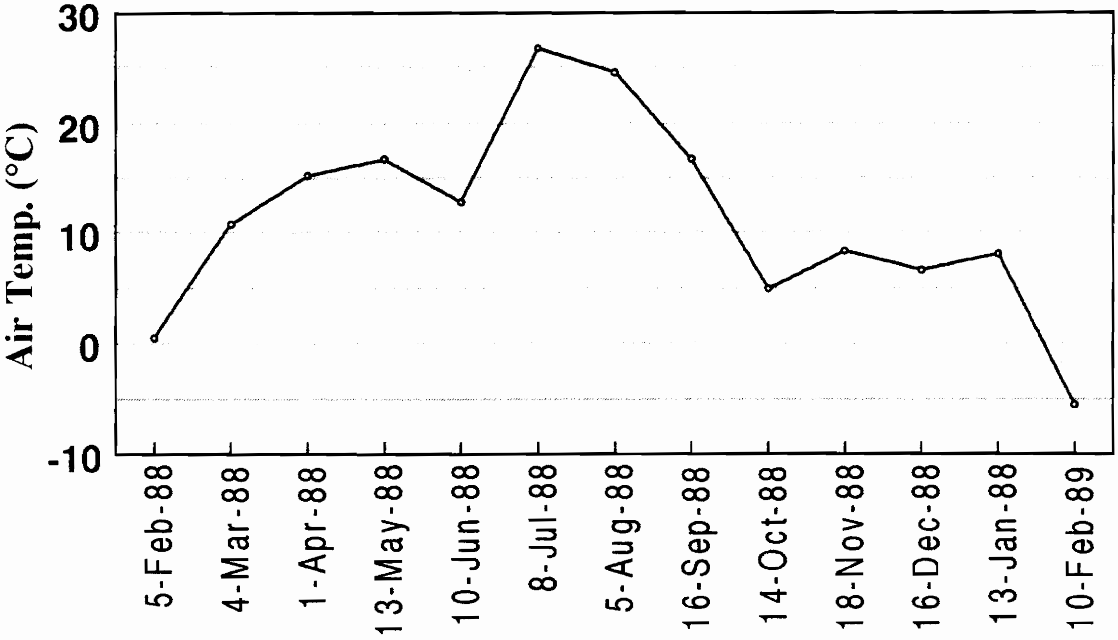


Fig. 8 Mean air temperature (°C) at experimental pond facility, 1988-89. Data obtained from Virginia Tech. Southern Piedmont Agricultural Station.

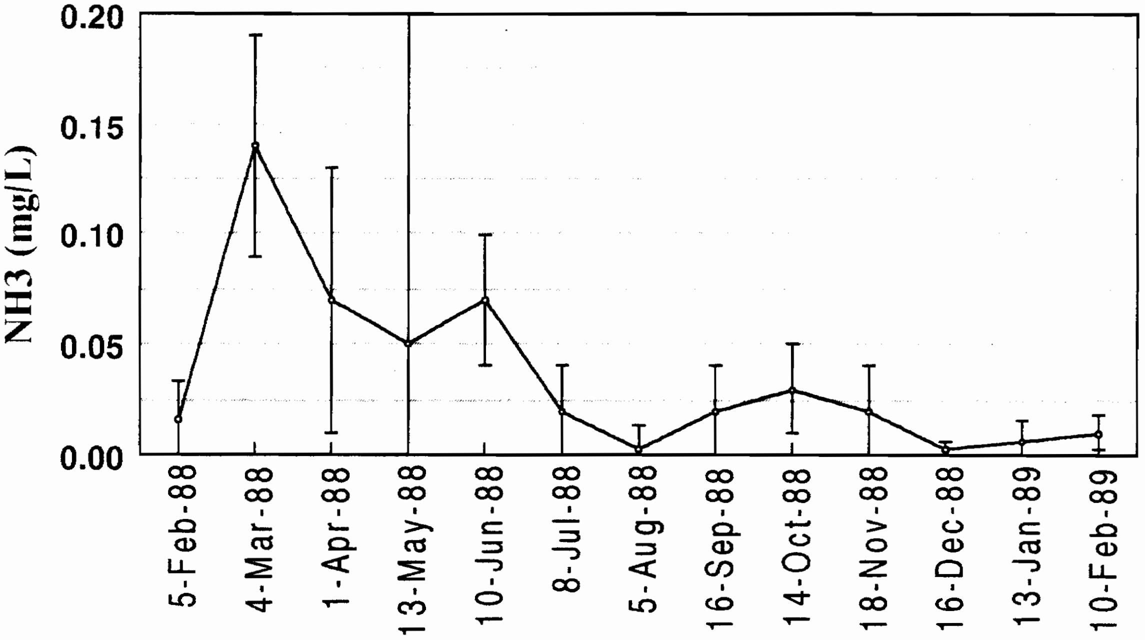


Fig. 9 Mean NH_3 (mg/L) for all ponds, 1988-89. Detection limits = 0.02 - 5.00 mg/L. Error bars represent standard deviation.

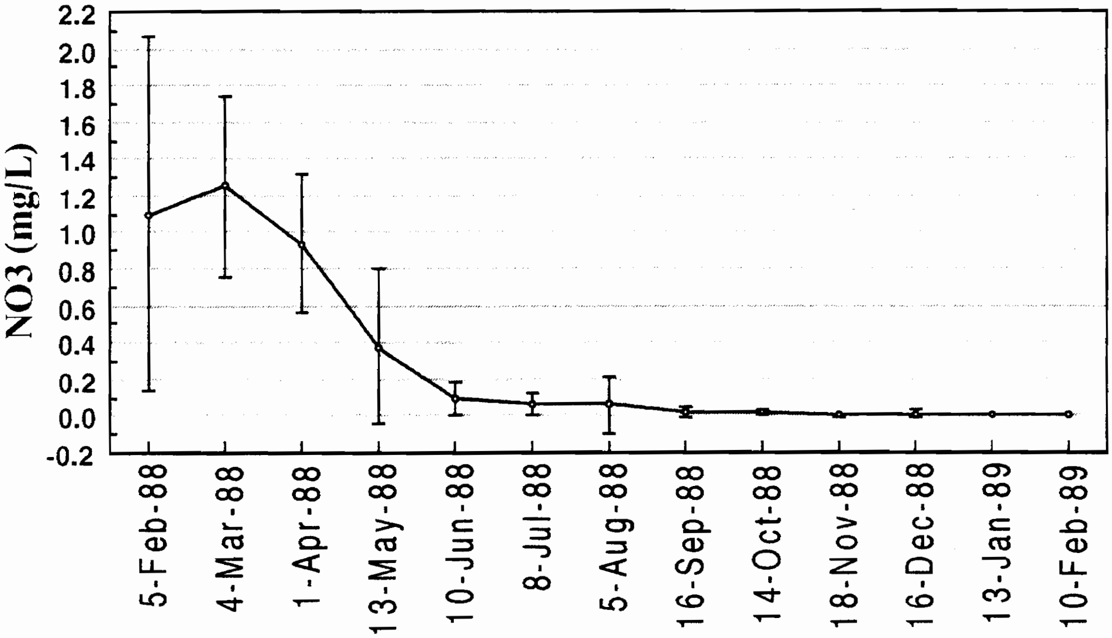


Fig. 10 Mean NO_3 (mg/L) for all ponds, 1988-89, by ion chromatography. Error bars represent standard deviation.

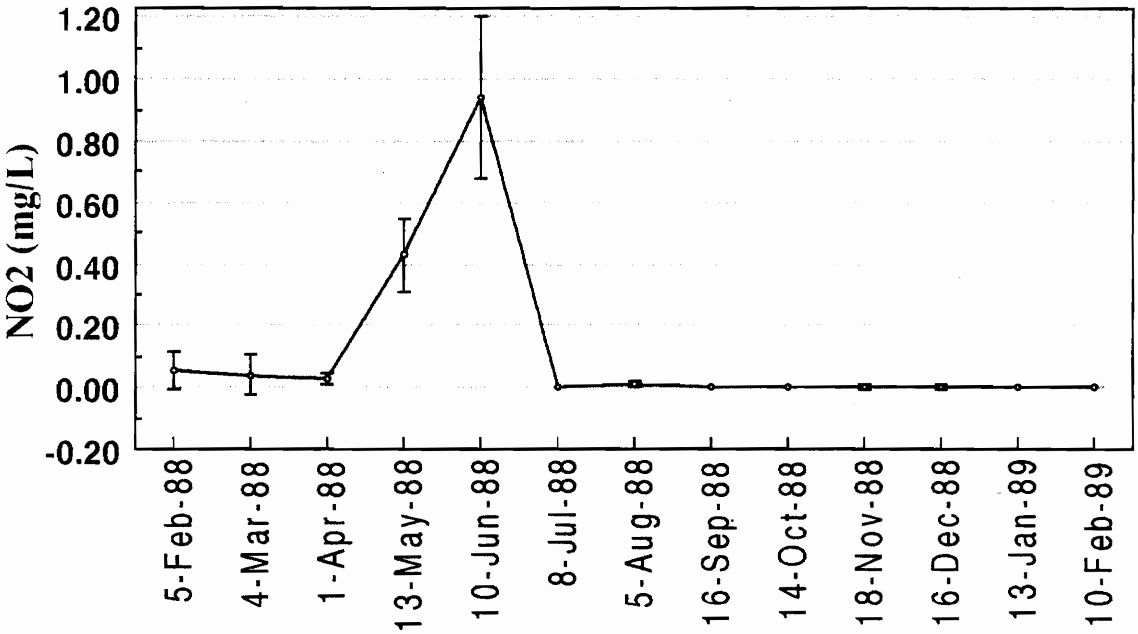


Fig. 11 Mean NO_2 (mg/L) for all ponds, 1988-89, by ion chromatography. Error bars represent standard deviation.

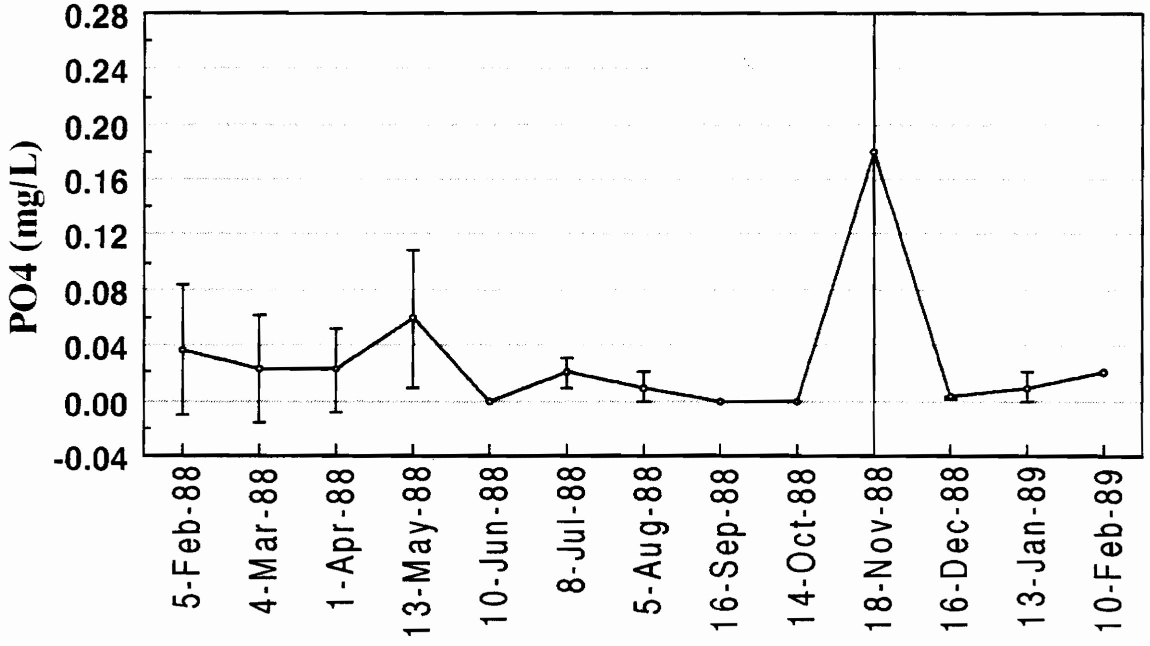


Fig. 12 Mean PO4 (mg/L) for all ponds, 1988-89. Detection limits = 0.02 - 2.00 mg/L. Error bars represent standard deviation.

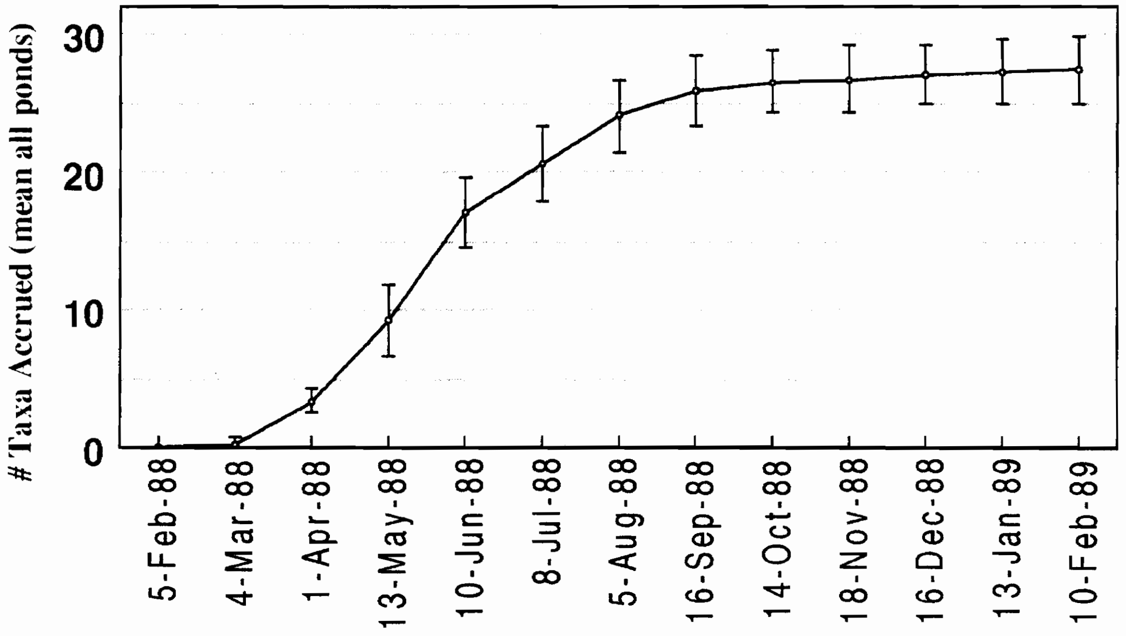


Fig. 13 Taxa accrued in experimental ponds, 1988-89. Mean of all ponds. Error bars represent standard deviation.

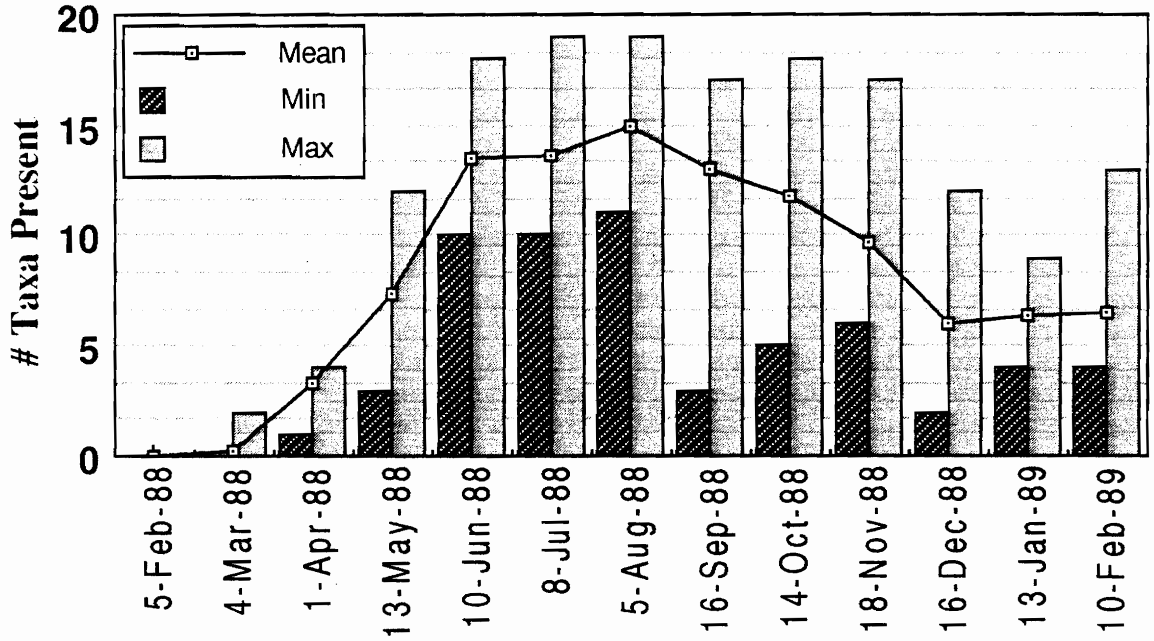


Fig. 14 Number of taxa present in all ponds, 1988-89. Minimum and maximum values are shown with a line representing the mean to illustrate the heterogeneity of the ponds.

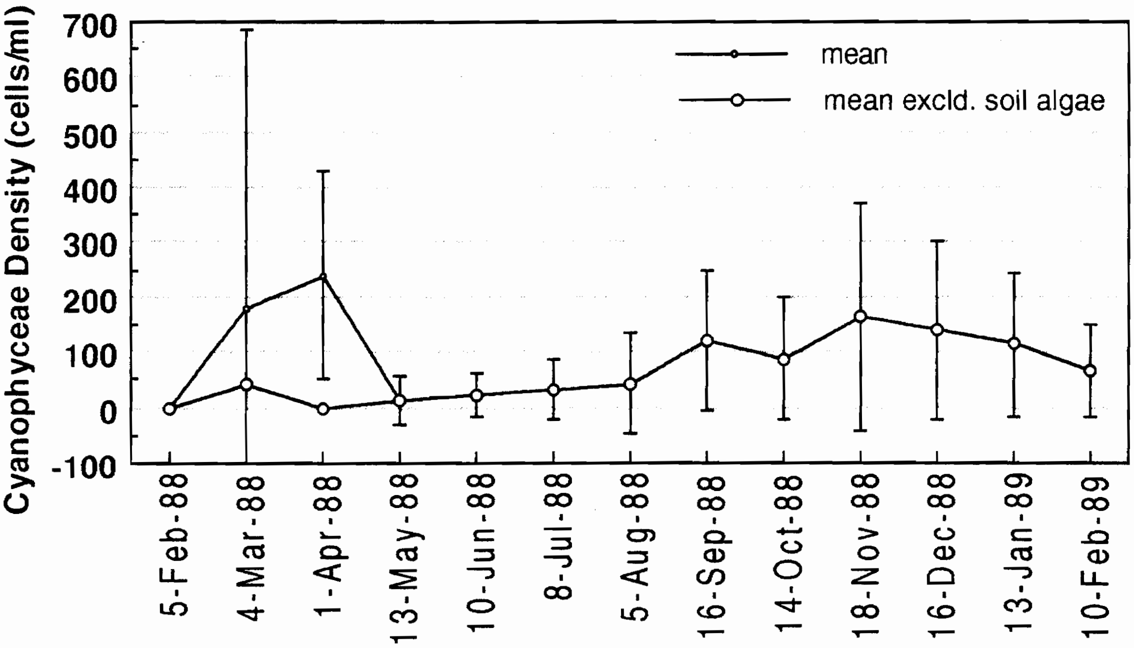


Fig. 15 Cyanophyceae density (cells/ml). Means of all ponds, 1988-89. Soil algae are excluded to represent true phytoplankton colonization.Error bars represent standard deviation.

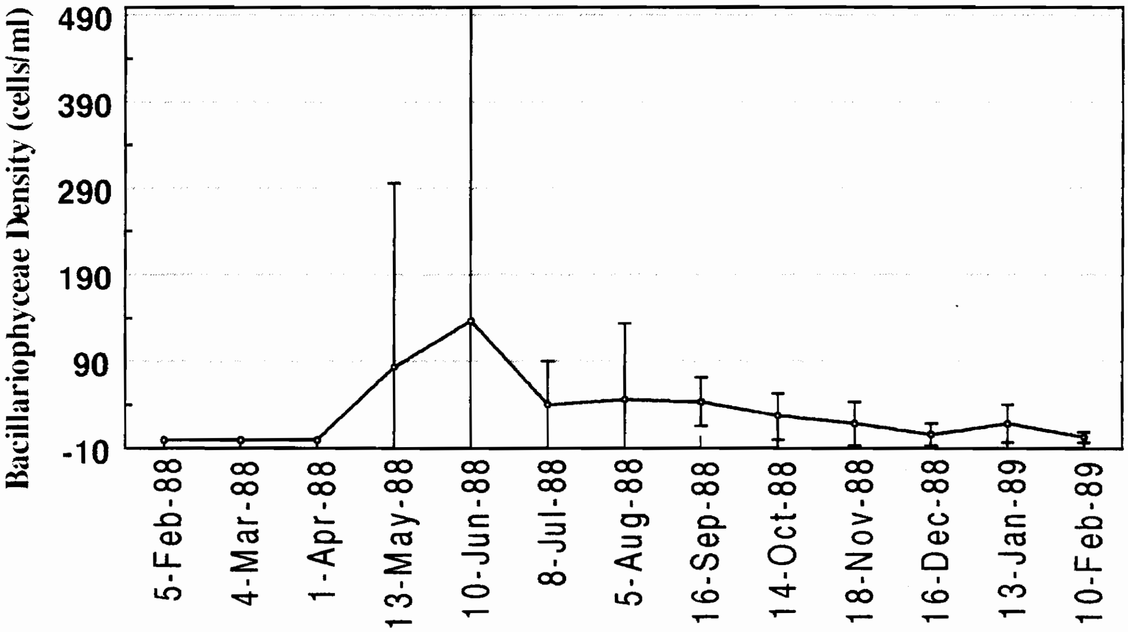


Fig. 16 Bacillariophyceae density (cells/ml). Means of all ponds, 1988-89. Error bars represent standard deviation.

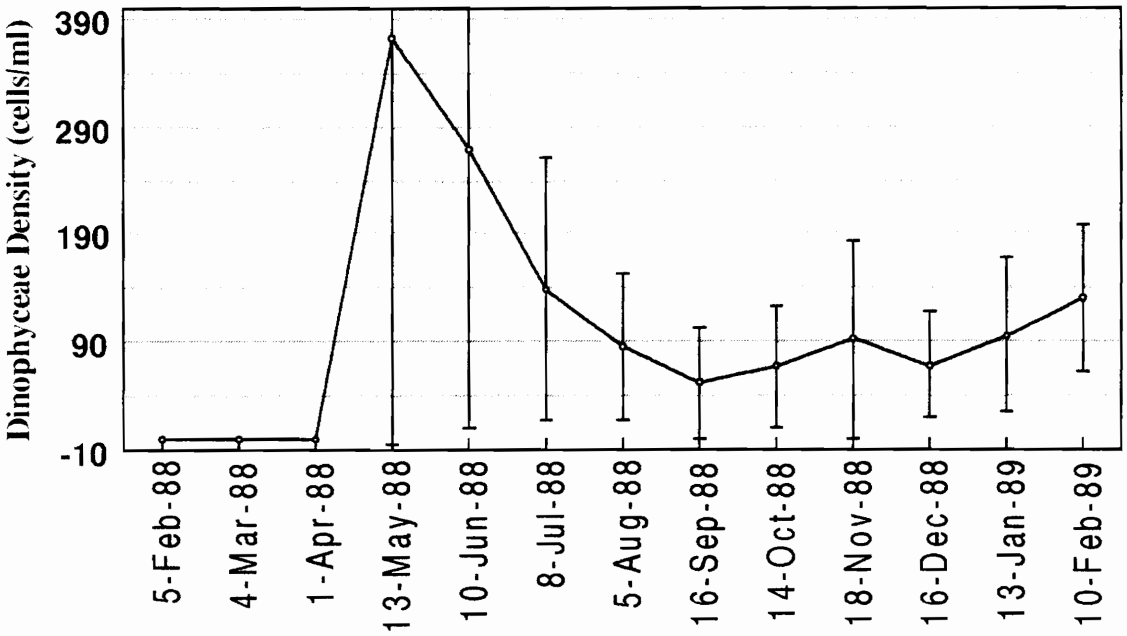


Fig. 17 Dinophyceae density (cells/ml). Means of all ponds, 1988-89. Error bars represent standard deviation.

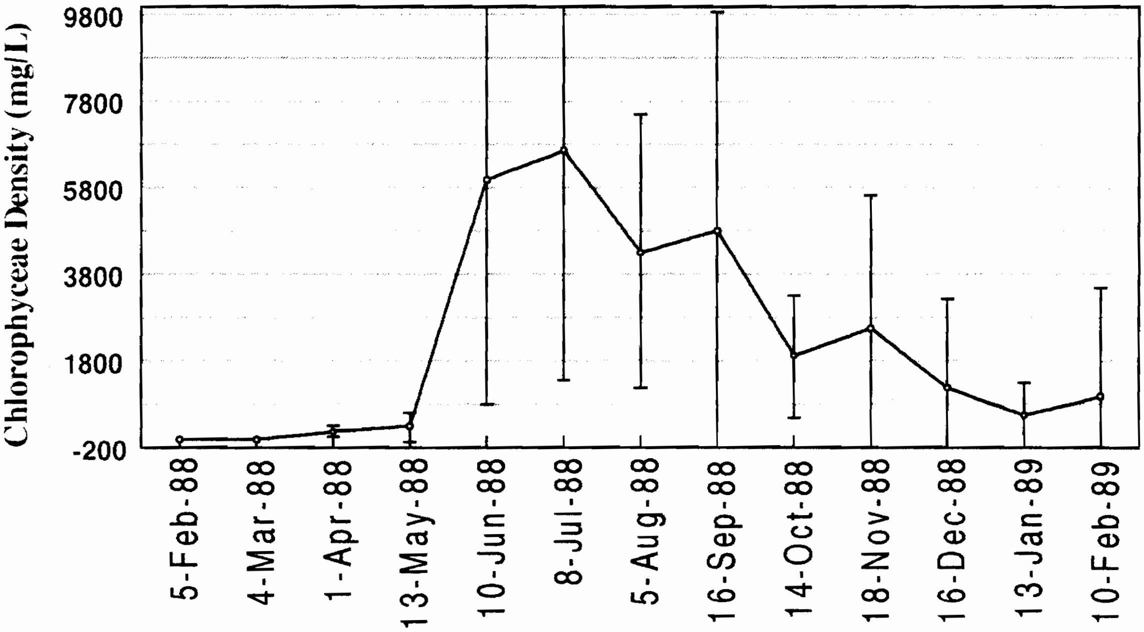


Fig. 18 Chlorophyceae density (cells/ml). Means of all ponds, 1988-89. Error bars represent standard deviation.

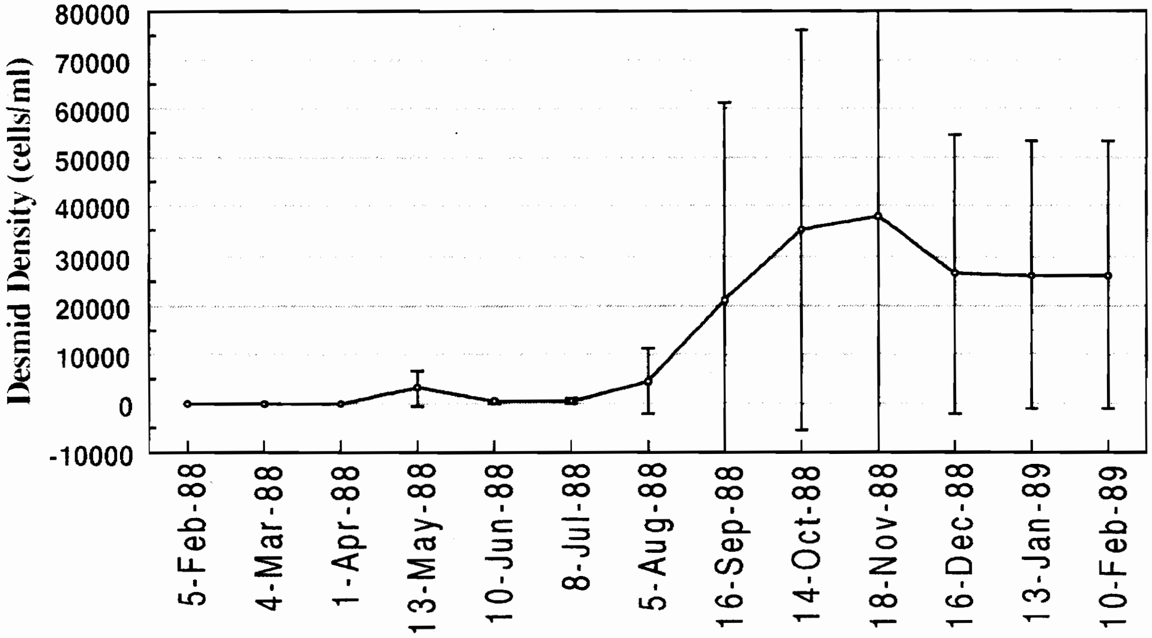


Fig. 19 Desmidaceae (Chlorophyceae) density (cells/ml). Means of all ponds, 1988-89. Error bars represent standard deviation.

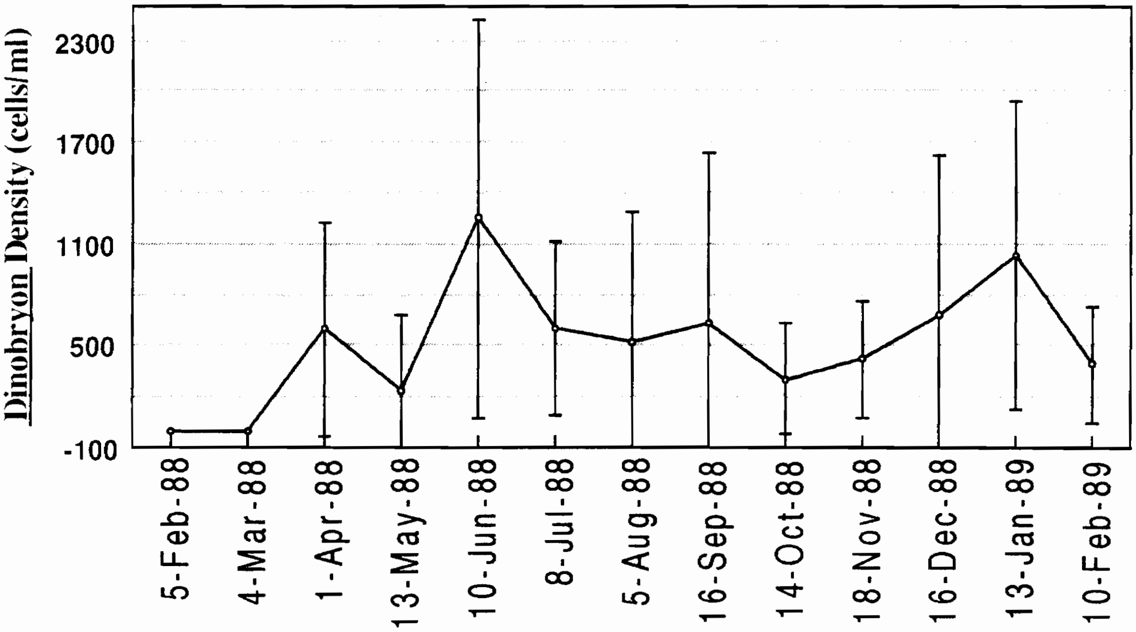


Fig. 20 Dinobryon (Chrysophyceae) density (cells/ml). Means of all ponds, 1988-89. Error bars represent standard deviation.

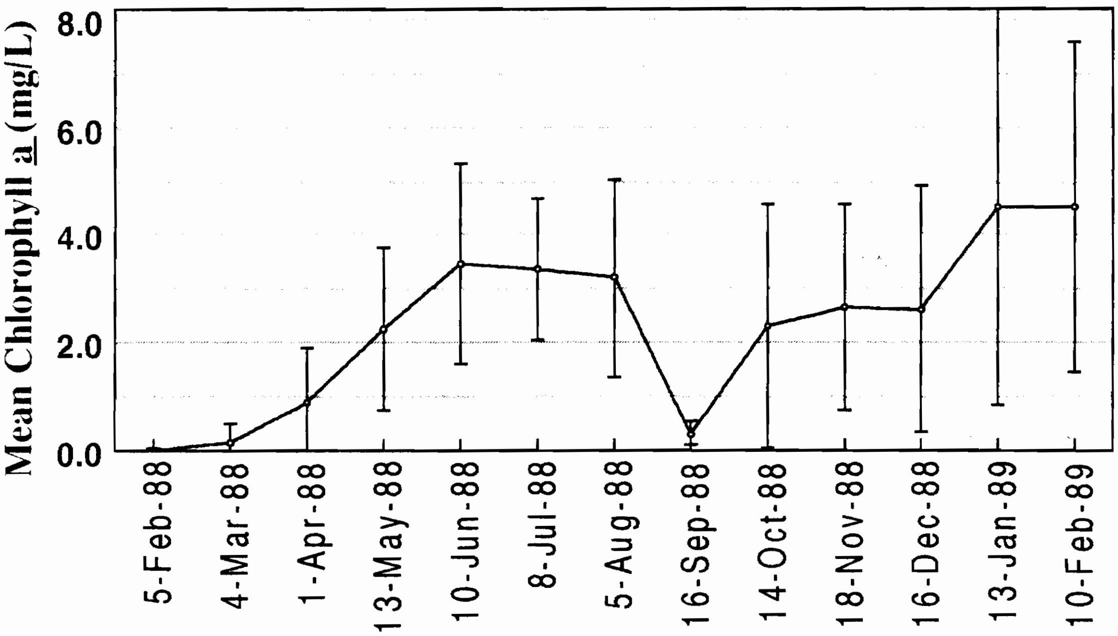


Fig. 21 Mean chlorophyll a (mg/L) of all ponds, 1988-89. Error bars represent standard deviation.

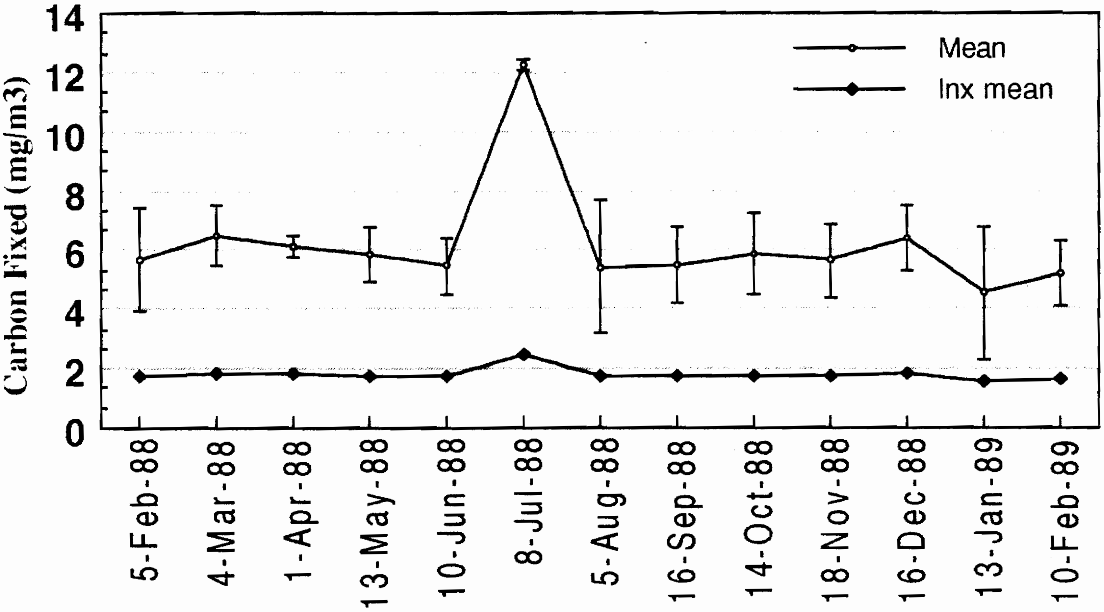


Fig. 22 Mean Primary Productivity (mg. carbon fixed/m^3) of all ponds, 1988-89. Error bars represent standard deviation. Log transformed data are also graphed.

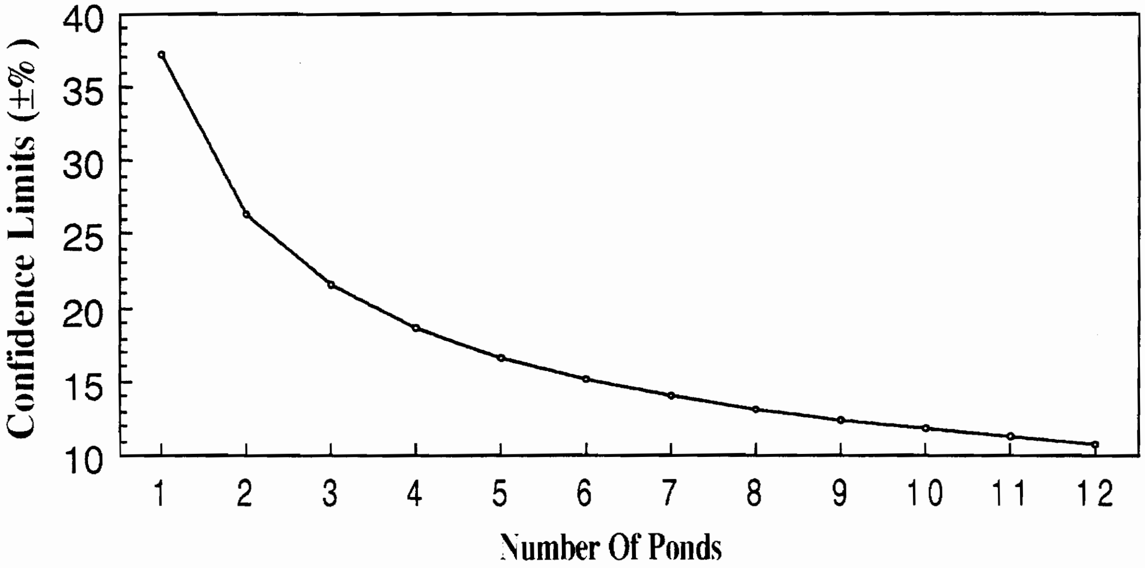


Fig. 23 Relationship of precision (± % confidence limits) to number of ponds for number of taxa accrued. (Based on May - February data)

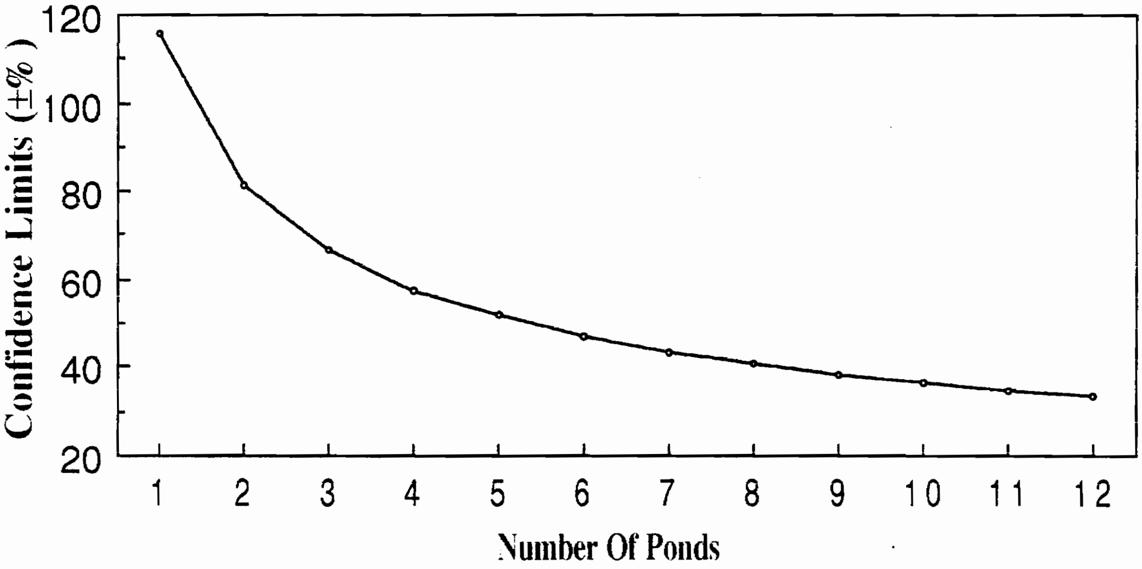


Fig. 24 Relationship of precision (± % confidence limits) to number of ponds for chlorophyll a. (Based on May - February data)

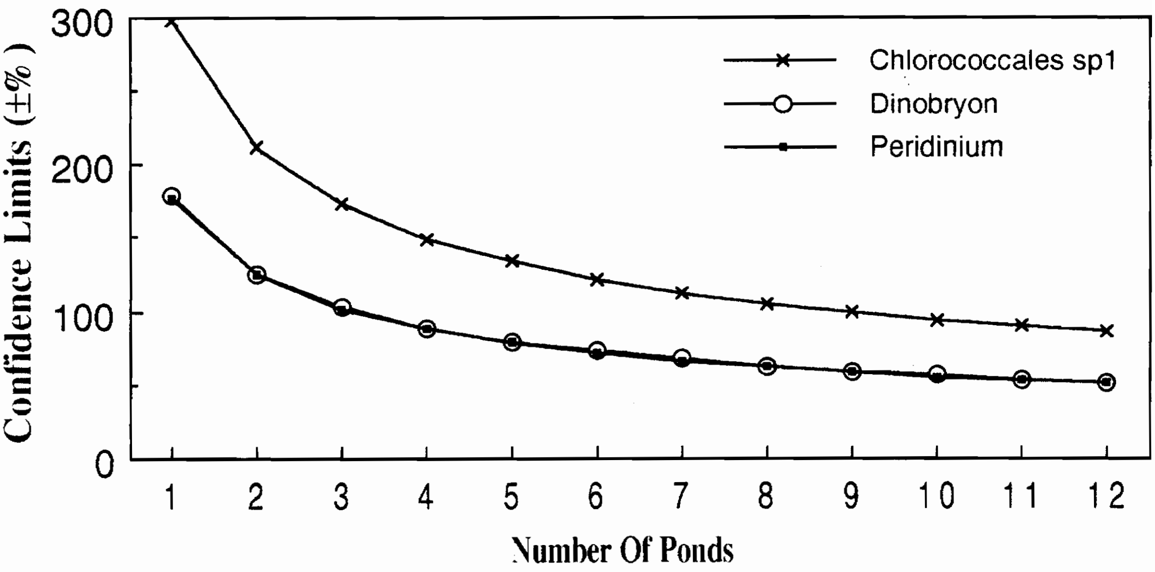


Fig. 25 Relationship of precision (± % confidence limits) to number of ponds for densities of dominant taxa. (Based on May - February data)

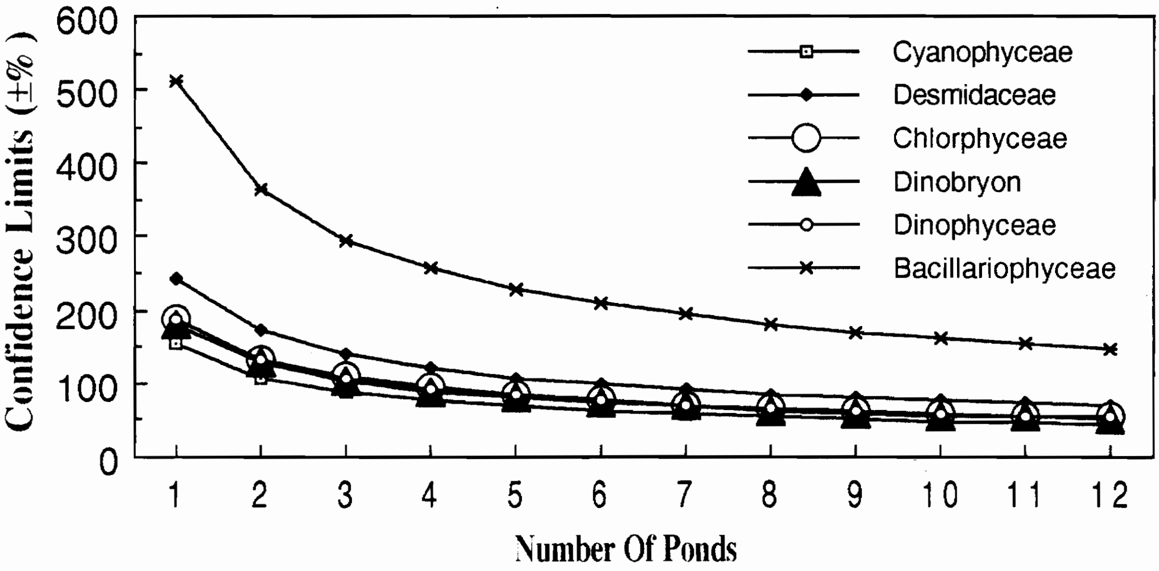


Fig. 26 Relationship of precision (± % confidence limits) to number of ponds for group densities. (Based on May - February data)

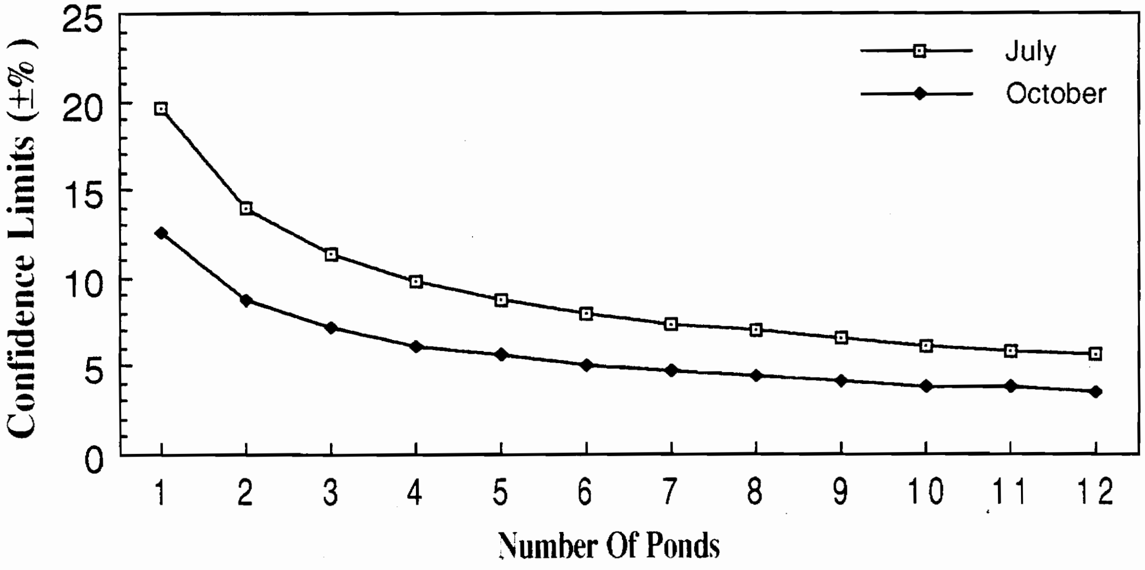


Fig. 27 Relationship of precision (± % confidence limits) to number of ponds for number of taxa accrued. (For July and October data.)

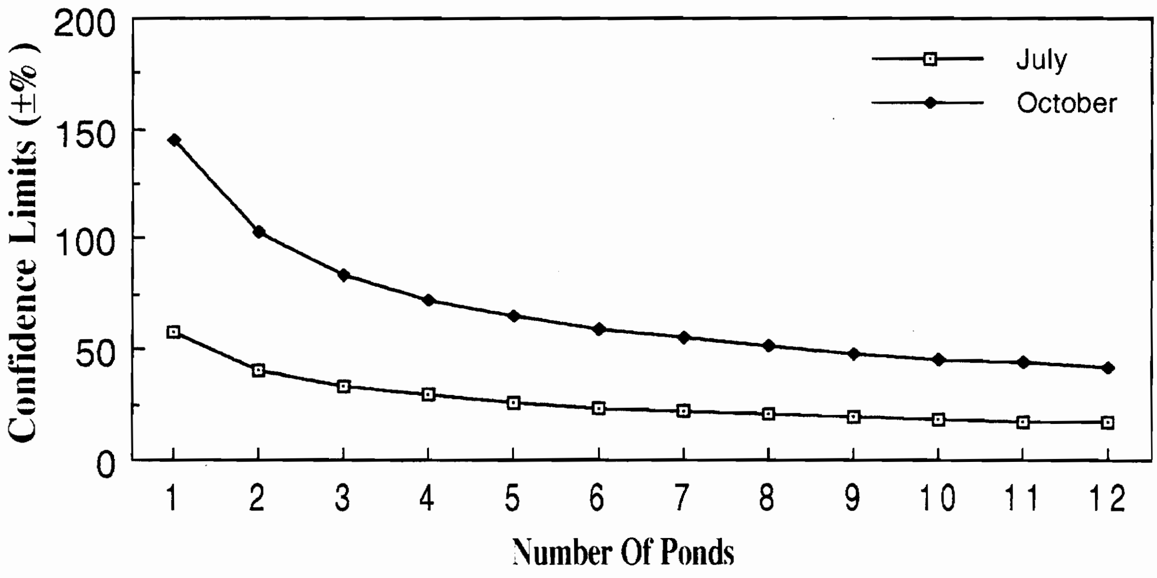


Fig. 28 Relationship of precision (± % confidence limits) to number of ponds for chlorophyll a. (For July and October data.)

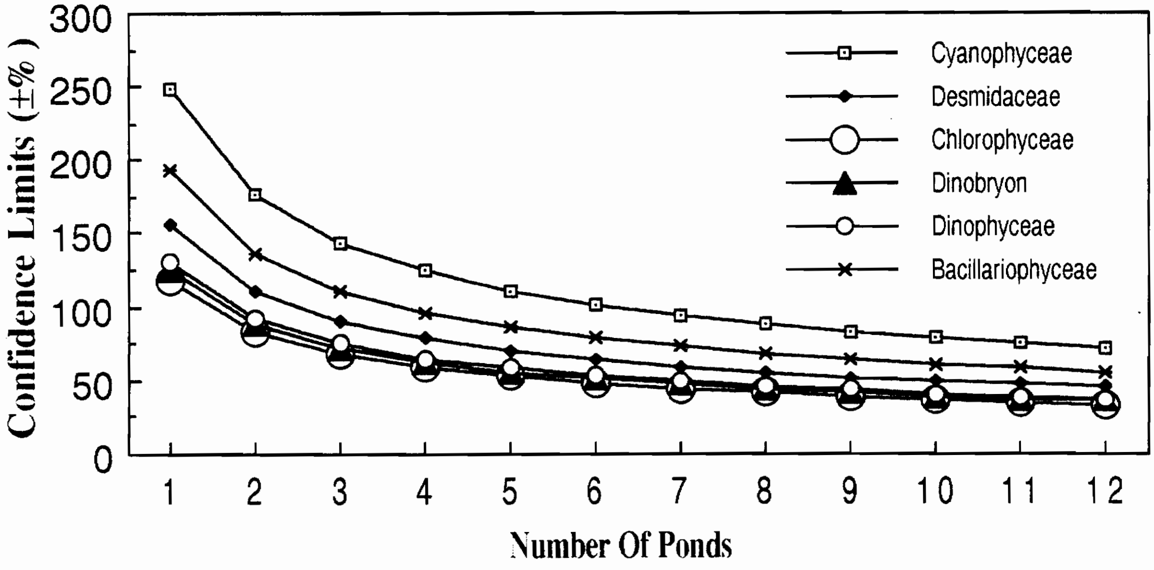


Fig. 29 Relationship of precision (± % confidence limits) to group densities. (July data.)

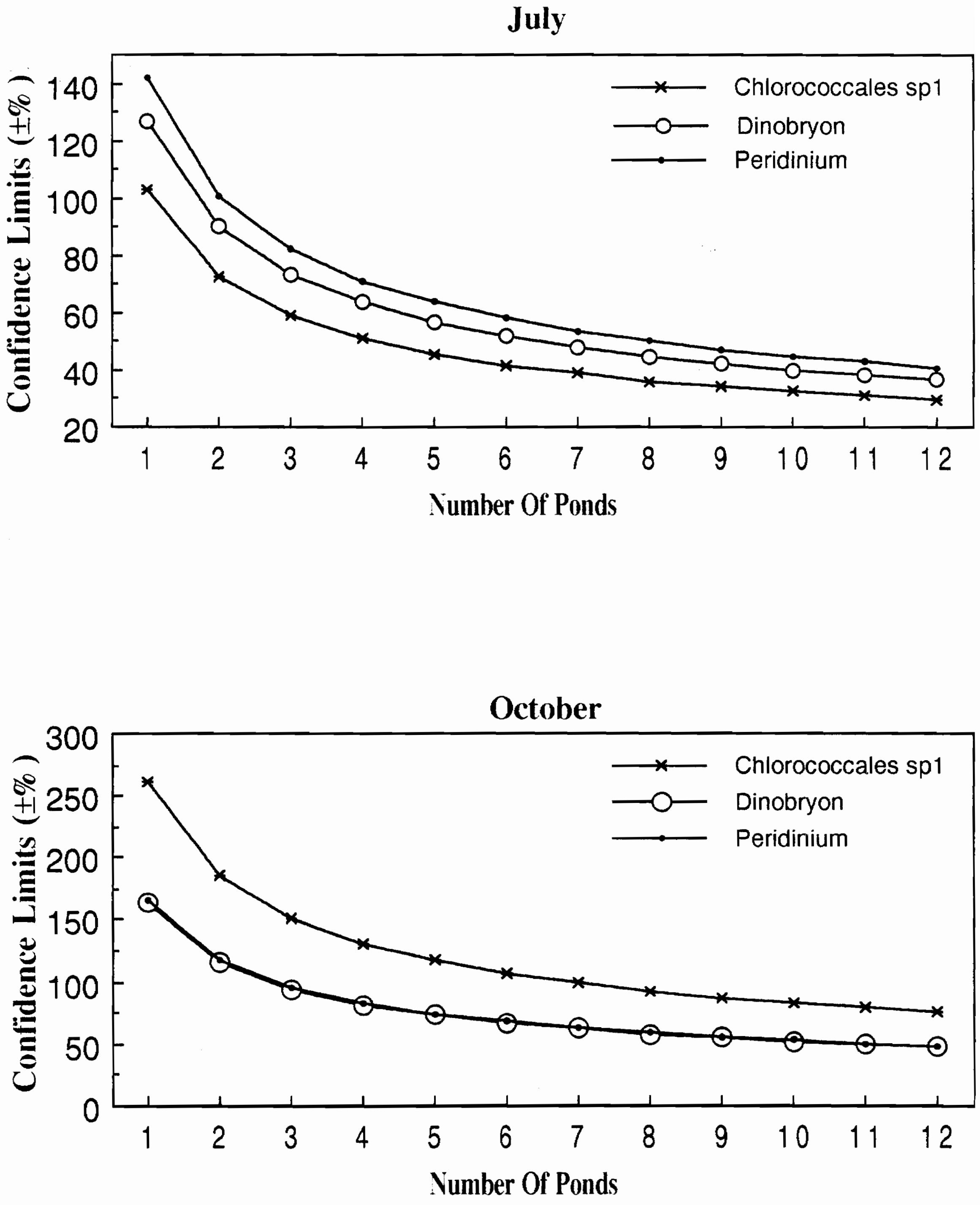
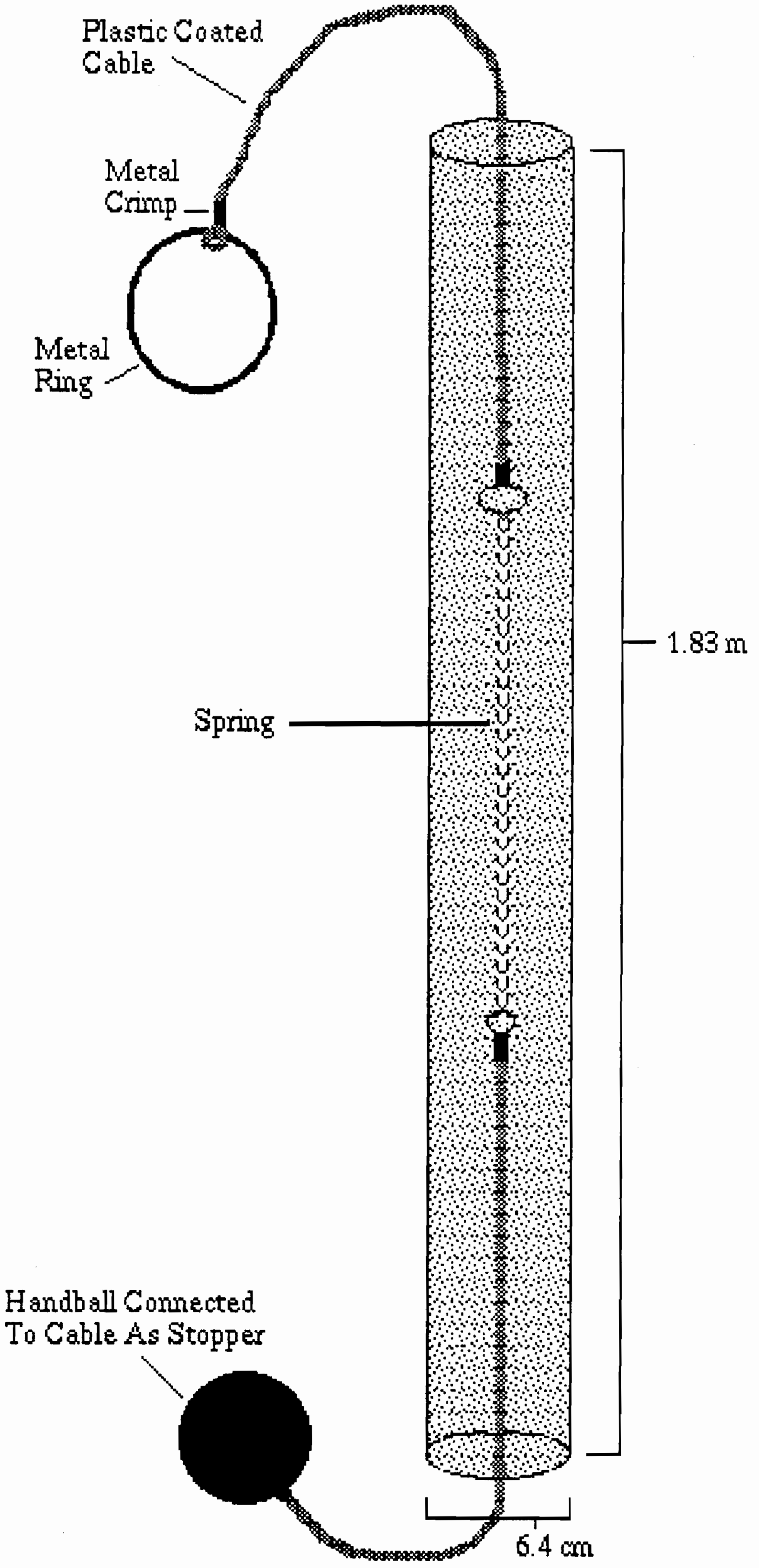


Fig. 30 Precision (± % conf. lim.) of densities of dominant taxa (July and October data).

Appendices

Contents:

Appendix 1. Integrated plankton sampling tube.



Appendix 2.1 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 5 Feb 1988.

	Pond											
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anabaena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dinobryon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurastrum sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gymnodinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Closteiopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp4 panamense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peridinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennate diatom sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ocillatoria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Desmidium type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gloeocystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccomyxaceae sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccomyxaceae sp2 (Dispora)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Palmellaceae sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kirchneriella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennate diatom sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coxxomyxaceae sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ulothrix type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 2.1 Continued

	Pond											
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorophyceae unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Penium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphaerocystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dimorphococcus lunatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glenodinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Merismopedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus opoliensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauastrum sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown "tear drop"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinocosmarium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
total density (5 Feb 88)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix2.2 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 4 March 1988.

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1662	0.0	0.0	0.0	0.0	139
Anabaena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	79	0.0	0.0	0.0	0.0	7
Chlorococcales sp.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dinobryon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurastrum sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gymnodinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Closteiopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp4 panamense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peridinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennate diatom sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ocillatoria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	425	0.0	0.0	0.0	35
Desmidium type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gloeocystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccomyxaceae sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccomyxaceae sp2 (Dispora)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Palmellaceae sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kirchneriella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennate diatom sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coxxomyxaceae sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ulothrix type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 2.2 Continued

Organism	**Pond** **1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorophyceae unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Penium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphaerocystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dimorphococcus lunatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glenodinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Merismopedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus opoliensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauastrum sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown "tear drop"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinocosmarium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
total density (4 Mar 88)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1741	425	0.0	0.0	0.0	180.6

Appendix 2.3 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 1 April 1988.

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	688	119	35	0.0	225	167	258	269	150	192	292	490	240.3
Anabaena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp.1	34	317	35	0.0	281	133	97	134	263	144	219	147	150.3
Chlorococcales sp2	0.0	0.0	0.0	0.0	113	200	0.0	0.0	0.0	96	37	0.0	37.1
Dinobryon	481	317	248	467	141	1500	129	1792	1575	144	219	196	600.6
Staurastrum sp1	0.0	0.0	35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Cosmarium sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	0.0	0.0	0.0	6.3
Gymnodinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Closteiopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp4 panamense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peridinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennate diatom sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ocillatoria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Desmidium type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gloeocystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccomyxaceae sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccomyxaceae sp2 (Dispora)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Palmellaceae sp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kirchneriella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pennate diatom sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coxxomyxaceae sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ulothrix type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorococcales sp3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 2.3 Continued

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlorophyceae unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium sp6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Penium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphaerocystis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dimorphococcus lunatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glenodinium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Merismopedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus opoliensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauastrum sp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unknown "tear drop"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinocosmarium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
total density (1 Apr 88)	1203	752	354	467	759	2000	484	2195	2063	575	766	832	1038

Appendix 2.4 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 13 May 1988.

	Pond											
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp.1	35	198	917	0	0	108	36	0	0	0	79	171	129
Chlorococcales sp2	35	79	92	38	69	217	36	0	90	32	119	0	67
Dinobryon	71	0	229	1125	0	0	328	142	1254	0	0	0	262
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp1	0	673	1833	0	69	0	0	0	1792	0	0	0	364
Gymnodinium	460	40	138	38	34	704	0	142	134	323	119	470	217
Closteiopsis	0	79	0	0	0	54	0	0	0	0	0	0	11
Cosmarium sp2	7579	2533	1054	150	138	9425	0	35	6002	936	40	3886	2648
Cosmarium sp3	0	0	46	0	0	54	0	0	0	0	0	0	8
Cosmarium sp4 panamense	0	0	0	38	0	0	0	35	0	0	0	0	6
Peridinium	35	158	92	75	138	704	109	0	179	0	79	299	156
Pennate diatom sp1	35	0	46	38	0	758	0	0	0	0	40	85	84
Cosmarium sp5	460	158	92	0	34	0	36	0	448	0	0	0	102
Ocillatoria	0	0	0	150	0	0	0	0	0	0	0	0	13
Desmidium type	0	40	46	0	0	0	0	0	179	0	0	0	22
Gloeocystis	0	40	0	0	0	0	0	0	0	0	40	0	7
Coccomyxaceae sp1	0	238	0	0	0	0	73	0	0	0	198	0	42
Coccomyxaceae sp2 (Dispora)	0	158	0	0	0	0	0	0	0	0	40	0	16
Palmellaceae sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelastrum	0	0	0	0	0	0	0	0	0	0	0	0	0
Kirchneriella	0	0	0	0	0	0	0	0	0	0	0	0	0
Pennate diatom sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ankistrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0
Coxxomyxaceae sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2.4 Continued

							Pond						
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp6	0	0	0	0	0	0	0	0	0	0	0	0	0
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	0	0	0	0	0	0	0	0	0	0	0	0	0
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	0	0	0	0	0	0
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(13 May 88)	8713	4394	4583	1650	481	12025	620	354	10078	1292	752	4911	4154

Appendix2.5 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 10 June 1988.

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp.1	85	244	248	35	4297	417	458	196	283	550	96	438	612
Chlorococcales sp2	0	244	283	71	4503	0	275	49	885	275	144	569	608
Dinobryon	0	81	1381	496	344	2708	4079	1273	496	1581	1054	1488	1248
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp1	85	0	0	0	34	0	0	0	496	241	48	131	86
Gymnodinium	0	0	0	71	241	125	0	196	35	69	96	263	91
Closteiopsis	0	0	0	35	0	0	0	0	0	0	0	0	3
Cosmarium sp2	85	41	35	106	34	0	0	0	354	69	144	350	102
Cosmarium sp3	0	0	0	0	0	0	0	147	0	0	0	44	16
Cosmarium sp4 panamense	85	0	0	106	0	42	0	98	0	0	48	0	32
Peridinium	256	41	0	106	516	42	504	49	106	34	0	481	178
Pennate diatom sp1	0	0	0	0	0	0	0	0	0	0	0	1444	120
Cosmarium sp5	43	41	0	0	0	0	0	49	35	0	0	44	18
Ocillatoria	0	41	106	0	0	42	0	0	0	0	48	0	20
Desmidium type	0	0	71	0	0	0	0	0	0	0	0	0	6
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	171	0	0	0	172	0	138	196	0	69	0	394	95
Coccomyxaceae sp2 (Dispora)	0	0	35	0	584	0	138	0	0	0	96	88	78
Palmellaceae sp1	0	0	0	0	275	0	0	0	0	447	0	131	71
Coelastrum	85	81	106	0	1031	0	92	49	0	172	48	350	168
Kirchneriella	128	1219	35	3754	378	125	688	343	0	275	383	2406	811
Pennate diatom sp2	43	0	0	0	34	0	0	98	0	0	0	44	18
Ankistrodesmus	214	691	1240	35	309	14708	46	147	106	4194	1342	350	1948
Coxxomyxaceae sp3	0	81	283	35	2922	42	275	10036	142	1856	96	0	1314
Ulothrix type	0	0	0	0	0	250	0	0	0	0	0	0	21
Chlorococcales sp3	0	0	0	0	309	0	46	0	106	0	719	0	98

Appendix 2.5 Continued

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	35	0	0	46	0	0	0	0	0	7
Chlorophyceae unknown	0	0	0	0	172	0	0	0	0	0	0	0	14
Cosmarium sp6	85	163	460	71	275	0	92	0	0	0	0	0	95
Penium	0	0	0	0	0	0	0	0	35	0	0	0	3
Sphaerocystis	0	41	1594	0	0	0	0	0	0	0	0	0	136
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	0	0	0	0	0	0	0	0	0	0	0	0	0
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	0	0	0	0	0	0
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(10 Jun 88)	1367	3006	5879	4958	16431	18500	6875	12925	3081	9831	4360	9013	8019

Appendix 2.6 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 8 July 1988.

	Pond											
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp.1	0	333	555	226	267	194	121	433	447	117	35	515	270
Chlorococcales sp2	0	67	513	32	167	32	0	0	0	0	248	238	108
Dinobryon	1422	767	1110	775	67	291	453	0	1422	642	71	238	605
Staurastrum sp1	36	0	0	0	33	32	0	0	0	0	35	0	11
Cosmarium sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnodinium	36	0	0	97	0	0	30	0	0	0	35	40	20
Closteiopsis	0	0	0	32	33	32	0	0	41	58	0	79	23
Cosmarium sp2	0	0	0	0	0	0	0	0	0	0	390	40	36
Cosmarium sp3	73	0	0	0	0	0	0	108	0	0	0	0	15
Cosmarium sp4 panamense	0	0	0	0	0	0	0	54	0	0	0	0	5
Peridinium	109	67	0	161	33	355	332	108	122	29	35	79	119
Pennate diatom sp1	0	0	0	32	0	32	0	0	81	0	71	40	21
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	0	85	65	67	0	0	0	0	0	0	0	18
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	146	267	0	129	67	97	60	217	0	0	106	396	124
Coccomyxaceae sp2 (Dispora)	0	0	0	0	67	0	0	0	0	0	0	79	12
Palmellaceae sp1	36	67	0	32	0	0	91	108	0	1429	248	752	230
Coelastrum	0	33	299	32	1367	0	30	108	0	58	35	238	183
Kirchneriella	328	300	598	549	233	2519	363	1896	2884	554	5915	8946	2090
Pennate diatom sp2	0	0	0	0	33	0	30	0	81	0	35	40	18
Ankistrodesmus	474	1000	1281	65	500	2777	121	1408	12594	3325	142	4631	2360
Coxxomyxaceae sp3	328	533	3118	420	300	291	876	4604	203	88	0	238	916
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	73	33	171	0	100	0	0	163	41	117	106	198	83

Appendix 2.6 Continued

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	36	0	0	0	0	0	0	0	0	0	0	0	3
Chlorophyceae unknown	0	0	0	65	0	0	0	0	0	0	567	238	72
Cosmarium sp6	693	300	1025	258	1100	0	91	0	41	0	283	79	322
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	67	2434	0	67	32	0	0	0	0	0	0	217
Dimorphococcus lunatus	0	0	0	0	33	0	0	0	0	0	0	0	3
Glenodinium	0	0	0	0	0	0	0	0	0	0	0	0	0
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	0	0	0	0	0	0
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(8 July 88)	3792	3833	11190	2971	4533	6684	2598	9208	17956	6417	8358	17100	7887

Appendix 2.7 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 5 Aug. 1988.

						Pond							
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp.1	356	1445	108	300	813	408	24	317	379	300	300	1056	484
Chlorococcales sp2	40	0	108	0	41	29	0	0	29	713	33	81	89
Dinobryon	356	1385	1760	0	163	58	0	396	2071	38	0	0	519
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	33	0	3
Cosmarium sp1	0	40	108	0	41	0	0	40	0	0	0	54	24
Gymnodinium	20	0	27	0	0	0	24	0	204	0	33	0	26
Closteiopsis	79	0	0	1033	975	292	24	0	88	1819	0	1192	458
Cosmarium sp2	2236	119	27	3900	0	10413	6133	1306	29	0	22000	135	3858
Cosmarium sp3	20	20	0	33	41	29	0	119	0	38	33	54	32
Cosmarium sp4 panamense	20	0	27	0	0	0	24	0	0	0	0	0	6
Peridinium	139	20	0	33	0	29	120	79	0	38	67	54	48
Pennate diatom sp1	0	0	0	267	0	88	72	0	0	56	33	0	43
Cosmarium sp5	0	0	0	33	0	0	0	0	0	19	0	0	4
Ocillatoria	0	0	0	267	0	0	0	0	0	0	0	0	22
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	20	0	81	33	0	0	0	0	58	0	0	0	16
Coccomyxaceae sp2 (Dispora)	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmellaceae sp1	178	336	190	100	1097	29	192	8946	5483	2438	1067	596	1721
Coelastrum	79	59	298	233	203	29	120	79	0	38	200	190	127
Kirchneriella	336	495	325	567	0	58	48	119	58	0	100	27	178
Pennate diatom sp2	0	0	0	33	0	0	24	0	0	0	0	0	5
Ankistrodesmus	317	3741	677	0	325	263	192	871	1371	1538	100	325	810
Coxxomyxaceae sp3	119	158	244	133	122	58	0	79	29	0	0	163	92
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	0	139	0	0	325	58	0	0	58	131	300	352	114

Appendix 2.7 Continued

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	257	416	488	367	0	117	0	0	1546	206	0	0	283
Cosmarium sp6	277	0	840	133	41	58	431	0	0	19	433	27	188
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	20	0	0	0	0	0	0	0	0	0	0	2
Dimorphococcus lunatus	0	40	0	0	0	0	0	0	0	0	0	0	3
Glenodinium	20	20	0	33	0	0	0	0	0	0	67	0	12
Merismopedia	20	59	0	33	0	88	0	0	0	0	0	0	17
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	29	0	0	0	2
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	0	0	0	0	0	0
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(5 Aug 88)	4889	8510	5308	7533	4184	12104	7427	12350	11433	7388	24800	4306	9186

Appendix 2.8 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 16 Sep. 1988.

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	125	0	0	10
Anabaena	50	0	0	181	0	319	75	0	0	42	0	0	56
Chlorococcales sp.1	200	298	321	302	33	531	1050	0	1575	1042	253	484	507
Chlorococcales sp2	100	108	92	121	67	142	713	0	338	500	28	517	227
Dinobryon	25	3088	0	604	1133	531	2100	0	38	0	0	0	627
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	0	32	3
Cosmarium sp1	0	0	0	0	0	0	38	0	0	0	0	0	3
Gymnodinium	0	0	0	0	0	0	0	0	0	0	0	0	0
Closteiopsis	700	217	5225	91	500	3931	0	0	188	5750	84	0	1390
Cosmarium sp2	1325	30171	6050	4652	67	57694	4088	0	8700	0	136828	65	20803
Cosmarium sp3	50	27	0	60	0	0	0	0	0	0	0	0	11
Cosmarium sp4 panamense	0	0	0	0	0	0	0	0	113	0	0	32	12
Peridinium	75	81	0	30	0	35	0	0	75	83	28	65	39
Pennate diatom sp1	50	27	46	30	67	35	75	0	0	42	56	65	41
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	27	0	91	0	0	150	0	0	0	225	0	41
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	125	27	0	0	0	0	113	35	113	917	56	194	132
Coccomyxaceae sp2 (Dispora)	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmellaceae sp1	0	27	0	151	300	142	225	0	225	2917	478	2616	590
Coelastrum	50	163	92	151	133	106	0	35	38	83	113	129	91
Kirchneriella	0	27	0	60	0	0	0	0	300	0	0	0	32
Pennate diatom sp2	0	0	0	0	0	0	0	0	0	0	0	32	3
Ankistrodesmus	175	81	138	0	167	744	188	0	563	1125	0	420	300
Coxxomyxaceae sp3	375	27	92	30	0	0	38	0	150	0	28	129	72
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	25	0	46	30	33	0	113	35	0	917	28	1873	258

Appendix 2.8 Continued

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	0	135	0	91	0	0	113	0	11700	417	0	904	1113
Cosmarium sp6	25	0	0	0	0	142	0	0	0	0	0	0	14
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	0	0	0	0	0	0	0	75	0	0	0	6
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	25	0	0	30	0	0	0	0	0	0	0	97	13
Merismopedia	0	0	0	0	0	35	0	0	0	42	0	0	6
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	27	0	0	0	0	0	0	0	0	0	0	2
Unknown "tear drop"	0	0	0	0	0	0	0	0	0	0	0	0	0
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(16 Sep 88)	3375	34558	12100	6706	2500	64387	9075	106	24188	14000	138206	7653	26405

Appendix 2.9 Phytoplankton densities (cells/ml) collected from the experimental ponds using integrated plakton sampler, 14 Oct. 1988.

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	32	0	0	27	0	300	146	0	100	0	263	156	85
Chlorococcales sp.1	32	25	25	54	206	50	29	25	533	0	29	938	162
Chlorococcales sp2	161	375	225	54	0	700	117	25	100	31	2858	52	392
Dinobryon	775	925	75	352	550	0	292	50	533	63	0	0	301
Staurastrum sp1	32	0	0	0	0	0	0	0	0	0	0	0	3
Cosmarium sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnodinium	0	25	0	0	0	50	29	50	0	0	0	0	13
Closteiopsis	65	500	2250	731	1306	1625	29	25	133	969	29	104	647
Cosmarium sp2	10172	41350	25	33610	103	79800	54483	0	119000	500	82338	2708	35341
Cosmarium sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp4 panamense	0	0	0	0	0	0	0	0	0	0	0	0	0
Peridinium	194	25	25	27	0	50	58	0	0	31	88	104	50
Pennate diatom sp1	32	25	25	0	0	25	58	0	33	31	0	52	24
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	0	0	0	0	0	0	0	33	0	0	0	3
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	32	0	0	0	0	25	29	0	33	156	58	938	106
Coccomyxaceae sp2 (Dispora)	65	0	0	0	0	0	0	0	0	0	0	0	5
Palmellaceae sp1	65	25	25	0	0	25	0	0	167	406	0	2083	233
Coelastrum	0	75	100	108	69	25	58	0	0	0	0	52	41
Kirchneriella	0	0	125	54	0	0	29	0	33	0	0	0	20
Pennate diatom sp2	0	0	0	0	0	0	29	0	0	0	0	0	2
Ankistrodesmus	129	100	75	0	0	475	88	0	267	188	0	469	149
Coxxomyxaceae sp3	32	0	0	0	0	25	0	0	100	0	0	0	13
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	129	0	0	0	0	25	117	0	0	219	0	469	80

Appendix 2.9 Continued

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	0	0	0	0	0	0	117	0	200	0	0	208	44
Cosmarium sp6	65	0	0	27	0	0	58	0	33	94	0	104	32
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	0	0	0	0	0	0	29	25	0	0	0	0	5
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	32	0	0	0	0	0	0	0	33	0	0	0	5
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	75	0	0	0	0	6
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(14 Oct 88)	12045	43450	2975	35046	2234	83200	55796	275	121333	2688	85663	8438	37762

Appendix 2.10 Phytoplankton densities (cells/ml) collected from experimental ponds using integrated plakton sampler, 18 Nov. 1988.

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	23	156	0	65	0	467	172	0	100	0	594	385	163
Chlorococcales sp.1	0	0	65	97	0	133	0	0	0	0	119	77	41
Chlorococcales sp2	46	31	65	258	103	1467	69	25	67	73	8194	617	918
Dinobryon	871	813	194	129	309	0	550	350	200	693	0	964	423
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp1	0	0	32	0	34	0	0	0	0	0	0	0	6
Gymnodinium	0	31	0	0	0	0	0	0	0	0	0	0	3
Closteiopsis	46	469	7363	258	69	4133	0	0	67	802	0	39	1104
Cosmarium sp2	7540	55938	161	40203	653	4800	83772	0	80967	36	166844	12064	37748
Cosmarium sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp4 panamense	0	0	0	0	0	0	0	0	67	0	0	0	6
Peridinium	69	94	0	32	0	167	138	0	67	0	297	154	85
Pennate diatom sp1	23	0	0	32	0	0	0	0	0	0	0	39	8
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	0	0	0	0	0	0	69	0	0	36	59	154	27
Coccomyxaceae sp2 (Dispora)	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmellaceae sp1	0	0	0	0	0	67	103	75	0	0	0	463	59
Coelastrum	0	0	65	32	34	0	0	0	0	0	0	77	17
Kirchneriella	0	0	32	0	34	0	0	0	0	36	0	39	12
Pennate diatom sp2	0	0	0	0	34	0	0	50	0	0	0	0	7
Ankistrodesmus	92	63	32	0	34	400	34	0	133	547	0	385	143
Coxxomyxaceae sp3	0	0	0	0	0	0	0	0	0	0	0	39	3
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	23	63	0	0	0	0	34	0	0	0	0	1542	138

Appendix 2.10 Continued

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	34	0	0	0	0	0	3
Chlorophyceae unknown	0	0	0	0	0	0	0	0	200	0	0	0	17
Cosmarium sp6	0	31	32	0	69	67	0	0	0	146	0	39	32
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	0	31	0	0	0	0	0	25	0	0	0	39	8
Merismopedia	0	31	0	0	0	0	0	0	0	0	0	0	3
Scenedesmus opoliensis	23	0	0	0	0	0	0	0	0	0	0	0	2
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	800	0	0	0	0	67
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(18 Nov 88)	8754	57750	8041	41107	1375	11700	84975	1325	81867	2370	176106	17113	41040

Appendix 2.11 Phytoplankton densities (cells/ml) collected from experimental ponds using integrated plakton sampler, 16 Dec. 1988.

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	29	208	0	0	0	263	333	0	129	0	177	333	123
Chlorococcales sp.1	0	0	0	0	0	75	0	0	0	0	0	333	34
Chlorococcales sp2	0	0	0	0	0	0	0	0	0	0	0	200	17
Dinobryon	438	547	300	100	474	0	750	129	0	3442	1381	567	677
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnodinium	58	0	0	0	36	113	0	0	0	0	0	0	17
Closteiopsis	58	391	6733	350	109	3413	0	0	0	117	0	67	936
Cosmarium sp2	15750	58333	567	36225	36	7050	66958	0	79082	117	22454	28000	26214
Cosmarium sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp4 panamense	0	0	0	0	0	0	0	0	0	0	0	0	0
Peridinium	88	52	0	75	0	0	0	0	97	29	71	100	43
Pennate diatom sp1	29	0	33	0	0	0	0	0	0	0	0	0	5
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	0	0	0	0	0	0	0	0	0	0	167	14
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	0	0	0	0	0	0	0	0	0	0	0	133	11
Coccomyxaceae sp2 (Dispora)	0	0	0	0	0	0	83	0	0	58	0	200	28
Palmellaceae sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelastrum	0	0	0	25	0	0	0	0	0	0	0	0	2
Kirchneriella	58	0	0	0	0	0	0	0	0	0	0	0	5
Pennate diatom sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ankistrodesmus	146	26	100	0	0	225	0	0	97	117	0	400	93
Coxxomyxaceae sp3	0	0	0	0	0	38	0	0	0	0	0	0	3
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	0	0	0	0	0	0	0	0	0	0	0	333	28

Appendix 2.11 Continued

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp6	0	0	0	0	0	0	0	0	0	0	35	0	3
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	0	0	0	36	0	0	0	0	0	0	0	3
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	0	0	67	0	0	38	0	0	0	0	0	0	9
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	97	0	0	0	0	8
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(16 Dec 88)	16654	59557	7800	36775	693	11213	68125	226	79405	3879	24119	30833	28273

Appendix 2.12 Phytoplankton densities (cells/ml) collected from experimental ponds using integrated plakton sampler, 13 Jan. 1989.

			Pond										
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	60	35	0	284	0	113	226	0	113	0	0	214	87
Chlorococcales sp.1	0	0	0	0	29	0	0	0	0	0	0	0	2
Chlorococcales sp2	0	0	27	0	0	0	0	0	0	39	0	0	5
Dinobryon	544	390	406	678	788	0	1550	1616	75	3160	1583	1623	1034
Staurastrum sp1	0	0	0	0	0	0	0	0	38	0	0	0	3
Cosmarium sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnodinium	60	0	27	0	0	0	0	0	0	0	0	0	7
Closteiopsis	91	638	1110	459	29	2503	0	34	38	77	42	43	422
Cosmarium sp2	17974	49548	569	39484	88	6525	72172	0	72750	77	20083	34423	26141
Cosmarium sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp4 panamense	0	0	0	0	0	0	0	0	0	0	0	0	0
Peridinium	151	71	135	22	117	197	97	0	113	0	42	128	89
Pennate diatom sp1	30	71	0	0	0	28	0	0	0	0	0	0	11
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	0	54	0	0	0	0	0	263	0	0	0	26
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	0	0	0	0	0	0	0	0	0	0	0	43	4
Coccomyxaceae sp2 (Dispora)	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmellaceae sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelastrum	0	0	0	0	0	0	0	0	0	0	0	0	0
Kirchneriella	0	0	0	0	0	0	0	0	0	0	0	0	0
Pennate diatom sp2	0	0	27	0	29	0	0	34	0	0	0	0	8
Ankistrodesmus	211	35	54	0	0	169	0	103	38	77	0	256	79
Coxxomyxaceae sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	0	0	0	0	0	0	0	0	0	0	0	85	7

Appendix 2.12 Continued

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp6	0	0	0	0	0	0	0	0	0	0	0	43	4
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	0	0	0	0	0	0	0	0	0	0	0	0	0
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	275	0	0	0	0	23
Spinocosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0
total density(13 Jan 89)	19122	50788	2410	40928	1079	9534	74045	2063	73425	3430	21750	36857	27953

Appendix 2.13 Phytoplankton densities (cells/ml) collected from experimental ponds using integrated plakton sampler, 10 Feb. 1989.

							Pond						
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena	0	69	0	263	0	84	121	0	0	0	83	168	66
Chlorococcales sp.1	0	0	0	0	0	197	0	0	0	0	0	0	16
Chlorococcales sp2	0	0	0	0	178	0	0	0	0	163	63	24	36
Dinobryon	216	46	0	613	59	0	1027	677	515	190	583	743	389
Staurastrum sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnodinium	0	0	0	0	99	28	0	0	40	108	0	24	25
Closteiopsis	96	275	219	175	59	759	0	27	0	108	0	24	145
Cosmarium sp2	37495	59331	500	38588	0	7678	63226	0	67410	190	8854	35674	26579
Cosmarium sp3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp4 panamense	0	0	0	0	0	0	0	0	0	0	0	0	0
Peridinium	168	92	188	44	40	169	91	81	79	54	42	72	93
Pennate diatom sp1	0	0	0	0	0	0	0	0	0	0	0	24	2
Cosmarium sp5	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocillatoria	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmidium type	0	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccomyxaceae sp2 (Dispora)	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmellaceae sp1	0	0	0	0	0	0	0	0	0	0	0	72	6
Coelastrum	0	0	0	0	0	0	0	0	0	0	0	24	2
Kirchneriella	0	0	0	0	0	0	0	0	0	0	0	0	0
Pennate diatom sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ankistrodesmus	96	92	63	0	0	113	0	81	119	135	0	240	78
Coxxomyxaceae sp3	0	0	0	0	0	0	0	0	0	0	0	24	2
Ulothrix type	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcales sp3	0	0	0	0	0	0	0	0	0	0	0	168	14

Appendix 2.13 Continued

	Pond												
Organism	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chlamydomonas	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceae unknown	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium sp6	0	0	0	0	0	0	0	0	0	0	0	0	0
Penium	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerocystis	0	23	31	0	0	0	0	0	0	0	0	0	5
Dimorphococcus lunatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Glenodinium	24	0	31	0	0	56	0	0	40	0	0	0	13
Merismopedia	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauastrum sp2	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown "tear drop"	0	0	0	0	0	0	0	488	0	0	0	0	41
Spinocosmarium	0	0	31	0	0	0	0	0	0	0	0	0	3
total density(10 Feb 89)	38094	59927	1063	39681	435	9084	64465	1354	68202	948	9625	37279	27513

Appendix 3.1 Environmental parameters measured from the experimental ponds, 5 February 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Mg C fixed/m3	4.0	787.5	212.5	18.8	862.5	675.0	900.0	215.6	-281.3	881.3	-731.3	1443.7	415.7
secchi (ft.)	2.0	2.0	3.5	3.0	2.5	4.0	2.0	2.5	3.0	2.0	3.8	2.0	2.7
D.O. (mg/L) 1m	10.6	9.4	10.4	10.6	9.6	10.7	10.4	10.2	10.7	9.0	12.2	10.0	10.3
temp °C (1m)	6.0	7.0	6.0	6.0	7.4	6.0	6.0	5.5	7.0	5.0	5.5	7.0	6.2
pH	6.9	6.8	6.9	6.9	6.9	6.9	6.9	6.8	6.8	6.8	6.9	6.8	6.8
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.8	1.1	1.0	1.1	0.9	0.0	1.0	0.9	0.9	1.4	1.2	0.0	0.9
NO2	0.1	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.1
PO4 (.02-2 mg/L)	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Hardness (mg/L)	75.0	70.0		70.0	70.0	70.0	75.0		75.0			75.0	48.3
Alkalinity (mg/L)	31.2	28.6		31.2	28.6	28.6	28.6		31.2			31.2	19.9
Conductivity (25°C)	213.5	232.3	233.9	215.0	206.0	192.8	175.7	163.4	181.4	166.5	213.2	194.1	199.0

Appendix 3.2 Environmental parameters measured from the experimental ponds, 4 March 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.2	0.2	0.1	0.1	0.2
Mg C fixed/m3	656.2	637.5	675.0	806.3	431.2	1593.8	-37.5	562.5	918.7	1387.5	1012.5	1387.5	835.9
secchi (ft.)	2.5	3.0	3.0	3.0	3.5	2.5	2.5	2.5	3.5	2.5	3.0	2.5	2.8
D.O. (mg/L) 1m	11.2	11.1	11.6	11.1	11.0	11.1	11.4	11.4	10.4	11.4	11.4	11.0	11.2
temp °C (1m)	8.5	8.5	9.0	8.2	8.7	9.0	8.0	9.0	8.9	8.1	8.0	8.0	8.5
pH	6.9	6.9	6.8	6.8	6.9	6.7	6.8	6.8	6.7	6.9	6.9	7.0	6.8
NH3 (.02-5 mg/L)	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.1	0.1
NO3	1.2	1.2	1.1	1.1	2.7	1.5	1.2	1.0	0.6	1.2	1.2	1.1	1.3
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	75.0	70.0	75.0	75.0	65.0	75.0	70.0	75.0	75.0	75.0	75.0	75.0	73.3
Alkalinity (mg/L)	33.8	31.2	28.6	31.2	33.8	33.8	31.2	36.4	36.4	31.2	33.8	31.2	32.7
Conductivity (25°C)	230.2	235.5	233.9	202.0	195.9	220.1	159.5	177.2	180.3	190.9	213.2	185.1	202.0

Appendix 3.3 Environmental parameters measured from the experimental ponds, 1 April 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	2.6	0.5	1.0	1.0	0.8	0.0	2.1	0.0	2.5	0.0	0.0	0.2	0.9
Mg C fixed/m3	-375.0	-600.0	-637.5	-468.7	-656.2	-450.0	-375.0	-937.5	-431.3	300.0	-243.8	356.3	-376.6
secchi (ft.)	2.5	2.5	3.0	2.5	4.0	3.0	2.5	4.0	3.5	2.0	3.5	3.0	3.0
D.O. (mg/L) 1m	10.2	9.6	9.6	10.0	10.6	9.8	10.4	10.4	9.8	10.4	10.4	9.8	10.1
temp °C (1m)	16.0	16.9	16.5	16.0	16.7	16.0	16.0	16.0	17.0	14.0	16.5	16.5	16.2
pH	6.8	6.8	7.0	7.1	6.8	6.8	7.0	7.0	7.0	6.9	6.9	7.0	6.9
NH3 (.02-5 mg/L)	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
NO3	1.2	1.1	0.9	1.7	1.3	0.7	1.1	0.3	0.4	1.0	0.9	0.8	0.9
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
PO4 (.02-2 mg/L)	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	75.0	75.0	75.0	71.3
Alkalinity (mg/L)	28.6	26.0	28.6	31.2	31.2	33.8	28.6	33.8	33.8	28.6	28.6	31.2	30.3
Conductivity (25°C)	235.5	237.6	225.6	194.0	223.1	181.7	188.8	190.9	201.5	194.1	193.1	178.8	203.7

Appendix 3.4 Environmental parameters measured from the experimental ponds, 13 May 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	4.3	2.7	4.3	0.8	0.5	3.3	1.6	1.1	4.4	1.2	0.5	2.6	2.3
Mg C fixed/m3	506.3	600.0	487.5	-1163	993.8	-412.5	168.8	-300.0	-37.5	225.0	-300.0	-600.0	14.1
secchi (ft.)	2.5	2.0	2.5	5.0	3.0	2.0	2.5	5.0	2.0	1.5	3.0	2.0	2.8
D.O. (mg/L) 1m	10.0	10.8	9.6	9.0	7.4	9.4	7.8	8.5	8.9	8.0	8.8	9.2	9.0
temp °C (1m)	21.0	21.0	21.0	21.0	21.0	20.0	21.0	21.0	20.5	21.0	21.0	21.0	20.9
pH	7.6	7.3	7.3	7.2	7.1	7.5	7.0	7.2	7.2	7.1	7.1	7.2	7.2
NH3 (.02-5 mg/L)	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0
NO3	0.3	0.1	0.5	0.3	0.4	0.3	1.4	0.0	0.0	0.4	0.0	0.9	0.4
NO2	0.2	0.3	0.4	0.5	0.4	0.4	0.5	0.4	0.5	0.5	0.6	0.6	0.4
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Hardness (mg/L)	80.0	75.0	75.0	80.0	70.0	70.0	75.0	70.0	70.0	75.0	80.0	80.0	75.0
Alkalinity (mg/L)	33.8	31.2	28.6	33.8	36.4	41.6	33.8	44.2	44.2	33.8	31.4	33.8	35.6
Conductivity (25°C)	235.8	231.3	218.3	222.0	186.8	203.9	174.7	213.2	204.7	225.9	182.5	169.5	205.7

Appendix 3.5 Environmental parameters measured from the experimental ponds, 10 June 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	2.8	2.2	1.7	0.9	6.4	2.1	5.7	3.3	5.4	5.3	4.2	1.7	3.5
Mg C fixed/m3	-375.0	56.2	375.0	-300.0	431.3	168.7	693.7	75.0	-318.8	56.3	956.2	-187.5	135.9
secchi (ft.)	2.5	2.5	3.0	3.5	3.0	2.5	2.0	3.0	1.5	2.5	3.0	2.0	2.6
D.O. (mg/L) 1m	8.0	6.6	8.2	7.4	10.1	7.8	9.8	7.6	7.0	9.7	8.4	8.4	8.3
temp °C (1m)	21.0	20.0	21.5	22.0	21.0	20.5	20.0	21.0	20.0	21.0	21.5	21.0	20.9
pH	7.2	7.0	7.2	7.2	7.2	7.1	7.2	7.1	7.0	7.3	7.3	7.2	7.2
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NO3	0.3	0.2	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1
NO2	1.7	0.8	0.8	0.8	0.8	0.8	0.9	0.7	0.9	1.0	1.0	1.1	0.9
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	80.0	70.0	70.0	75.0	70.0	70.0	75.0	65.0	70.0	70.0	80.0	75.0	72.5
Alkalinity (mg/L)	36.4	33.8	33.8	41.6	41.6	44.2	39.0	46.8	46.8	39.0	39.0	41.6	40.3
Conductivity (25°C)	238.0	234.4	229.8	190.0	213.0	209.0	209.0	213.2	192.0	204.7	175.0	179.9	207.3

Appendix 3.6 Environmental parameters measured from the experimental ponds, 8 July 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	2.8	3.5	2.5	2.5	1.6	3.9	1.0	4.6	4.9	4.1	5.3	3.7	3.4
Mg C fixed/m3	193519	167306	249694	228544	209400	213994	270788	304144	172856	186731	252450	149288	216559
secchi (ft.)	6.0	4.0	3.5	4.0	5.0	4.0	4.0	5.0	3.5	3.0	4.5	3.0	4.1
D.O. (mg/L) 1m	7.5	8.0	8.4	7.9	8.0	7.8	9.6	8.6	7.3	7.6	9.4	9.0	8.3
temp °C (1m)	27.0	27.5	28.0	27.5	27.5	27.5	28.5	29.5	27.0	27.0	29.0	27.5	27.8
pH	7.2	7.1	7.4	7.4	7.3	7.2	7.4	7.5	7.2	7.0	7.5	7.1	7.3
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
NO3	0.0	0.1	0.2	0.0	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	75.0	75.0	70.0	75.0	70.0	70.0	75.0	65.0	75.0	75.0	80.0	80.0	73.8
Alkalinity (mg/L)	39.9	39.9	38.0	45.6	43.7	45.6	39.9	45.6	51.3	45.6	45.6	47.5	44.0
Conductivity (25°C)	225.7	239.7	213.1	206.0	212.0	229.2	214.0	200.5	180.3	198.4	182.5	163.2	205.4

Appendix 3.7 Environmental parameters measured from the experimental ponds, 5 August 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	1.5	2.6	5.0	3.6	2.1	3.2	3.5	5.3	6.8	3.1	0.6	1.0	3.2
Mg C fixed/m3	107006	18.7	-337.5	-93.7	-412.5	-206.3	75.0	37.5	937.5	-56.2	112.5	-243.8	8903
secchi (ft.)	7.0	6.5	5.0	6.0	5.0	4.5	4.0	4.0	3.0	3.5	3.5	3.0	4.6
D.O. (mg/L) 1m	7.0	7.4	6.6	7.1	7.0	7.5	7.9	7.8	7.8	7.5	8.4	6.9	7.4
temp °C (1m)	29.8	30.0	29.8	29.8	29.5	29.5	30.0	29.0	29.5	29.2	30.0	29.5	29.6
pH	7.5	7.2	7.2	7.5	7.0	7.0	7.3	7.7	7.3	7.2	7.7	7.2	7.3
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	70.0	60.0	60.0	70.0	60.0	55.0	72.5	55.0	67.5	65.0	75.0	75.0	65.4
Alkalinity (mg/L)	45.6	39.9	39.9	49.4	45.6	49.4	47.5	49.4	53.2	47.5	47.5	53.2	47.3
Conductivity (25°C)	223.5	236.6	231.9	210.0	230.2	220.1	225.9	195.2	176.1	209.0	166.5	148.7	206.1

Appendix 3.8 Environmental parameters measured from the experimental ponds, 16 September 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	0.3	0.2	0.4	0.1	0.3	0.1	0.2	0.0	0.8	0.4	0.4	0.6	0.3
Mg C fixed/m3	-206.3	-18.7	-581.3	-693.8	-225.0	168.8	-375.0	393.8	-18.7	-1106	-487.5	-337.5	-291
secchi (ft.)	6.0	4.5	5.0	6.9	6.9	3.8	7.0	7.1	3.5	5.0	3.5	6.5	5.5
D.O. (mg/L) 1m	8.5	9.0	8.4	8.2	8.4	8.8	8.4	7.7	8.6	8.8	11.0	8.2	8.7
temp °C (1m)	23.0	24.0	23.8	23.8	23.0	23.6	23.0	24.0	23.0	23.8	24.0	23.0	23.5
pH	7.7	7.8	7.7	7.9	7.8	7.7	7.6	7.4	7.6	7.4	8.6	7.6	7.7
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	80.0	70.0	60.0	70.0	60.0	60.0	60.0	60.0	70.0	60.0	80.0	70.0	66.7
Alkalinity (mg/L)	49.4	38.0	41.8	45.6	49.4	49.4	47.5	47.5	49.4	47.5	49.4	49.4	47.0
Conductivity (25°C)	246.9	227.0	224.6	218.0	231.2	206.0	204.7	186.7	186.7	193.1	149.6	187.1	205.1

Appendix 3.9 Environmental parameters measured from the experimental ponds, 14 October 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	0.9	1.8	0.7	0.6	1.9	4.9	6.1	0.5	6.6	1.7	0.4	1.6	2.3
Mg C fixed/m3	-412.5	-150.0	-937.5	-900.0	-1369	-1181	-1163	-450.0	-18.7	75.0	-787.5	-75.0	-614.1
secchi (ft.)	7.0	6.0	6.9	6.0	7.0	3.0	4.5	6.8	3.3	6.8	3.5	6.3	5.6
D.O. (mg/L) 1m	10.0	10.0	9.8	9.8	10.3	10.5	10.6	9.6	11.0	9.8	10.4	10.4	10.2
temp °C (1m)	13.8	14.0	13.2	13.5	13.8	13.2	13.3	13.5	14.0	13.7	13.0	13.5	13.5
pH	8.1	8.0	7.8	7.9	7.9	8.1	7.4	7.9	8.0	7.9	8.0	8.2	7.9
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	40.0	40.0	30.0	50.0	50.0	50.0	50.0	40.0	50.0	40.0	40.0	50.0	44.2
Alkalinity (mg/L)	43.7	43.7	41.8	49.4	43.7	51.3	49.4	49.4	55.1	49.4	51.3	55.1	48.6
Conductivity (25°C)	252.5	233.4	237.1	230.0	225.2	213.0	198.4	195.2	170.8	174.0	198.4	139.3	205.6

Appendix 3.10 Environmental parameters measured from the experimental ponds, 18 November 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	1.9	1.4	0.7	2.9	0.9	3.0	5.0	0.9	7.3	2.4	3.0	2.5	2.7
Mg C fixed/m3	-796.9	-281.3	637.5	-56.3	-187.5	-750.0	1200.0	37.5	112.5	-731.2	56.3	-1013	-147.7
secchi (ft.)	2.0	2.0	4.5	2.5	5.5	2.5	2.0	3.0	2.0	2.0	2.0	2.0	2.7
D.O. (mg/L) 1m	10.6	10.4	10.4	10.8	10.9	10.0	10.4	10.0	11.0	11.2	10.3	10.8	10.6
temp °C (1m)	10.5	11.5	10.8	11.5	10.8	11.3	10.6	11.2	10.5	11.0	10.2	11.0	10.9
pH	7.4	7.7	7.7	7.8	7.6	7.6	7.4	7.8	7.8	7.7	7.6	7.5	7.6
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.4	0.1	0.5	0.0	0.7	0.0	0.1	0.1	0.0	0.1	0.2
Hardness (mg/L)	40.0	30.0	30.0	40.0	30.0	30.0	40.0	30.0	30.0	40.0	40.0	40.0	35.0
Alkalinity (mg/L)	49.4	51.3	47.5	45.6	45.6	47.5	49.4	45.6	49.4	45.6	45.6	49.4	47.7
Conductivity (25°C)	238.2	241.9	236.0	227.2	223.1	189.8	209.0	182.5	151.7	219.6	150.6	160.1	202.5

Appendix 3.11 Environmental parameters measured from the experimental ponds, 16 December 1988.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	1.1	1.2	1.3	1.7	0.5	3.7	3.2	0.6	8.2	2.8	5.6	1.7	2.6
Mg C fixed/m3	-1069	600.0	-56.3	900.0	-2297	440.6	-1209	1275.0	1106.3	-150.0	206.3	1875.0	135.2
secchi (ft.)	6.0	4.5	6.5	4.5	6.8	4.8	2.5	6.0	2.5	4.0	3.0	2.5	4.5
D.O. (mg/L) 1m	11.6	11.8	11.6	12.0	12.0	12.4	11.9	11.6	12.5	12.6	12.6	12.2	12.1
temp °C (1m)	4.0	4.0	4.0	4.0	3.5	3.9	4.0	3.8	4.0	4.0	4.0	4.0	3.9
pH	7.7	7.6	7.6	7.6	7.5	7.5	7.8	7.7	7.7	7.8	7.6	7.4	7.6
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	30.0	20.0	30.0	30.0	30.0	30.0	40.0	30.0	30.0	30.0	30.0	30.0	30.0
Alkalinity (mg/L)	41.8	41.8	38.0	49.4	47.5	47.5	47.5	45.6	47.5	47.5	47.5	49.4	45.9
Conductivity (25°C)	240.4	244.0	219.0	219.1	212.0	189.8	193.1	163.4	200.5	163.4	167.6	160.1	197.7

Appendix 3.12 Environmental parameters measured from the experimental ponds, 13 January 1989.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	3.9	5.8	1.1	4.8	0.7	1.5	7.4	2.6	14.4	3.2	4.0	4.7	4.5
Mg C fixed/m3	150.0	-206.3	0.0	506.3	187.5	56.2	337.5	168.8	0.0	750.0	318.8	243.7	209.4
secchi (ft.)	5.5	4.0	6.5	3.0	6.7	4.5	3.5	5.0	3.5	4.0	3.5	2.5	4.3
D.O. (mg/L) 1m	11.8	11.7	11.4	11.7	11.6	11.5	11.8	11.4	12.2	11.6	11.7	11.6	11.7
temp °C (1m)	7.1	7.8	5.8	7.5	5.8	7.1	5.5	7.0	5.8	7.0	7.1	5.5	6.6
pH	7.5	7.6	7.7	8.3	7.5	7.9	7.6	7.9	7.8	7.7	8.7	7.6	7.8
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hardness (mg/L)	60.0	60.0	60.0	60.0	50.0	50.0	70.0	50.0	50.0	50.0	60.0	60.0	56.7
Alkalinity (mg/L)	41.8	38.0	36.1	43.7	41.8	41.8	43.7	41.8	43.7	41.8	43.7	41.8	41.6
Conductivity (25°C)	245.4	226.7	221.0	218.1	224.1	180.7	174.0	214.3	146.4	177.2	166.5	176.8	197.6

Appendix 3.13 Environmental parameters measured from the experimental ponds, 10 February 1989.

	Pond												
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**
Chl. a (mg/m3)	4.3	5.9	1.5	4.8	0.9	2.1	7.5	2.7	12.3	3.4	4.3	4.8	4.5
Mg C fixed/m3	609.4	403.1	18.8	271.9	337.5	618.8	-168.8	-140.6	-28.1	375.0	159.4	121.9	214.8
secchi (ft.)	4.5	3.5	6.8	4.0	6.8	4.5	3.0	5.8	3.8	4.5	4.0	2.8	4.5
D.O. (mg/L) 1m	11.7	11.6	11.6	12.2	11.7	12.2	11.8	11.4	12.0	11.7	12.8	11.6	11.9
temp °C (1m)	4.8	4.0	4.5	4.8	4.0	4.1	3.8	4.8	4.5	4.0	4.0	4.0	4.3
pH	7.6	7.7	7.5	7.5	7.4	7.6	7.8	7.7	7.5	7.7	7.5	7.6	7.6
NH3 (.02-5 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO4 (.02-2 mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hardness (mg/L)	60.0	60.0	60.0	50.0	50.0	60.0	60.0	60.0	70.0	60.0	70.0	60.0	60.0
Alkalinity (mg/L)	34.2	38.0	41.8	43.7	41.8	43.7	45.6	45.6	49.8	45.6	47.5	45.6	43.6
Conductivity (25°C)	230.2	229.8	225.0	223.1	206.0	165.6	219.6	159.1	169.7	190.9	187.8	175.7	198.5

Appendix 4.1. Summary statistics for chlorophyll a (Mg./L) measured in the experimental ponds

DATE	Min	Max	Mean	S.D.	C.V.
5-Feb-88	n.d.	0.13	0.02	0.04	245.4
4-Mar-88	n.d.	1.15	0.17	0.34	195.1
1-Apr-88	n.d.	2.64	0.90	1.01	112.8
13-May-88	0.53	4.44	2.27	1.52	66.7
10-Jun-88	0.87	6.35	3.47	1.86	53.6
8-Jul-88	1.03	5.31	3.37	1.31	39.0
5-Aug-88	0.59	6.77	3.20	1.82	57.0
16-Sep-88	n.d.	0.79	0.32	0.23	71.9
14-Oct-88	0.41	6.62	2.31	2.25	97.6
18-Nov-88	0.72	7.35	2.68	1.91	71.2
16-Dec-88	0.46	8.17	2.63	2.29	87.2
13-Jan-89	0.71	14.4	4.51	3.68	81.6
10-Feb-89	0.87	12.3	4.54	3.08	67.7

Appendix 4.2. Summary statistics for primary productivity (Mg. Carbon Fixed/m3) measured in the experimental ponds.

Date	Min	Max	Mean	S.D.	C.V.
5-Feb-88	1.4	7.3	5.7	1.8	147.7
4-Mar-88	3.6	7.4	6.5	1.0	54.9
1-Apr-88	5.5	6.8	6.1	0.4	-99.4
13-May-88	3.6	7.1	5.9	0.9	4274.4
10-Jun-88	4.0	6.9	5.5	0.9	306.4
8-Jul-88	11.9	12.6	12.3	0.2	21.3
5-Aug-88	2.9	11.6	5.4	2.2	347.0
16-Sep-88	2.9	7.0	5.5	1.3	-139.2
14-Oct-88	2.9	7.2	5.9	1.4	-82.3
18-Nov-88	3.6	7.1	5.6	1.3	-432.0
16-Dec-88	4.0	7.7	6.4	1.1	877.2
13-Jan-89	n.d.	6.6	4.6	2.2	120.4
10-Feb-89	2.9	6.4	5.2	1.1	124.0

Appendix 4.3. Number of taxa accured in the experimental ponds from Feb. 5, 1988 to Feb. 10, 1989.

Date	Min	Max	Mean	S.D.	C.V.	C.Disp.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	2	0.2	0.2	0.3	0.6
1-Apr-88	1	4	3.4	0.3	0.8	0.9
13-May-88	6	14	9.3	0.7	6.2	2.5
10-Jun-88	14	21	17.1	0.7	6.6	2.6
8-Jul-88	16	25	20.7	0.8	7.5	2.7
5-Aug-88	20	28	24.1	0.8	7.0	2.6
16-Sep-88	20	30	25.8	0.7	6.5	2.6
14-Oct-88	23	30	26.6	0.6	5.0	2.2
18-Nov-88	23	31	26.8	0.7	5.8	2.4
16-Dec-88	23	31	27.1	0.6	5.0	2.2
13-Jan-89	23	31	27.3	0.7	5.5	2.3
10-Feb-89	23	31	27.4	0.7	6.3	2.5

Appendix 4.4. Number Of Taxa Present at each sampling date in the experimental ponds.

Date	Min	Max	Mean	S.D.	C.V.	C.Disp.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	2	0.3	0.2	0.4	0.6
1-Apr-88	1	4	3.3	0.3	0.8	0.9
13-May-88	3	12	7.3	0.8	7.2	2.7
10-Jun-88	10	18	13.5	0.6	4.6	2.2
8-Jul-88	10	19	13.6	0.9	9.5	3.1
5-Aug-88	11	19	14.9	0.7	5.9	2.4
16-Sep-88	3	17	13.0	1.2	16.6	4.1
14-Oct-88	5	18	11.8	1.2	17.3	4.2
18-Nov-88	6	17	9.7	0.8	8.2	2.9
16-Dec-88	2	12	6.0	0.8	6.9	2.6
13-Jan-89	4	9	6.3	0.5	3.3	1.8
10-Feb-89	4	13	6.5	0.7	5.6	2.4

Appendix 4.5. Cyanophyceae density in the experimental ponds.

Date	Min	Max	Mean	S.D.	C.V.	C.D.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	1741.7	180.6	506.7	280.6	1420.9
1-Apr-88	0	687.0	240.2	189.8	79.0	149.9
13-May-88	0	4150.0	345.8	1198.0	346.4	4150.4
10-Jun-88	0	106.3	23.1	37.6	162.7	61.1
8-Jul-88	0	166.7	32.0	53.5	167.4	89.5
5-Aug-88	0	300.0	43.8	90.0	205.3	184.7
16-Sep-88	0	354.2	119.7	128.2	107.1	137.4
14-Oct-88	0	300.0	88.1	109.1	123.9	135.1
18-Nov-88	0	593.8	166.1	206.1	124.1	255.8
16-Dec-88	0	500.0	139.7	162.2	116.2	188.4
13-Jan-89	0	375.0	113.5	129.4	114.1	147.6
10-Feb-89	0	262.5	67.5	84.9	125.8	106.8

Appendix 4.6. Desmidaceae density in the experimental ponds.

Date	Min	Max	Mean	S.D.	C.V.	C.D.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	0	0	0	0	0
1-Apr-88	0	75.0	9.2	23.1	250.9	57.9
13-May-88	36.5	9479.0	3151.0	3610.0	114.6	4135.8
10-Jun-88	41.7	920.8	357.3	236.6	66.2	156.7
8-Jul-88	0	1133.0	389.3	412.2	105.9	436.5
5-Aug-88	29.2	22500.0	4109.0	6630.0	161.4	10698.0
16-Sep-88	0	136828.0	20738.3	40422.0	194.9	78787.1
14-Oct-88	0	119033.0	35375.0	40709.0	115.1	46846.9
18-Nov-88	0	166844.0	37779.0	51584.0	136.5	70434.5
16-Dec-88	0	79082.0	26217.0	28271.0	107.8	30487.3
13-Jan-89	0	72787.0	26148.0	27425.0	104.9	28764.6
10-Feb-89	0	67410.0	25942.0	27357.0	105.5	28849.3

Appendix 4.7. Chlorophyceae density in the experimental ponds.

Date	Min	Max	Mean	S.D.	C.V.	C.D.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	0	0	0	0	0
1-Apr-88	0	393.8	187.4	130.7	69.7	91.1
13-May-88	0	1008.0	272.5	329.3	120.8	397.8
10-Jun-88	683.3	15542.0	5982.0	5171.0	86.4	4470.0
8-Jul-88	1422	16546.0	6685.0	5291.0	79.2	4188.2
5-Aug-88	598.9	10140.0	4324.0	3149.0	72.8	2292.7
16-Sep-88	106.3	15188.0	4824.0	5038.0	104.4	5262.0
14-Oct-88	150	5313.0	1904.0	1431.0	75.2	1075.0
18-Nov-88	229.2	8372.0	2562.0	3080.0	120.2	3702.9
16-Dec-88	0	6833.0	1165.0	2083.0	178.8	3726.0
13-Jan-89	0	2672.0	542.1	750.0	138.4	1037.7
10-Feb-89	0	8916.0	996.4	2501.0	250.9	6277.0

Appendix 4.8. Chrysophyceae (Dinobryon) density in the experimental ponds.

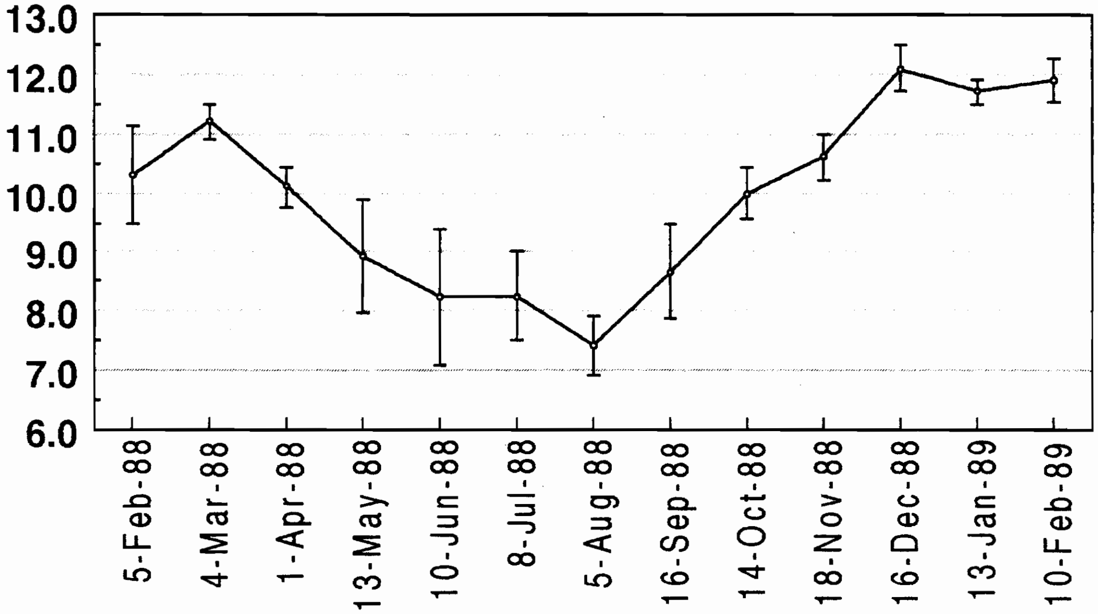
Date	Min	Max	Mean	S.D.	C.V.	C.D.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	0	0	0	0	0
1-Apr-88	129.2	1791.7	600.6	630.0	104.9	660.9
13-May-88	0	1254.2	237.7	451.2	189.8	856.3
10-Jun-88	0	4079.0	1248.0	1177.0	94.3	1110.2
8-Jul-88	0	1422.0	604.7	508.5	84.1	427.6
5-Aug-88	0	2071.0	518.9	762.2	146.9	1119.5
16-Sep-88	0	3088.0	626.6	1007.0	160.8	1619.9
14-Oct-88	0	925.0	301.2	326.9	108.5	354.8
18-Nov-88	0	963.5	422.7	343.5	81.3	279.2
16-Dec-88	0	3442.0	677.3	951.8	140.5	1337.4
13-Jan-89	0	3160.0	1034.0	904.6	87.5	791.3
10-Feb-89	0	1027.0	389.0	346.1	89.0	307.9

Appendix 4.9. Dinophyceae density in the experimental ponds.

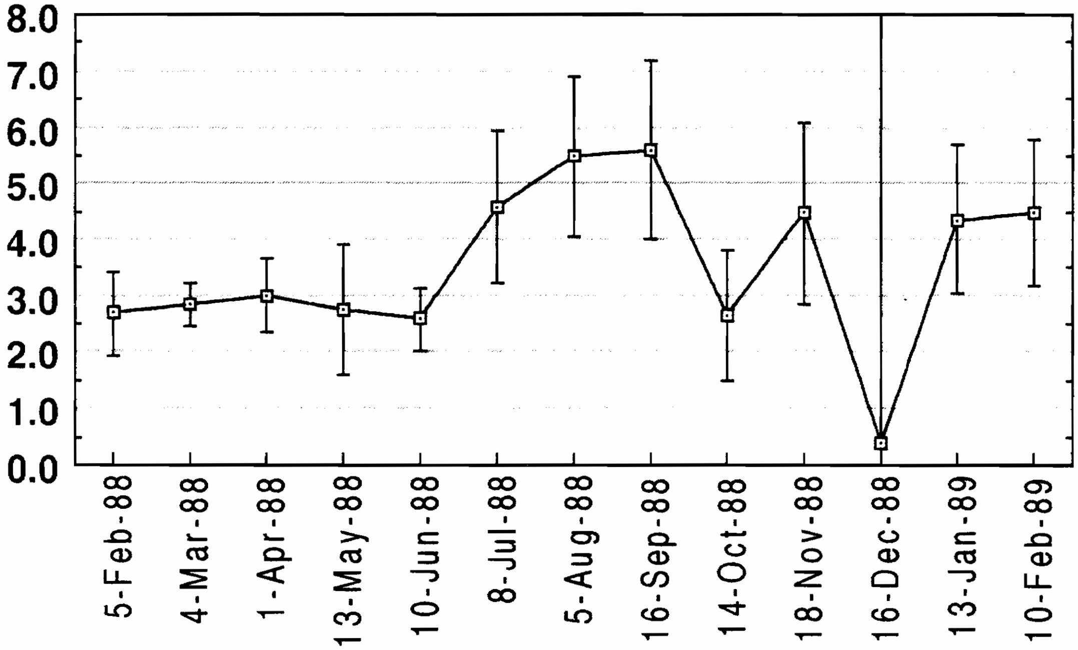
Date	Min	Max	Mean	S.D.	C.V.	C.D.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	0	0	0	0	0
1-Apr-88	0	0	0	0	0	0
13-May-88	109.4	1408.0	372.5	376.9	101.2	381.4
10-Jun-88	0	756.3	269.2	258.7	96.1	248.6
8-Jul-88	0	362.5	139.2	122.5	88.0	107.8
5-Aug-88	0	204.2	85.5	69.0	80.7	55.6
16-Sep-88	0	161.5	52.1	50.8	97.5	49.5
14-Oct-88	0	193.8	67.5	56.7	84.0	47.6
18-Nov-88	0	296.9	92.0	91.6	99.5	91.1
16-Dec-88	0	150.0	68.6	49.3	71.8	35.4
13-Jan-89	0	211.5	96.6	72.1	74.6	53.8
10-Feb-89	41.7	253.1	130.6	67.8	51.9	35.2

Appendix 4.10. Bacillariophyceae density in the experimental ponds.

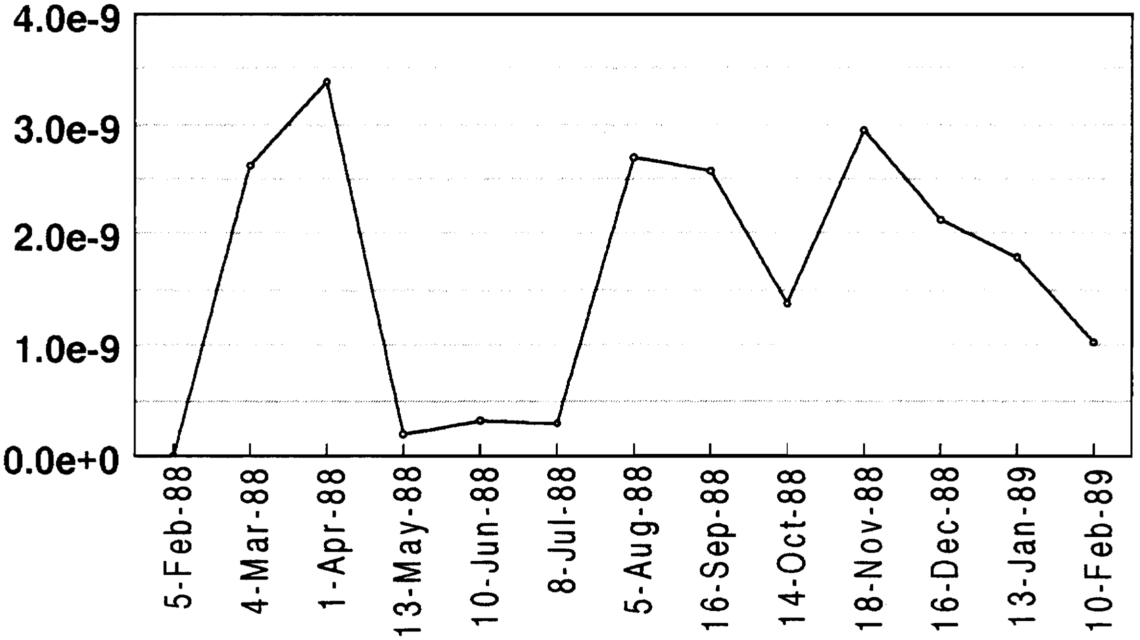
Date	Min	Max	Mean	S.D.	C.V.	C.D.
5-Feb-88	0	0	0	0	0	0
4-Mar-88	0	0	0	0	0	0
1-Apr-88	0	0	0	0	0	0
13-May-88	0	758.3	83.5	214.3	256.6	549.8
10-Jun-88	0	1487.0	138.5	425.9	307.4	1309.4
8-Jul-88	0	162.5	39.7	51.5	129.8	66.9
5-Aug-88	0	300.0	47.7	87.3	182.8	159.5
16-Sep-88	0	96.9	43.8	28.4	65.0	18.5
14-Oct-88	0	87.5	26.0	25.7	99.2	25.5
18-Nov-88	0	77.1	18.1	25.7	142.5	36.6
16-Dec-88	0	33.3	5.2	12.2	234.2	28.6
13-Jan-89	0	70.8	18.3	22.3	121.6	27.1
10-Feb-89	0	24.0	2.0	6.9	346.4	24.0



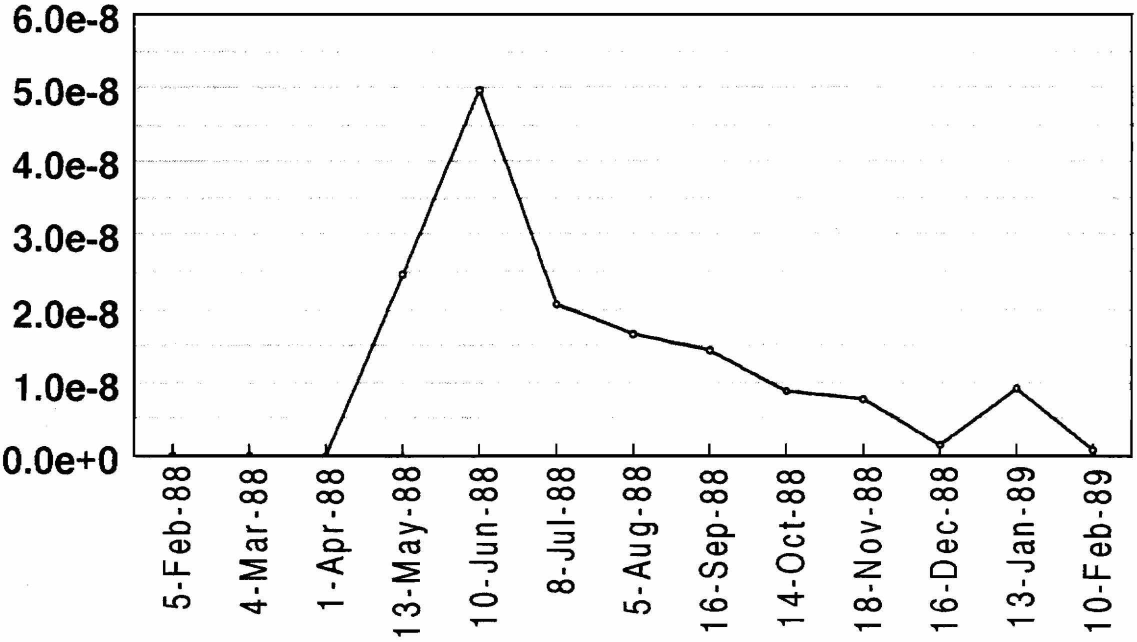
Appendix 4.11 Mean dissolved oxygen at 1 m depth (mg/L). Error bars represent standard deviation.



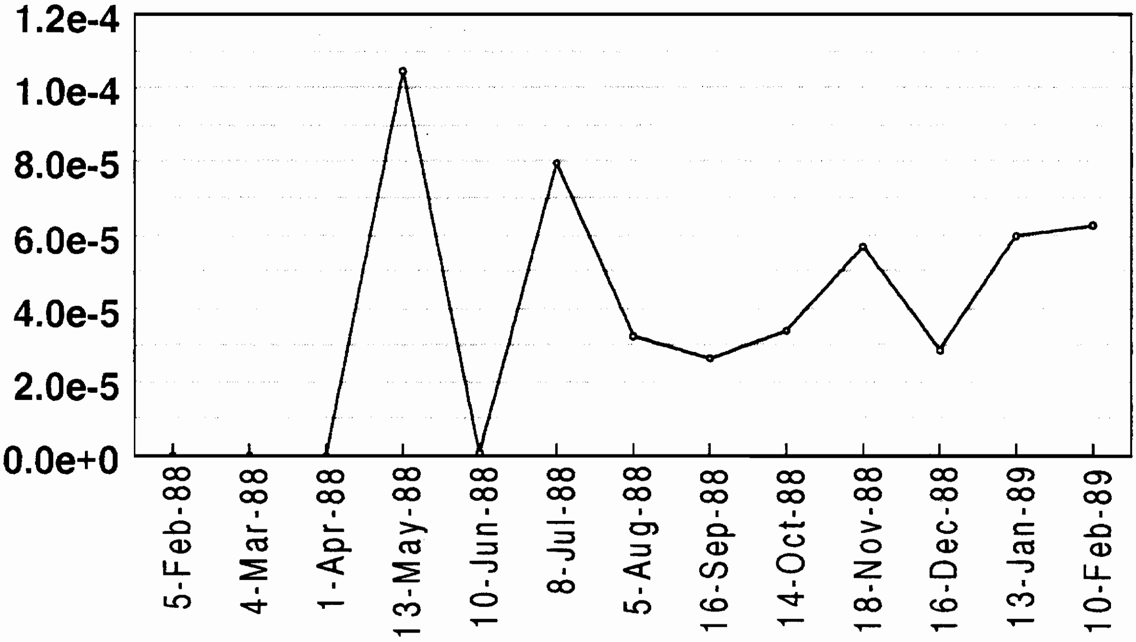
Appendix 4.12 Mean secchi depth (feet). Error bars represent standard deviation.



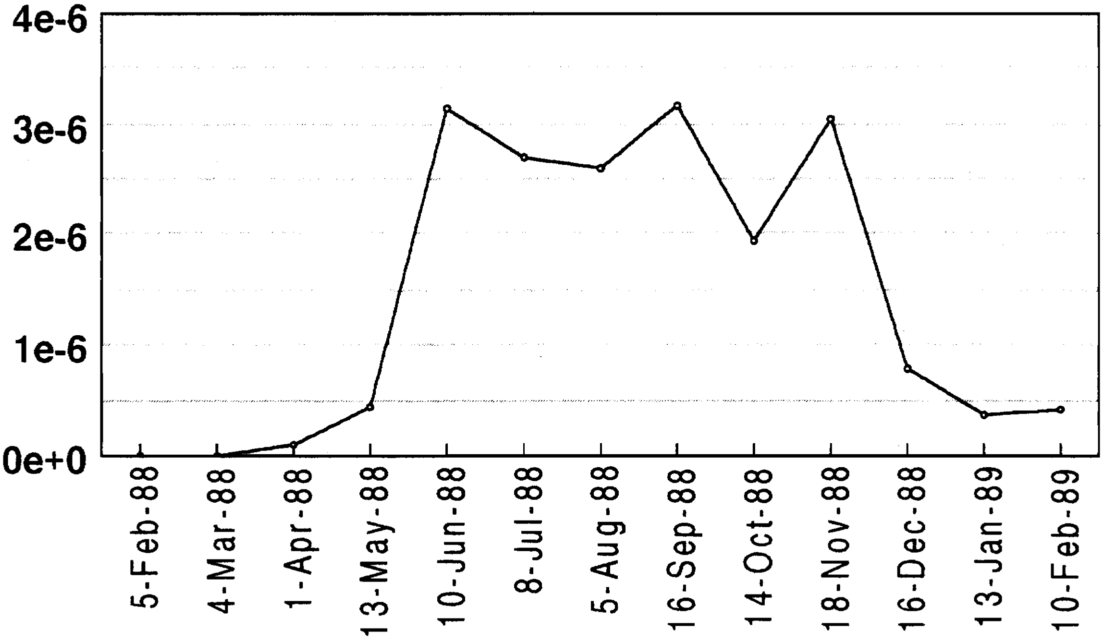
Appendix 4.13. Cyanophyceae Biovolume (Biomass/cm^3): Means Of All Ponds At Each Date.



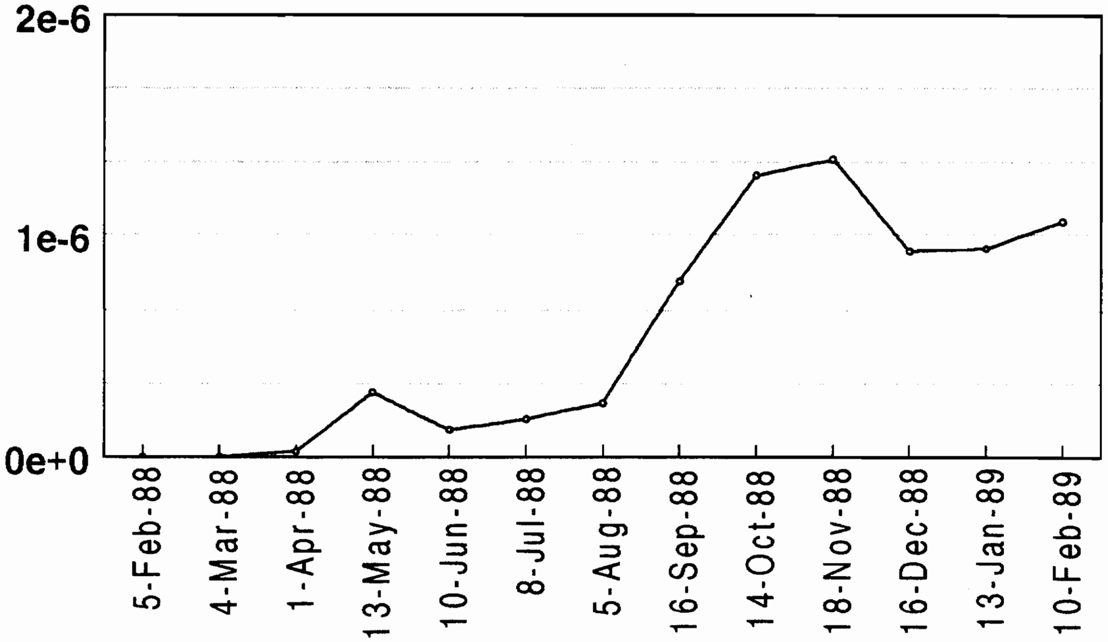
Appendix 4.14. Bacillariophyceae Biovolume (Biomass/cm^3): Means Of All Ponds At Each Date.



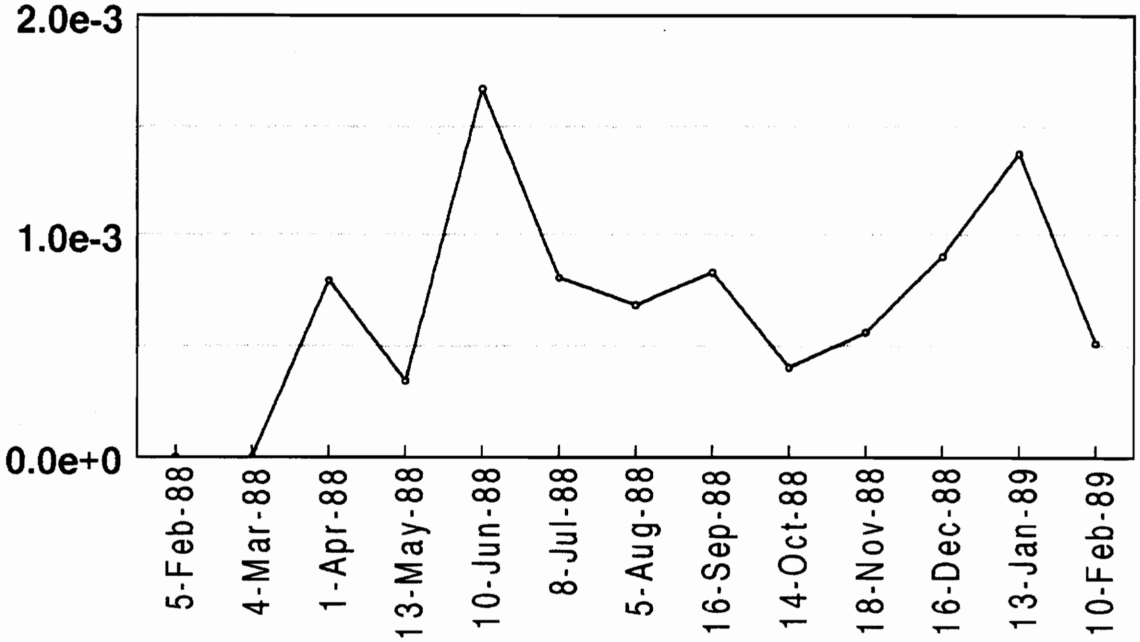
Appendix 4.15. Dinophyceae Biovolume (Biomass/cm^3): Means Of All Ponds At Each Date.



Appendix 4.16 Chlorophyceae Biovolume (Biomass/cm^3): Means Of All Ponds At Each Date.

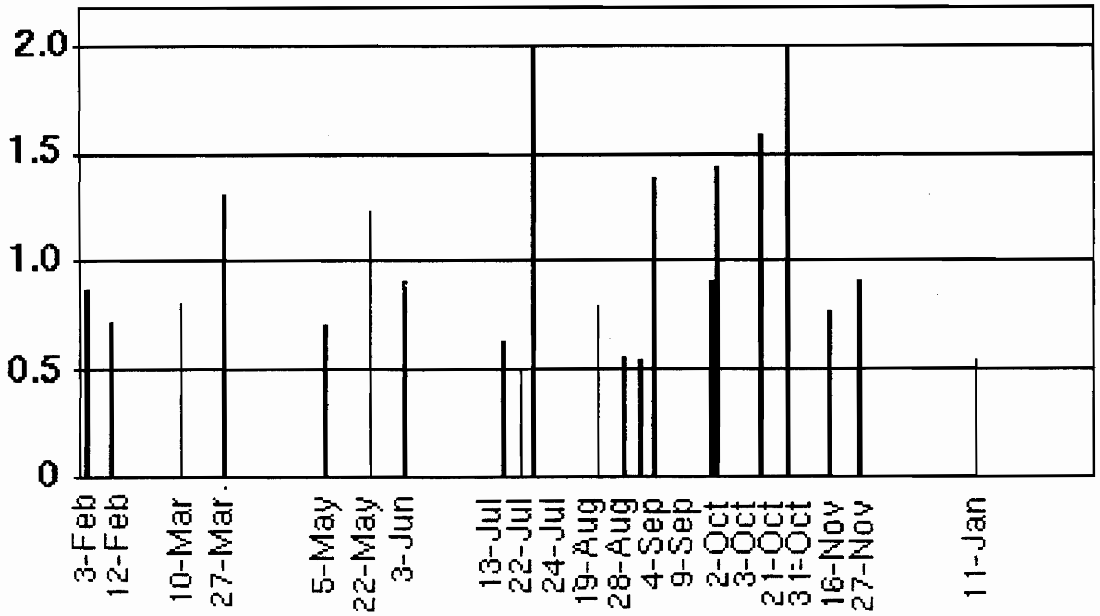


Appendix 4.17 Desmidaceae (Chlorophyceae) Biovolume (Biomass/cm^3): Means Of All Ponds At Each Date.

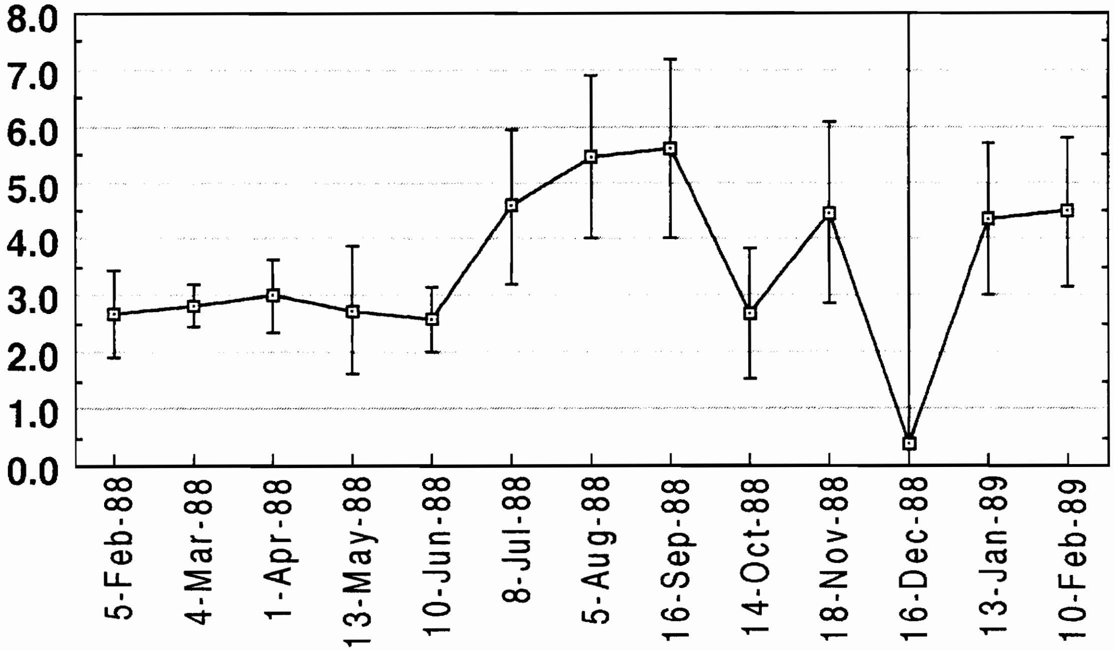


Appendix 4.18 Dinobryon (Chrysophyceae) Biovolume (Biomass/cm^3): Means Of All Ponds At Each Date.

Precipitation Events > 0.5 Inches



Mean Light Penetration (ft. Secchi Depth)



Appendix 4.19 Precipitation > 0.5 in. and Water Turbidity (Error bars represent standard deviation).

Vita

I was born in New York, N.Y. in 1963. I grew up in New York state, Florida, and Pennsylvania. I graduated from Clark University, Worcester, Ma. in May, 1985 with a B.A. with high honors in Biology. My honors research investigated population characteristics of Aedes triseriatus mosquitoes. While at Clark, I was also the Academic Coordinator of the freshman orientation program. After graduation, I resided in Massachusetts (Shrewsbury and Martha's Vineyard). I began studies at Virginia Tech in 1987 towards the Master of Biology. I have traveled extensively in Kenya, East Africa, Andros Island, Bahamas, St. Thomas, U.S. Virgin Islands, and have explored the east coast from Maine to the Florida Keys and Gulf coast.