Special Publication SJ2004-SP3

Assessment of Lake Griffin Algal Blooms

Final Report to

St. Johns River Water Management District

Contract #SD419AA

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Department of Fisheries and Aquatic Sciences
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EXECUTIVE SUMMARY

Recent research on Lake Griffin has shown that the phytoplankton community is characterized by blooms of cyanobacteria (aka, blue-green algae). Paleolimnological indicators suggest an increasing frequency of algal blooms over the past 50 years, peaking over the past two decades. It is clear from chlorophyll records for the past three decades that Lake Griffin is a nutrient-rich environment that falls into the eutrophic/hypereutrophic range under many established trophic state guidelines. It is therefore not surprising that the lake is subject to algal blooms.

Another issue of concern in Lake Griffin is the prominence of potentially harmful cyanobacteria species in the phytoplankton community. Among the cyanobacteria that have been dominant in the lake over the past few years *Cylindrospermopsis* appears to have been the most prolific and persistent. The fact that certain species of *Cylindrospermopsis* have caused human and animal health problems in other parts of the world has precipitated considerable local concern.

The concerns just described focus attention on two important aspects of the ecology of Lake Griffin: (1) The factors that control phytoplankton standing crops in the lake and (2) The factors that contribute to domination of the phytoplankton community by blue-green algae, like *Cylindrospermopsis.* These two questions are central to the management-related question of whether the character and intensity of algal blooms in Lake Griffin can be controlled. The objectives of this study were to examine key aspects of the structure and function of algal blooms in Lake Griffin in order to investigate possible causes for the structure and dynamics of blooms. Two primary sampling sites were established in Lake Griffin, one in the northern basin ('north' site) and one in the southern basin ('south' site). Samples were collected at these sites on twenty-two dates over a nineteen month period from August of 2000 to March of 2002. Routine analyses included chlorophyll a and basic water chemistry parameters. In addition, rates of primary production and nutrient limitation status were determined on 10 sampling dates spread over the sampling period.

Total phosphorus concentrations ranged from 34 to 126 µg/liter. The lowest total phosphorus levels were observed in the spring of 2001. Soluble reactive phosphorus concentrations were generally below 5 µg/liter. Total nitrogen concentrations were relatively high by comparison to total phosphorus, as indicated by the high TN/TP ratios, which ranged from 36-72. Nitrite plus nitrate concentrations were low throughout the sampling period. By contrast, ammonium concentrations were higher and showed considerable variability. In general, spatial variation of macronutrient concentrations between stations in Lake Griffin was relatively small, with a few exceptions. It is clear that the northern and southern basins of the lake are relatively similar most of the time, at least from the point of view of macronutrient concentrations.

The primary measure of phytoplankton standing crop used in this study was chlorophyll a concentration. Over the study period chlorophyll a values ranged from 8 to 175 µg/liter.

For much of the sampling period concentrations exceeded 100 µg/liter, but dropped dramatically in the winter of 2000/2001 and early spring of 2001. The concentrations also dropped below 100 µg/liter for a brief period in the winter of 2001/2002.

The three major algal groups observed in Lake Griffin over the sampling periods were cyanobacteria (aka, blue-green algae), diatoms (i.e., Bacillariophyceae) and green algae (i.e., Chlorophyta). Other taxonomic groups were periodically represented but were seldom major contributors to total phytoplankton abundance, e.g. chrysophytes, cryptophytes, euglenoids and dinoflagellates. Within the cyanobacteria eight taxa were commonly found in high abundance; i.e. *Cylindrospermopsis* sp., *Oscillatoria* sp. (2µm diameter), *Rhaphidiopsis* sp., *Microcystis incerta, Chroococcus* sp. (2µm diameter), 2µm spherical cyanobacterium, *Lyngbya contorta* and *Merismopedia tenuissima*. Among the filamentous forms of cyanobacteria *Cylindrospermopsis* was numerically and biovolumetrically dominant during a large portion of the sampling period. In the late spring of 2001 a 2µm form of *Oscillatoria* took over as the dominant filamentous cyanobacteria until March of 2002.

Maximum rates of gross primary production (GPP) observed during the sampling period ranged from 1113 to 2833 mg $C/m^3/hr$. GPP exceeded 500 mg $C/m^3/hr$ for most of the sampling dates. As a measure of photosynthetic capacity, volumetric GPP values were converted to mg C/mg chlorophyll a/hr . Values for maximum photosynthetic capacity ranged from 1.4 to 24. Examination of the relationships between photosynthesis and irradiance showed that the phytoplankton community of Lake Griffin was highly efficient at using the limited amount of light available in the water column, at least for most of the sampling period. This may be in part related to the high levels of chlorophyll in the phytoplankton. During two parts of the sampling period, the spring and fall of 2001, photosynthetic efficiency went down, as did the standing crops of phytoplankton. This was also the two time periods during which phosphorus limitation of phytoplankton growth was observed.

The results of the nutrient limitation bioassays indicated that nitrogen was the most frequently limiting element in Lake Griffin during the sampling period. On eight of ten bioassay dates at both the north and south sampling sites the addition of nitrogen resulted in algal standing crop above that observed in the control group. Phosphorus was the primary limiting nutrient on two bioassay dates at both the north and south sampling sites.

From a water management perspective, understanding the factors that control changes in phytoplankton standing crop is critical to the task of identifying viable options for maintaining or improving the condition of specific ecosystems. These factors include a wide range of physical, chemical and biological elements that affect the major gain (growth and import of phytoplankton) and loss (dilution or export, grazing, death, sedimentation, dilution and export) processes for phytoplankton. The primary gain function in most lakes is primary production. Over the nineteen month study period Lake Griffin exhibited four periods of increasing and three periods of decreasing phytoplankton standing crop. As mentioned above, the periods of decreasing standing

crop coincided with observations of low photosynthetic efficiency in primary production experiments. It is possible to hypothesize that one of the main factors responsible for the periods of decreasing standing crop in Lake Griffin is low photosynthetic efficiency.

The observation of periods of low photosynthetic capacity in Lake Griffin leads to the next level of inquiry, namely the cause of low capacity. One factor that is undoubtedly important in regulating photosynthetic capacity and hence primary production in Lake Griffin is nutrient availability. Certainly the sensitivity of the lake's phytoplankton standing crops to changes in nutrient loading is a central issue in the management of the lake. From a historical perspective, it does not appear that phytoplankton standing crops are strongly correlated to total phosphorus levels. For example, total phosphorus concentrations in the lake were at equally high levels in the late 1970's and late 1990's, yet the mean annual chlorophyll a concentrations were dramatically higher during the latter period. However, the correlation between TP and chlorophyll, or the lack thereof, can be misleading in interpreting the role of phosphorus in limiting primary production because the relationship is sensitive to a wide range of factors, including differences in the bioavailability of different phosphorus-containing compounds and the influence of other limiting factors like nitrogen or light. The results of nutrient enrichment bioassay experiments revealed phosphorus limitation on two of ten test dates.

These observations, taken together, suggest that the phytoplankton community of Lake Griffin may be sensitive to changes in external phosphorus load, at least under the drought and low lake stage conditions prevalent during our study period. Due to the exceptionally low rainfall levels and lake stage conditions encountered during the current study period, it would be premature to conclude that the patterns observed for water chemistry, phytoplankton standing crop, productivity and nutrient limitation are typical of Lake Griffin under a wider range of climatic conditions. The observations made during this time period do, however, provide valuable insight into the structure and function of the lake under conditions of exceptionally low external nutrient input and low water turnover rates.

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INTRODUCTION

Recent research on Lake Griffin has shown that the phytoplankton community is characterized by blooms of cyanobacteria (aka, blue-green algae). Unfortunately, the general paucity of rigorous historical information on the lake's plankton community makes it difficult to determine how long these blooms have been a prominent feature of the system. Paleolimnological studies indicate that the rate of TP sedimentation experienced a sharp increase beginning about 1950 and the planktonic/benthic diatom microfossil ratio reached its highest level in the 1980's and early 1990's (Schelske 1998). Both of these paleolimnological indicators suggest an increasing frequency of algal blooms over the past 50 years, peaking over the past two decades. It is clear from chlorophyll records for the past three decades (Fulton, personal communication) that Lake Griffin is a nutrient-rich environment that falls into the eutrophic/hypereutrophic range under many established trophic state guidelines, including total phosphorus, total nitrogen and chlorophyll *a* concentration (Carlson 1977). It is therefore not surprising that the lake is subject to algal blooms. Historic data for Lake Griffin show that chlorophyll a concentrations over 100 :g/l have been common since at least 1977. Until 1996 peak chlorophyll a concentrations were generally below 200:g/l. In 1996, this threshold was transcended, with numerous observations of chlorophyll a concentrations higher than 250 :g/l. While the reasons for the apparent step increase in phytoplankton abundance in 1996 remain uncertain, it has become an issue of serious public concern.

Another issue of concern in Lake Griffin is the prominence of potentially harmful cyanobacteria species in the phytoplankton community. Among the cyanobacteria that have been dominant in the lake over the past few years *Cylindrospermopsis* appears to have been the most prolific and persistent. The fact that certain species of *Cylindrospermopsis* have caused human and animal health problems in other parts of the world (Chorus and Bartram 1999) has precipitated considerable local concern (Williams et al. 2001). How far back *Cylindrospermopsis* has been a major player in Lake Griffin's phytoplankton community is uncertain. Despite the fact that some researchers have hypothesized that it is a recent addition to the phytoplankton assemblage (Chapman and Schelske 1997), there is currently insufficient data to adequately test this hypothesis for

Florida lakes. Similarily, the specific level of risk to animal health posed by the strains of *Cylindrospermopsis* found in Lake Griffin remains largely unresolved.

The concerns just described focus attention on two important aspects of the ecology of Lake Griffin: (1) The factors that control phytoplankton standing crops in the lake and (2) The factors that contribute to domination of the phytoplankton community by blue-green algae, like *Cylindrospermopsis.* These two questions are central to the management-related question of whether the character and intensity of algal blooms in Lake Griffin can be controlled. The objectives of this study were to examine key aspects of the structure and function of algal blooms in Lake Griffin in order to investigate possible causes for the structure and dynamics of blooms.

METHODS

Site description – Two primary sampling sites were established in Lake Griffin, one in the northern basin ('north' site) and one in the southern basin ('south' site) (Figure 1). All of the experimental research was carried out at the two primary sites. In addition to the two primary sites, supplemental sites were collected on separate dates to evaluate spatial variability in phytoplankton standing crop (i.e. in terms of chlorophyll) (Figure 1).

Field Measurements - A number of basic water column characteristics were measured on site. Temperature and oxygen concentration were measured at regular depth intervals using Hydrolab Surveyor units and YSI instruments. This information was used to evaluate a number of key issues related to spatial and temporal variability of water masses, including locations of vertical discontinuity layers and presence of low oxygen zones.

Quantum flux was measured at depth intervals with Li-Cor PAR probes; 2π surface and 2π underwater downwelling. Light extinction coefficient was determined using the Beers Law equation (Wetzel 1983). Mean light available in the mixed layer, I_m, was estimated as described by Stefan et al. (1976).

Water Sample Analyses – Water was collected at the sampling sites using two basic methods. For experiments water was collected with a submersible pump. In some of the additional survey samplings water was collected with a water column integrating tube that samples water evenly from the surface to 0.2 meters from the bottom.

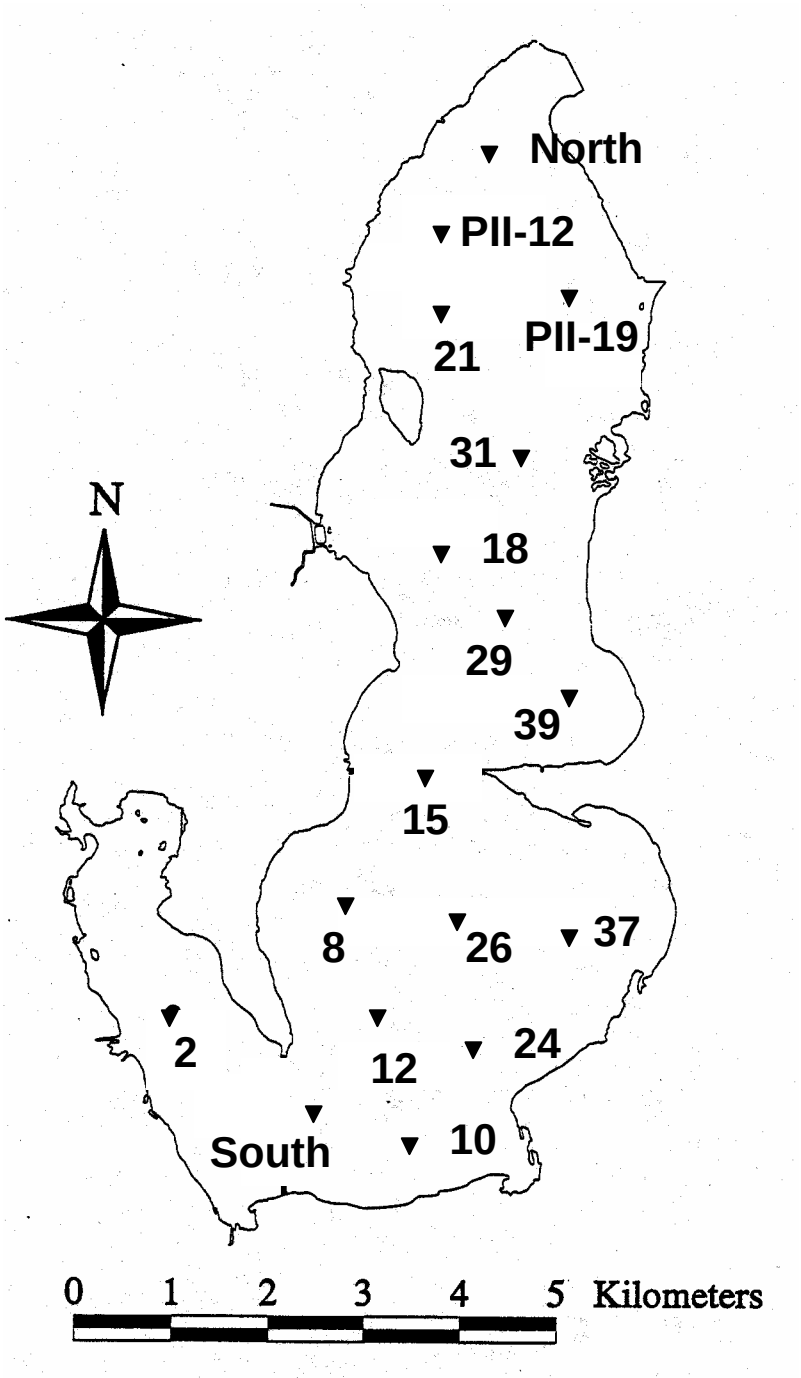

Figure 1. Locations of sampling sites in Lake Griffin.

Water samples were subdivided on site into aliquots for chlorophyll a, phytoplankton composition, color, turbidity, water chemistry analysis and experimental work. Chlorophyll was used as the primary estimator of phytoplankton abundance. Chlorophyll a samples were filtered and stored frozen for subsequent analysis using standard spectrophotometric methods. Color was analyzed spectrophotometrically using a platinum cobalt standard. Turbidity was determined using a Nephelometer. Total nitrogen, nitrate (+ nitrite), ammonium, total phosphorus, soluble reactive phosphorus, silica, urea and particulate organic carbon were analyzed using standard methods for water analysis. All methods are part of our EPA approved Comprehensive QA/QC Plan #910157 and Project QA Plan (QAPP #200064).

Phytoplankton composition was analyzed microscopically using the Utermohl settling method (Utermohl 1958). Counts for individual taxa were converted to biovolume using the closest geometric shape method. Biovolume is the most direct measure of phytoplankton standing crops, and provides a physiologically meaningful way of describing the relative importance of different phytoplankton species to community structure and function

Bioassay Experiments - Nutrient limitation/growth bioassay experiments were performed on eleven dates at two sites within the study area (shown as 'north' and 'south' in Figure 1). The locations of the two experimental sites were chosen in consultation with scientists from the St. Johns River Water Management. The experimental design was based on methods described by Aldridge et al. (1995). Assays were done under laboratory conditions in 500-ml flasks with 400 ml of whole water. Treatments included control ('C1' - no additions), nitrogen ('N1' - in the form of nitrate) addition (final flask concentration of 400 µg N l^{-1}), phosphorus ('P1' - in the form of orthophosphate) addition (final flask concentration of 40 µg P l^{-1}), N & P addition ('NP1' - final flask concentrations of 400 µg N l^{-1}+ 40 µg P l^{-1}), and N& P & Si ('NPS1' - final flask concentrations of 400 µg N l^{-1}+ 40 µg P l^{-1}+ 400 µg Si l^{-1}). All of the groups were run in duplicate ('a' and 'b'). In addition, five additional levels of nitrogen addition were included in the assay (final flask concentrations of 'N2' - 800, 'N3' - 1200, 'N4' - 1600, 'N5' - 2000 and 'N6' - 2400 µg N l^{-1}).

Incubations were done in laboratory chambers containing temperature-controlled water baths with bottom illumination. Incubation temperatures were held at ambient temperatures recorded on each sampling date. Light intensity was fixed at 120 μE/m^2/s. Photoperiod was 12/12 dark/light hours, respectively, from October through March and 10/14 dark/light from April through September. Algal biomass was estimated by net *in vivo* fluorescence of chlorophyll *a* (*IVF*) using a Turner Designs Model 10 fluorometer with a 1-cm path length at time 0, 1, 2, 3, 4, 5, 6 and 7 days, or until fluorescence values peaked. Ethanol extracted chlorophyll *a* concentrations were determined at time 0, and at the end point of the incubation period.

A nutrient was considered limiting when the standing crop of phytoplankton in the control was lower than that observed in a nutrient addition treatment group. When algal growth occurred in the control, it was concluded that no nutrient was limiting and that some component of the phytoplankton community was growing at the time of sampling or some controlled variable, such as light, was more optimal under the assay conditions than in the natural environment. Duncans Mulitple Range Test was used to evaluate the significance of differences in response to nutrient additions using chlorophyll *a* values at the point of greatest resolution, usually 96-120 hours of the incubation period.

Primary Production Experiments – Primary production measurements were made on Lake Griffin on ten sampling dates during the study period. Primary production was determined on the basis of oxygen evolution using basic light-dark bottle techniques. Bottles filled with lake water were incubated in the lake for 2-3 hour periods in the morning at the north and south sampling sites. Six light levels were tested simultaneously by placing replicate bottles in neutral density light screening bags, i.e. 100% of incident (i.e. no screen), 60% of incident, 25% of incident 9.6% of incident, 3.8% of incident and dark. Changes in oxygen concentration in the bottles were monitored in two ways. In the first four production experiments an Ocean Optics fluorescence oxygen probe was used to measure oxygen concentration. At the fifth production experiment a switch was made to the more traditional Winkler method (Wetzel and Likens 2000), due to technical problems encountered prior to that experiment with the fluorescence probe. Both methods proved to have problems with

unrealistic values for dark oxygen consumption rates. To overcome this problem, curves were fit to the light oxygen flux results. These curve fits proved to be quite good and consistent with the general shape of photosynthesis-irradiance relationships, as described in the literature (Kirk 1994). This allowed for estimates of dark respiration values, which were then used to derive values for gross primary production. Oxygen production values were converted to carbon fixation values using 1.2 as the photosynthetic quotient (Wetzel 1983).

RESULTS

Physical-chemical Properties

Temperatures encountered during the 22 sampling events ranged from 10.9 to 32^{o}C (Appendix 1). Water temperatures did not dip below 25^{o}C until October/November and exceeded 25^{o}C by May (Figure 2). Turbidity levels in the lake ranged from 5.5 to 28.3 NTU (Table 1). Color values ranged from 20.2 to 63 Platinum Cobalt Units (Table 1). Dissolved oxygen concentrations ranged from 4.29 to 12.08 mg/liter at the surface (Figure 3), but oxygen levels were frequently lower at the bottom of the water column. Secchi disk depths ranged from 0.20 to 0.90 m., but were generally less than 0.5 m. (Table 1). Light extinction coefficients, K_t, ranged from 2.1 to 9/m, but were generally greater than 4/m (Table 1). Based on estimated values for partial light extinction coefficients of water, color, phytoplankton and tripton (non-algal suspended solids), the latter two elements were the dominant contributors to light attenuation.

Macronutrient Concentrations

Total phosphorus concentrations ranged from 34 to 106 µg/liter (Figure 4). The lowest total phosphorous levels were observed in the spring of 2001. Soluble reactive phosphorus concentrations were generally below 5 µg/liter, except for two sampling dates (Table 2). For complete summary of chemical data see Appendix 2.

Total nitrogen concentrations were relatively high by comparison to total phosphorous (Figure 4), as indicated by the high TN/TP ratios, which ranged from 36-72. Total nitrogen also exhibited less temporal variation then TP (Figure 4). Nitrite and

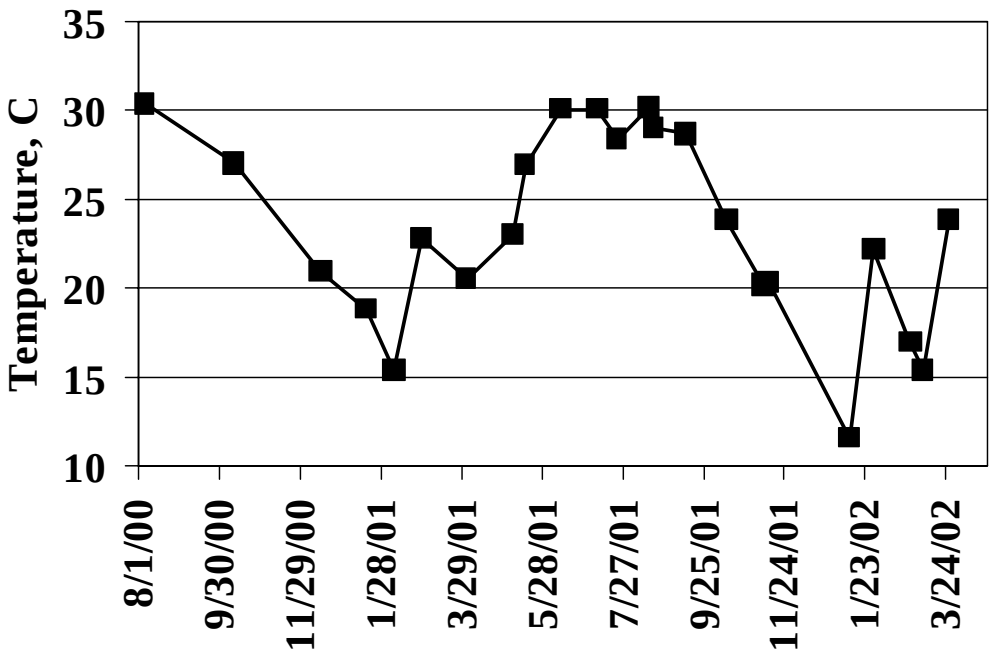

Figure 2. Surface temperature in Lake Griffin.

Table 1. Mean, standard deviation and range for turbidity (NTU), color (PCU, platinum cobalt units), Secchi disk depth (meters) and K_t (vertical light extinction coefficient, m^{-1}) for the primary north and south sampling sites. Mean values are followed by standard deviation in parentheses and range in the next row.

	North Site	South Site
Turbidity	18.7 NTU (6.9)	15.7 NTU (5.1)
	5.5-28.3	8.0-24.7
Color	38.1 PCU (13.0)	31.4 PCU (9.4)
	21.8-63.0	20.2-57.3
Secchi depth	0.36 m (0.16)	0.35 m (0.16)
	0.2-0.9	0.2-0.9
K_t	5.5 m^{-1} (2.3)	5.6 m^{-1} (1.4)
	2.1-9.0	2.4-7.4

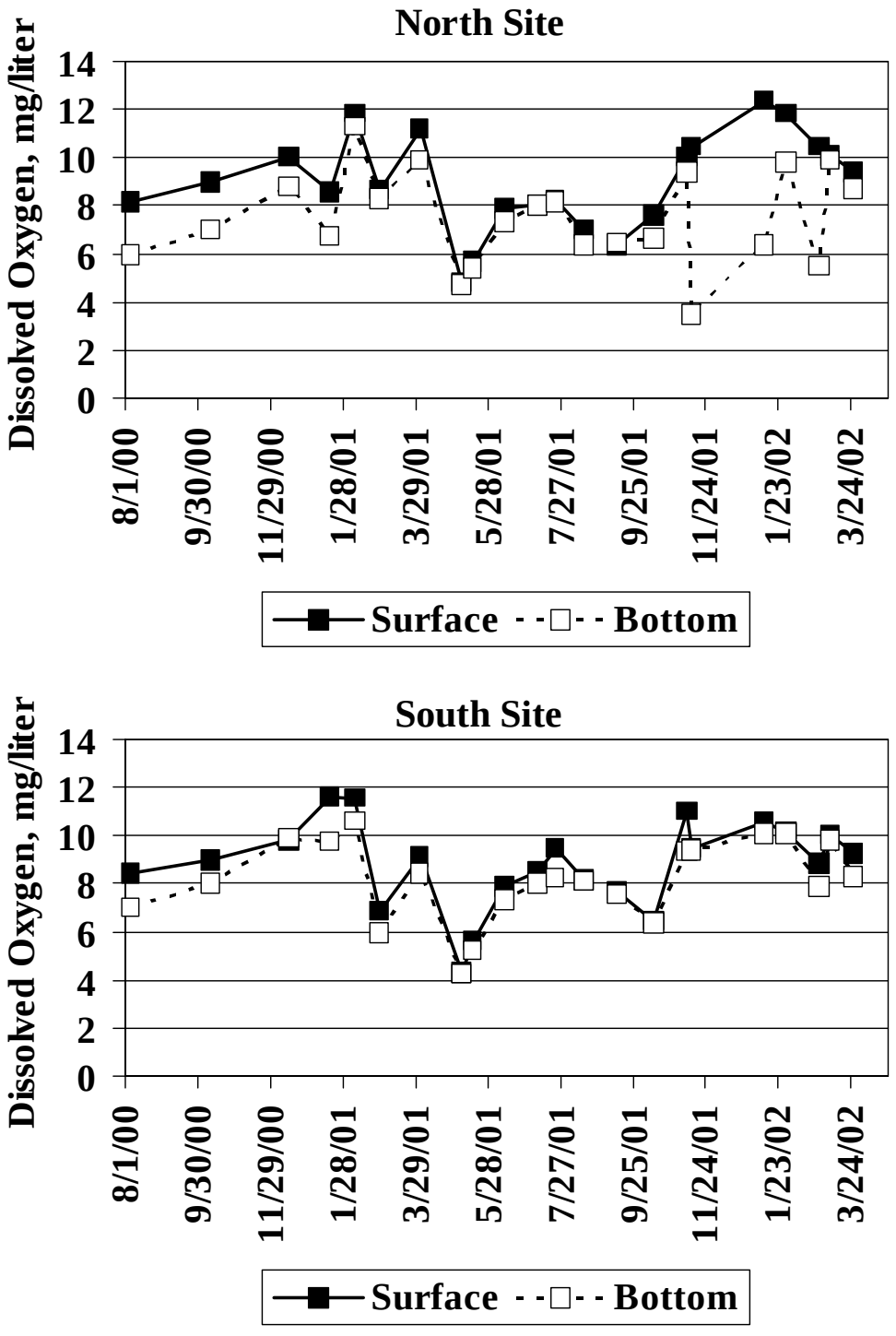

Figure 3. Dissolved oxygen concentrations at the north and South sampling sites in Lake Griffin.

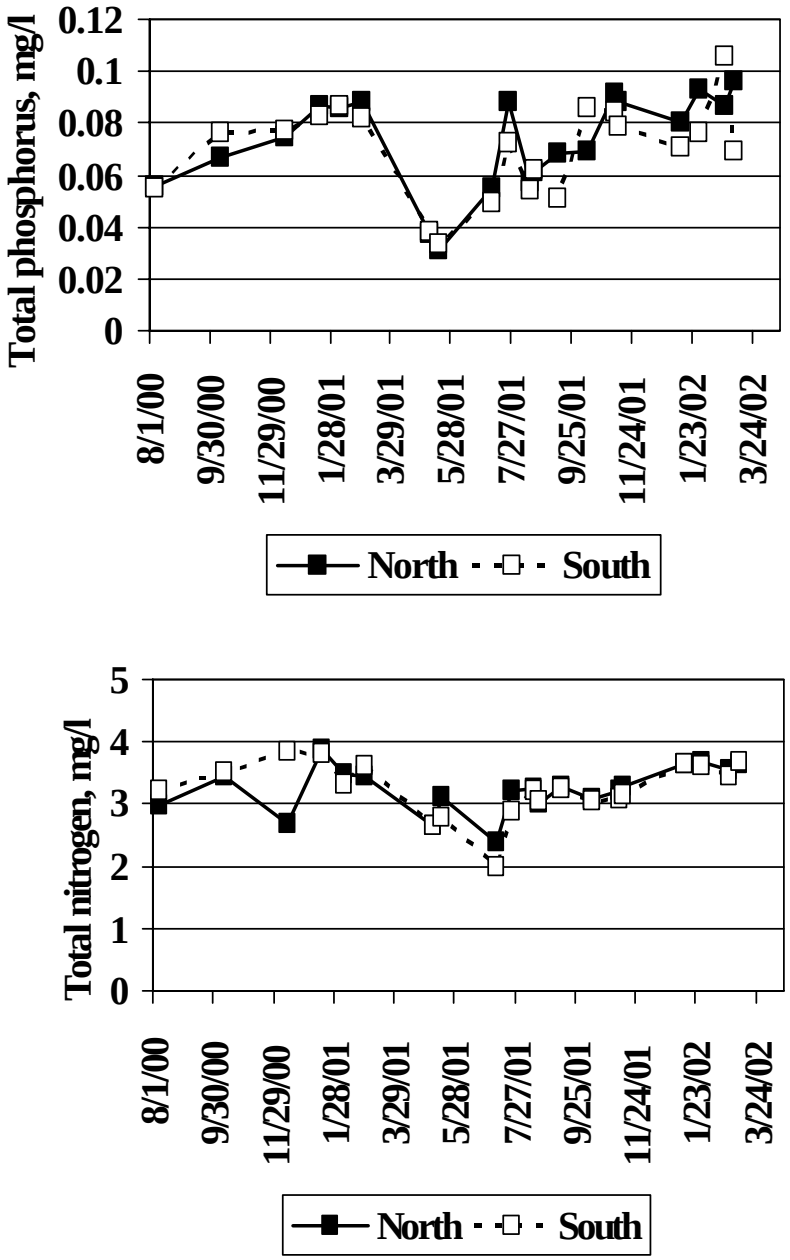

Figure 4. Total phosphorus (top) and total nitrogen (bottom) concentrations at the north and south sampling sites in Lake Griffin.

Table 2. Soluble reactive phosphorus and hot water extractable phosphorus concentrations at the north and south sampling sites in Lake Griffin.

	North Site		South Site	
Date	SRP µg/l	HEP µg/l	SRP µg/l	HEP µg/l
Aug-07-2000	1	13	1	13
Oct-11-2000	2	29	1	26
Dec-14-2000	1	37	3	25
Jan-17-2001	3	21	4	18
Feb-28-2001	3	32	3	29
May-07-2001	3	19	3	20
Jul-09-2001	1	31	3	27
Aug-20-2001	3	42	6	57
Oct-12-2001	2	--	3	--
Nov-12-2001	4	--	4	--
Jan-12-2002	2	53	1	53
Feb-26-2002	3	--	3	--
Mar-27-2002	26	42	29	37

nitrate concentrations were low throughout the sampling period (Table 3). By contrast, ammonium concentrations were higher and showed considerable variability (Table 3). On several sampling dates ammonium concentrations were near or higher than 400 µg/liter, i.e. January 17 and May 7 of 2001 and January 12 of 2002 (see Appendix 2 for summary of chemical analyses).

Silica concentrations were relatively high throughout the sampling period (Figure 5). In the summer of 2001 silica concentrations increased and several peaks in concentration occurred over the rest of the year.

Estimates of bioavailable nitrogen, BN (nitrite + nitrate + ammonium + urea), showed a wide range of values from 42 to 788 µg/liter (Table 4). Most of the large changes in BN were attributable to variations in ammonium concentrations (Table 2). Bioavailable phosphorous, BP (soluble reactive phosphorous + hot water extractable phosphorus), estimates exhibited a narrower range of values, 14 to 63 µg/liter (Table 4).

In general, spatial variation of macronutrient concentrations in Lake Griffin between stations was relatively small, with a few exceptions. It is clear that the northern and southern basins of the lake are relatively similar most of the time, at least from the point of view of macronutrient concentrations. The largest exceptions appear to be in the ammonium levels on specific dates.

Phytoplankton Standing Crops

The primary measure of phytoplankton standing crop used in this study was chlorophyll a concentration. Chlorophyll a values (uncorrected) ranged from 10.8 to 182 µg/liter over the study period (Figure 6 and Appendix 3). For much of the sampling period concentrations exceeded 100 µg/liter, but dropped in the spring of 2001 and fall of 2001. The concentrations also dropped below 100 µg/liter for a brief period in the winter of 2001/2002. The basic temporal patterns of chlorophyll a were similar for the sampling sites in the northern and southern basins of the lake (Figure 6), although the concentrations during individual sampling events sometimes exhibited a modest variation between the two basins. A more detailed survey of chlorophyll a distribution within each basin on ten sampling dates during the sampling period showed a relatively high degree

Table 3. Nitrate, nitrite, ammonium and urea concentrations at the north and south sampling sites in Lake Griffin.

	North Site				South Site			
Date	nitrite µg/l	nitrate µg/l	NH_4 µg/l	urea µg/l	nitrate µg/l	nitrate µg/l	NH_4 µg/l	urea µg/l
Aug-07-2000	0	6	33	29	0	3	32	42
Oct-11-2000	1	2	53	--	1	1	52	--
Dec-14-2000	1	4	33	--	1	30	121	--
Jan-17-2001	3	7	529	23	3	12	397	21
Feb-28-2001	1	4	35	--	1	2	84	--
May-07-2001	1	2	763	22	1	1	664	21
Jul-09-2001	1	1	36	21	0	2	44	31
Aug-20-2001	1	2	31	13	1	3	37	11
Oct-12-2001	2	0	20	--	1	0	39	--
Nov-12-2001	0	0	64	--	0	0	54	--
Jan-12-2002	2	8	467	18	2	9	261	34
Feb-26-2002	2	16	50	4	1	25	25	4
Mar-27-2002	2	0	57	5	3	0	60	17

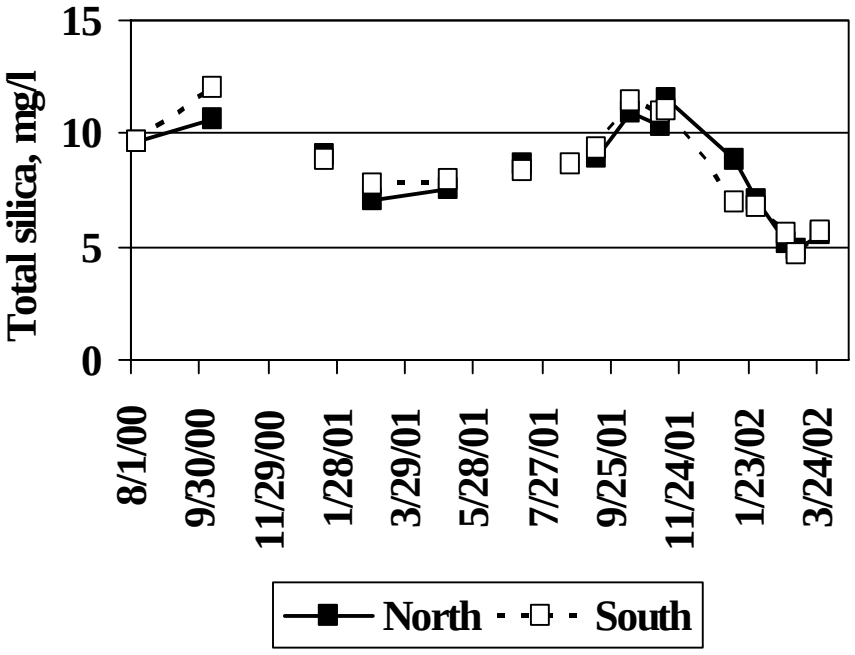

Figure 5. Total silica concentrations at the north and south sampling sites in Lake Griffin.

Table 4. Bioavailable nitrogen (BN) and bioavailable phosphorus (BP) concentrations at the north and south sampling sites in Lake Griffin. Bioavailable nitrogen is defined as the total of nitrite, nitrate, ammonia and urea. Bioavailable phosphorus is defined as the total of soluble reactive phosphorus and hot water extractable phosphorus.

	North Site		South Site	
	BN	BP	BN	BP
Date	µg/l	µg/l	µg/l	µg/l
Aug-07-2000	68	14	77	14
Oct-11-2000	82*	31	86*	27
Dec-14-2000	64*	38	184*	28
Jan-17-2001	562	24	433	22
Feb-28-2001	63	35	108	32
May-07-2001	788	22	687	23
Jul-09-2001	59	32	77	30
Aug-20-2001	47	45	52	63
Oct-12-2001	37*	50*	63*	58*
Nov-12-2001	74*	52*	77*	59*
Jan-12-2002	495	55	306	54
Feb-26-2002	72	51*	55	48*
Mar-27-2002	64	68	80	66

* Estimated – due to missing urea and HEP data, estimates were made based on interpolation of values for urea and HEP within the next nearest dates where they were present.

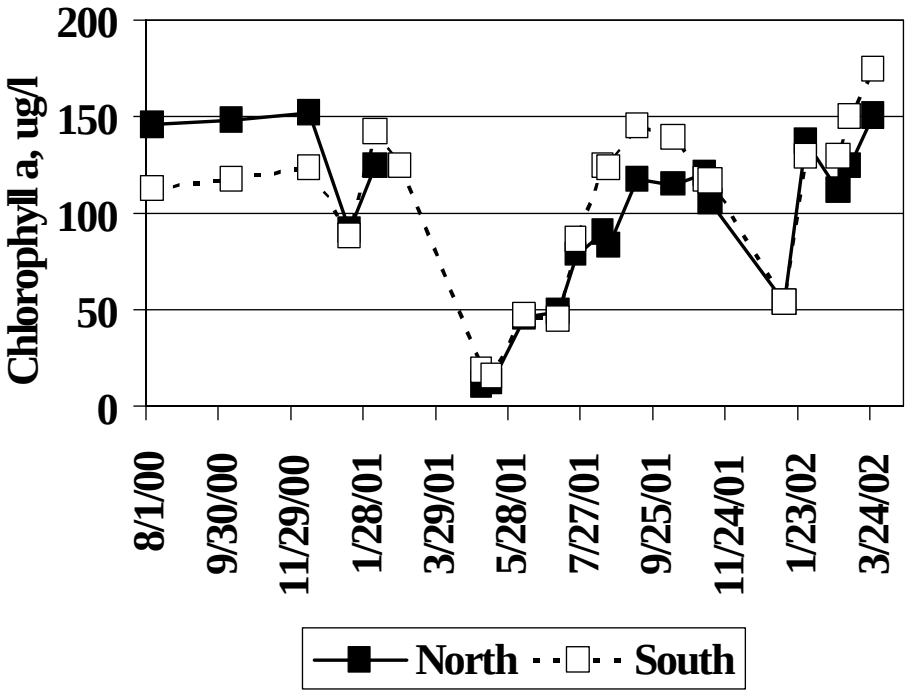

Figure 6. Chlorophyll a concentrations (uncorrected) at the north and South sampling sites in Lake Griffin.

Table 5. Spatial variability of chlorophyll a concentrations in the north and south basins of Lake Griffin. The northern basin survey included nine evenly distributed sampling sites and the southern basin contained eight sampling sites.

	Northern Basin			Southern Basin		
	Mean Chl a			Mean Chl a		
Date	µg/liter	Std. Dev.	Range	µg/liter	Std. Dev.	Range
Dec-14-2000	145.9	10.2	124.6-154.9	150.0	9.1	133.8-158.2
Feb-07-2001	127.5	5.0	118.9-136.8	143.4	6.9	134.1-156.1
May-16-2001	13.1	1.1	12.1-14.8	13.9	1.5	12.0-15.8
Jun-11-2001	45.4	2.1	43.3-48.2	42.2	5.6	36.4-53.0
Jul-24-2001	86.6	16.0	70.3-105.4	89.3	6.8	81.5-102.2
Aug-16-2001	106.0	7.2	90.2-110.3	123.0	7.3	116.7-135.4
Sep-12-2001	128.9	14.8	108.9-154.1	163.9	13.8	144.1-182.8
Nov-08-2001	127.6	7.7	117.2-138.2	131.5	8.2	117.2-139.2
Jan-30-2002	139.8	3.3	134.3-144.9	137.8	6.0	129.3-141.3

of intra-basin homogeneity (Table 5). To examine possible vertical stratification of chlorophyll a concentrations, surface sample (0.3m.) values were compared to integrated water column values (Table 6). On the occasions that the values were different the integrated concentrations generally exceeded surface values. In general, however, the differences between surface and integrated water column samples were relatively small (i.e. <10%).

Phytoplankton Community Structure

The three major algal groups observed in Lake Griffin over the sampling periods were cyanobacteria (aka, blue-green algae), diatoms (i.e., Bacillariophyceae) and green algae (i.e., Chlorophyta). Other taxonomic groups were periodically represented but were seldom major contributors to total phytoplankton abundance, e.g. chrysophytes, cryptophytes, euglenoids and dinoflagellates. On the basis of numerical abundance cyanobacteria were always the dominant taxonomic group, in most cases representing over 99% of total cell number (Table 7). Cyanobacteria also dominated the phytoplankton community on a biovolume basis most of the time, but diatoms and occasionally other algal taxa were major contributors to total biovolume (Table 8).

Within the cyanobacteria eight taxa were commonly found in high abundance, i.e. *Cylindrospermopsis* sp., *Oscillatoria* sp. (2µm diameter), *Rhaphidiopsis* sp., *Microcystis incerta*, *Chroococcus* sp. (2µm diameter), 2µm spherical cyanobacterium, *Lyngbya contorta* and *Merismopedia tenuissima* (Figures 7-9). Among the filamentous forms of cyanobacteria *Cylindrospermopsis* was numerically and biovolumetrically dominant during a large portion of the sampling period, i.e. August 2000 to May of 2001 (Figure 10). In the late spring of 2001 a 2µm form of *Oscillatoria* took over as the dominant filamentous cyanobacteria until March of 2002. Interpretation of this putative switch in dominance is somewhat complicated by the fact that the forms of *Cylindrospermopsis* and *Oscillatoria* found in Lake Griffin are similar in appearance with some specific distinctions, including (1) *Cylindrospermopsis* is distinguished by the presence of terminal heterocysts which are lacking altogether in *Oscillatoria*, and (2) *Cylindrospermopsis* trichomes are typically 3µm in diameter and around 110µm in

Table 6. A comparison of surface (0.3m) and integrated water column chlorophyll a concentrations for at the north and south sampling sites in Lake Griffin.

	Chlorophyll a Concentration			
	North Site		South Site	
	Surface	Integrated	Surface	Integrated
Date	µg/l	µg/l	µg/l	µg/l
Jul-09-2001	48.9	69.2	44.8	54.6
Aug-20-2001	83.7	86.2	123.9	132.3
Oct-12-2001	114.3	129.7	139.5	141.8
Nov-12-2001	105.9	113.4	117.1	122.8
Jan-12-2002	53.5	55.6	54.0	71.4
Feb-26-2002	111.8	121.6	129.4	120.3
Mar-27-2002	151.4	151.8	174.6	177.3

Table 7. Relative numerical abundance of major taxonomic groups in Lake Griffin at the north/south sites.

	Relative Abundance (%)			
Date	Cyanobacteria	Diatoms	Green Algae	Other
Aug-07-2000	99.78/99.87	0.08/0.11	0.12/0.01	0.03/0.01
Oct-11-2000	99.65/99.46	0.23/0.43	0.09/0.06	0.04/0.04
Dec-14-2000	99.73/99.79	0.01/0.05	0.24/0.05	0.02/0.10
Jan-17-2001	98.87/99.51	0.83/0.37	0.18/0.03	0.12/0.08
Feb-07-2001	98.07/96.60	0.42/1.58	1.30/1.11	0.21/0.70
Feb-27-2001	99.01/84.33	0.52/15.65	0.44/-----	0.03/0.02
May-07-2001	99.73/99.75	0.25/0.11	0.03/0.07	-----/0.07
Jun-11-2001	NS/99.82	NS/0.12	NS/0.05	NS/-----
Jul-09-2001	99.63/99.66	0.32/0.26	0.04/-----	0.01/0.08
Aug-20-2001	99.52/99.67	0.20/0.24	0.15/0.06	0.10/0.03
Sep-12-2001	99.89/99.67	0.10/0.16	0.01/0.01	-----/0.02
Oct-12-2001	99.84/99.07	0.08/0.84	0.04/0.03	0.04/0.06
Nov-12-2001	99.67/99.46	0.22/0.45	0.10/0.02	0.01/0.04
Jan-12-2002	99.52/99.55	0.27/0.31	0.12/0.02	0.10/0.12
Feb-26-2002	99.60/99.78	0.21/0.10	0.06/0.07	0.14/0.05
Mar-27-2002	99.51/99.72	0.35/0.19	0.05/0.03	0.09/0.06

'------' - value lower than 0.00% 'NS' – no sample

Table 8. Contibutions of cyanobacteria and diatoms to total phytoplankton biovolume (million μm^3/ml).

Date	Site	Total Biovolume	Cyanobacteria	Diatoms
8-7-00	North	22.1	21.4	0.5
	South	15.0	14.3	0.7
10-11-00	North	17.5	16.3	1.1
	South	17.8	15.2	2.4
1-17-01	North	12.0	10.7	1.2
	South	16.7	14.3	2.1
5-7-01	North	16.4	15.1	1.2
	South	17.8	16.9	0.7
7-9-01	North	15.3	13.0	2.0
	South	12.1	10.0	1.7
8-20-01	North	10.0	8.9	0.8
	South	10.2	8.7	1.4
10-12-01	North	12.4	11.7	0.4
	South	18.2	12.6	5.0
11-12-01	North	14.3	12.7	1.4
	South	16.5	13.6	2.7
1-12-02	North	12.1	10.5	1.3
	South	11.0	9.2	1.6
2-26-02	North	14.3	12.7	1.1
	South	15.6	14.2	0.9
3-27-02	North	17.5	15.4	1.8
	South	11.9	10.8	0.9

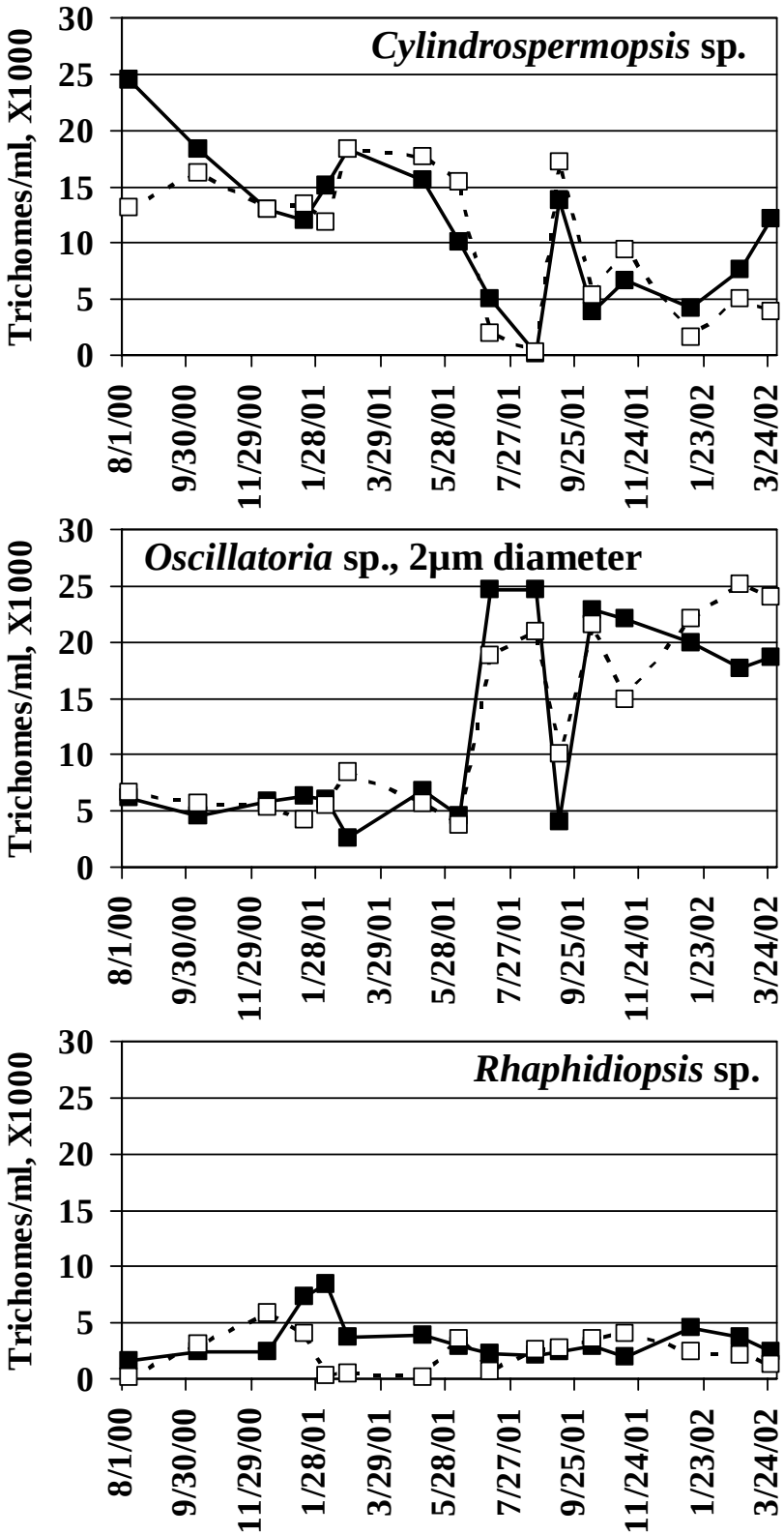

Figure 7. Dominant filamentous cyanobacteria at the North (filled squares) and South (empty squares) sampling sites.

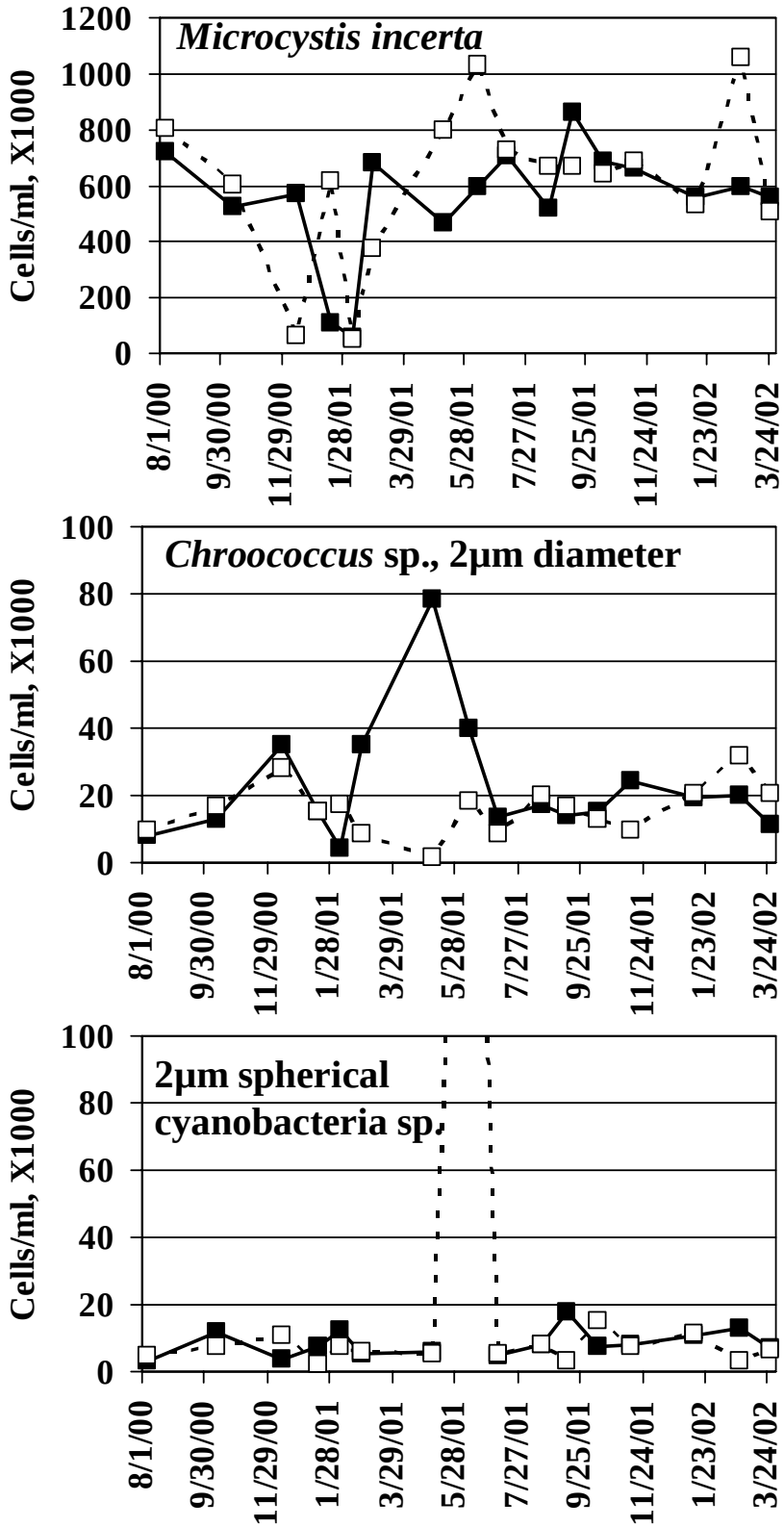

Figure 8. Dominant single-celled cyanobacteria at the North (filled squares) and South (empty squares) sampling sites.

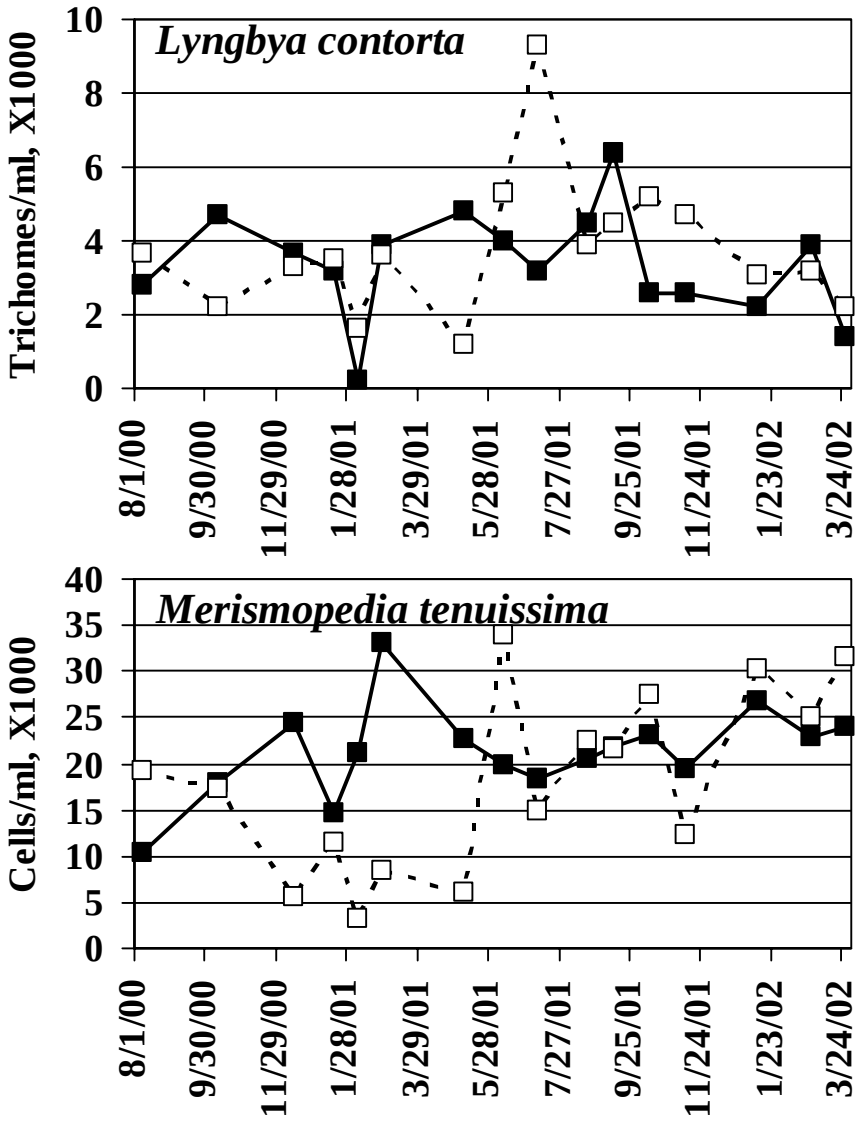

Figure 9. Other common cyanobacteria at the North (filled squares) and South (empty squares) sampling sites.

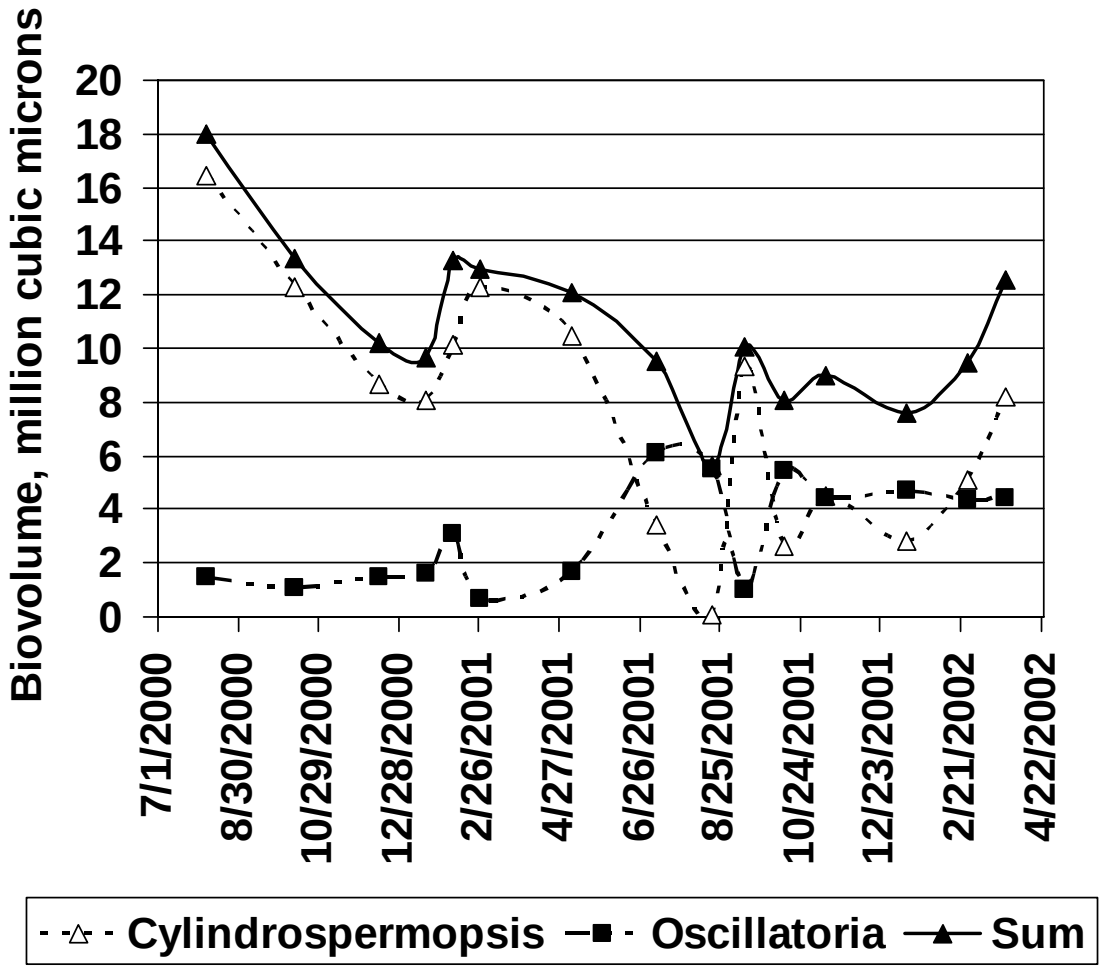

Figure 10. Comparison of the biovolume of *Cylindrospermopsis* and *Oscillatoria* over the study period.

length, while the 2µm form of *Oscillatoria* found in Lake Griffin typically has trichomes of 2µm diameter and around 70µm in length. In the absence of more specific genetic or biochemical markers it is not possible to completely exclude the possibility that the latter form of *Oscillatoria* is an ecomorphotype of *Cylindrospermopsis*. Although, classic morphometrically–based taxonomy would argue that these are distinct species.

Another form of cyanobacteria that is strongly represented in Lake Griffin is the single celled species *Microcystis incerta* (Figure 8). *M. incerta* densities exceeded 500,000 cells/ml through most of the sampling period. Its presence is one of the major reasons that cyanobacteria are numerically dominant in Lake Griffin. Due to the small size of *M. incerta* (averaging 1.5µm in diameter) it is typically less important on a biovolume basis than some of the filamentous species of cyanobacteria. It is noteworthy that *M. aeruginosa* and the genus *Anabaena* were seldom encountered in Lake Griffin, despite the importance of these cyanobacteria in many other eutrophic Florida lakes.

While diatoms rarely dominated the phytoplankton community of Lake Griffin during our sampling period, the meroplanktonic taxon *Aulacoseira* (a pennate diatom that typically resides near the sediment-water interface but is periodically resuspended into the water column) was regularly encountered, occasionally at relatively high concentrations (Figure 11). The highest concentrations of *Aulacoseira* were observed in samples from the southern basin.

Primary Productivity

Maximum rates of gross primary production (GPP) observed during the sampling period ranged from 267 to 1500 mg $C/m^3/hr$ (Table 9). The lowest GPP values were observed on January 17, 2000, May 7, 2001 and November 12, 2001. All of these dates coincided with downturns in phytoplankton standing crops. Overall, the photosynthesis versus irradiance relationships observed over the sampling period (see Appendix 4) were characterized by low light requirements to reach half of P_{max}, i.e. mostly <15% (Table 9).

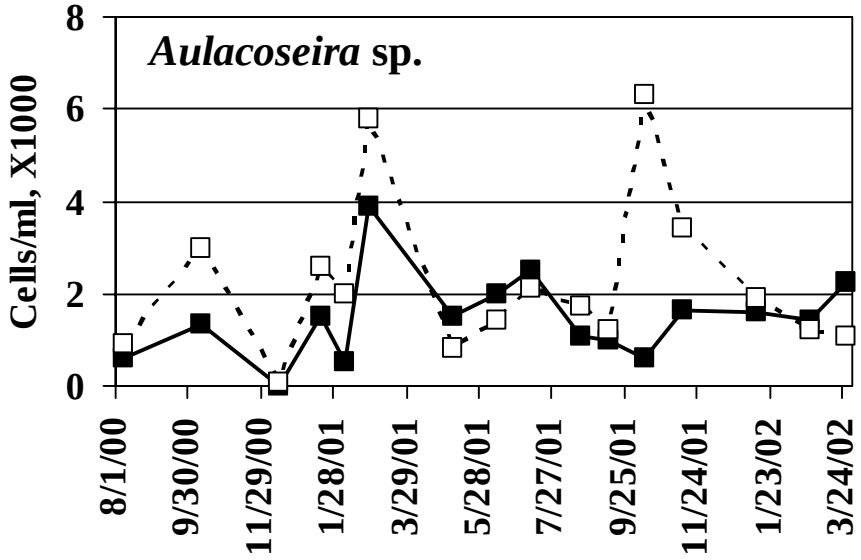

Figure 11 . Meroplanktonic diatom species at the North (filled squares) and South (empty squares) sampling sites.

Table 9. Summary of primary productivity experiments. The maximum rate of gross primary production (P_{max}) was derived by using a photosynthetic quotient of 1.2 to convert oxygen production to carbon fixed (mg carbon $m^{-3}hr^{-1}$). $I_{1/2\ Sat}$ (% of incident irradiance) is the light flux at which gross photosynthesis is half of P_{max}.

Date	Site	P_{max}	$I_{1/2\ Sat}$	% Inhibition at Full Light
8-7-00	North	875	10	-
	South	1500	3	73
10-11-00	North	583	16	0
1-17-01	North	580	5	0
	South	333	4	0
5-7-01	North	275	15	-
	South	267	15	-
7-9-01	North	1083	12	23
	South	958	9	45
10-12-01	North	1250	5	0
	South	1417	3	0
11-12-01	North	375	12	11
	South	166	9	0
1-12-02	North	1292	2	29
	South	1000	2	0
2-26-02	North	666	5	0
	South	975	6	0
3-27-02	North	875	9	0
	South	917	9	0

The lowest $I_{1/2\ SAT}$ values were associated with fall/winter months. These observations suggest a high efficiency of light utilization by the phytoplankton community of the lake, which may be supported by the high chlorophyll to cell biovolume ratios observed during the study (Table 10).

As a measure of photosynthetic capacity, volumetric GPP values were converted to mg C/mg chlorophyll a/hr . Values for maximum photosynthetic capacity ranged from 1.41 to 24.29 mg C/mg chlorophyll a/hr.

In order to examine the potential for light limitation of primary production in Lake Griffin the mean light availability in the mixed layer, I_m, was estimated using the observed extinction coefficients (from light data in Appendix 1b), station depth and average daily incident irradiance (estimated using information in Oswald and Gataas 1957). For all of the sampling dates except one (February 26, 2002), I_m values (Table 11) exceeded the threshold for light limitation of 3 mole photons/m_2/day identified by Phlips et. al. (1995) for Lake Okeechobee.

Nutrient Limitation Status

The results of the nutrient limitation bioassays indicated that nitrogen was the most frequently limiting element in Lake Griffin during the sampling period. On eight of ten bioassay dates at both the north and south sampling sites the addition of nitrogen resulted in algal standing crop above that observed in the control group (Table 12). Phosphorus was the primary limiting nutrient on two bioassay dates at both the north and south sampling site (Table 12). The two dates when phosphorus limitation was observed were May 7, 2001 and January 12, 2002. On four of the bioassay dates (i.e. 1/17/01, 2/28/01, 7/9/01 and 10/12/01), nitrogen/phosphorus co-limitation set in rapidly after the initial expression of primary limitation. This means that there was apparently very little bioavailable nitrogen or phosphorus in the water column at the time of sampling. The results of the nitrogen gradient series included in the bioassays further indicated that the surplus bioavailable phosphorus in the water column of the lake during the study period was not exceptionally high. This is shown by the lack of any major increase in phytoplankton growth response to higher levels of nitrogen enrichment (Appendix 5).

Table 10. Chlorophyll to biovolume ratio (µg l^{-1} chlorophyll/10^6 µ$m^3$$ml^{-1}$ biovolume) and estimated compensation light flux (% of incident light where dark respiration is equal to oxygen evolution).

Date	Site	Chl/Biovolume	Compensation Light
8-7-00	North	6.6	1.0
	South	7.5	1.0
1-17-01	North	7.6	0.5
	South	5.5	1.0
5-7-01	North	0.7	4.0
	South	1.0	3.0
7-9-01	North	3.2	2.0
	South	3.7	2.0
10-12-01	North	9.2	1.0
	South	7.7	1.0
11-12-01	North	7.4	3.0
	South	7.1	2.0
1-12-02	North	4.4	0.5
	South	4.9	0.5
2-26-02	North	7.8	1.0
	South	8.3	1.0
3-27-02	North	8.7	1.5
	South	14.7	1.5

Table 11. Vertical light extinction coefficients, K_t (m^{-1}), and mean light availability in the mixed layer, I_m (mole photons/m_2/day).

Date	Site	K_t	I_m
8-7-00	North	4.3	11.6
	South	4.5	13.8
10-11-00	North	6.2	12.9
	South	5.9	5.4
1-17-01	North	4.7	7.8
	South	4.7	8.8
5-7-01	North	2.1	28.3
	South	2.4	24.9
7-9-01	North	3.6	22.7
11-12-01	North	6.6	5.3
	South	7.3	3.2
1-12-02	North	5.6	3.6
	South	4.7	4.3
2-26-02	North	9.0	2.6
	South	7.4	2.7
3-27-02	North	7.1	5.3
	South	6.4	4.7

Table 12. Results of nutrient limitation bioassays. The mean chlorophyll a concentrations (ug/liter) at time=0 are shown along with the mean concentrations for the three primary treatment groups at the point of maximum separation of response. Chlorophyll values are based on in vivo fluorescence measurements. The results of Duncans Multiple Range Tests are shown as letters below the means. Means with the same letter are not significantly different. The nutrient identified as the primary limiting nutrient is shown in the last column.

Date	Site	Initial Chl	Control	+N	+P	Primary Limiting Nutrient
8-7-00	North	133	129 B	159 A	129 B	N
	South	102	95 B	114 A	96 B	N
2-28-01	North	126	97 B	126 A	104 B	N
	South	116	118 B	157 A	116 B	N
5-7-01	North	9	13 B	13 B	30 A	P
	South	15	15 B	16 B	28 A	P
7-9-01	North	44	35 B	44 A	33 B	N
	South	40	31 B	37 A	32 B	N
8-20-01	North	76	62 A	61 A	67 A	-
	South	114	94 B	97 A	91 B	-
10-12-01	North	103	80 B	92 A	85 B	N

	South	128	107 B	130 A	107 B	N
11-12-01	North	89	56 B	61 A	56 B	N
	South	98	60 B	69 A	61 B	N
1-12-02	North	49	42 B	42 B	49 A	P
	South	56	47 B	47 B	53 A	P
2-26-02	North	98	42 B	52 A	38 B	N
	South	110	43 B	52 A	42 B	N
3-27-02	North	135	109 B	136 A	107 B	N
	South	153	119 B	133 A	115 B	N

Table 13. The principal limiting factor is given by the letter designation, 'N' for nitrogen limited and 'P' for phosphorus limited. The ratios for bioavailable nitrogen to bioavailable phosphorus (BN/BP) and total nitrogen to total phosphorus (TN/TP) are provided along with the limiting status. Values for BN and BP are from Table 4.

	North Station			South Station		
Date	Limiting Status	BN/BP	TN/TP	Limiting Status	BN/BP	TN/TP
Aug-07-2000	N	4.9	53	N	5.5	58
Feb-28-2001	N	1.8	39	N	3.4	44
May-07-2001	P	35.9	72	P	29.9	69
Jul-09-2001	N	1.8	38	N	2.6	41
Aug-20-2001	N	1.0	41	N	0.8	50
Oct-12-2001	N	0.7	39	N	1.1	36
Jan-12-2002	P	9.1	41	P	5.7	43
Feb-26-2002	N	1.4	43	N	1.1	47
Mar-27-2002	N	0.9	----	N	1.2	----

The nutrient-limiting status observed over the sampling period did not appear to be related to any patterns in total nitrogen to total phosphorus ratios (TN/TP), which were consistently high and well above the Redfield ratio of 7.1 (Table 13). The Redfield ratio represents a value associated with nutrient sufficiency, therefore values above 7.1 should reflect phosphorus limitation. However, phosphorus limitation did appear to be correlated to dates when the ratios of bioavailable nitrogen to bioavailable phosphorus (BN/BP) were greater than the Redfield ratio and chlorophyll levels were relatively low.

Another noteworthy observation associated with the bioassay experiments was the decline in chlorophyll levels over incubation time observed for many of the bioassay dates. While some bioassays demonstrated a typical response to nutrient addition where both controls and treatment groups remained on the plus side in terms of standing crop, many other bioassays revealed a declining chlorophyll levels. It appears that the biomass loss processes exceeded the gain processes for a significant number of sampling dates. In order to explore this phenomenon further a series of additional experimental manipulations were tested beyond the basic protocol established in the original research proposal. In one test, the addition of higher doses of both nitrogen and phosphorus provided some additional stimulation of growth. In another test, even greater stimulation was observed by adding small aliqoutes of lake water to algal culture media. These results indicate that the high standing crops of phytoplankton present in Lake Griffin during the sampling period may have at times been near some threshold, possibly related to the presence of potentially toxic species like *Cylindrospermopsis*. These phenomena certainly warrant further investigation and may hold significant clues to the regulation of phytoplankton standing crops in the lake. Considering the generally low responses of phytoplankton growth to nutrient enrichment in this study a modification of bioassay methods may be warranted to adjust to the unique characteristics of Lake Griffin.

DISCUSSION AND CONCLUSIONS

Factors That Control the Abundance of Phytoplankton in Lake Griffin

From a water management perspective, understanding the factors that control changes in phytoplankton standing crop is critical to the task of identifying viable options

for maintaining or improving the condition of specific ecosystems. These factors include a wide range of physical, chemical and biological elements that affect the major gain (growth and import of phytoplankton) and loss (dilution or export, grazing, death, sedimentation) processes that dictate phytoplankton standing crops. Over the nineteen month sampling period of the current study chlorophyll a values spanned a wide range, from 10 to 175 µg/liter. Within this period there were two major decreases in phytoplankton standing crop, one in the spring of 2001 and one in the fall of 2001 (Figure 6). The periods of decreasing standing crop coincided with observations of low photosynthetic efficiency in primary production experiments, i.e. experimental dates May 7, 2001 and November 12, 2001 (see Table 9, 10 and Appendix 4). Conversely, periods of increasing standing crop were associated with moderate to high photosynthetic capacity. Photosynthetic capacity and efficiency are measures of the efficiency of light energy conversion to fixed carbon. Literature values for photosynthetic capacity reported by Kalff (2002) range from 0.6 to 40 mg C/mg chl/hr. Values observed in this study ranged from 1.4 to 25 mg C/mg chl/hr. It is possible to hypothesize that one of the main factors responsible for the periods of decreasing standing crop in Lake Griffin is low photosynthetic efficiency brought about by nutrient limitation. This hypothesis is supported by the observation that phosphorus limitation was observed during both periods of decreasing standing crop. The potential for phosphorus limitation in Lake Griffin certainly warrants additional investigation. From a management perspective, the limitation of phosphorus availability provides the most direct way to reduce the frequency and intensity of algal blooms.

The observation of periods of low photosynthetic capacity in Lake Griffin leads to the next level of inquiry, namely the cause of low capacity. It is important to recognize that photosynthetic capacity is not necessarily proportional to standing crop. Frequently, very high standing crops, or algal scums, are associated with low to moderate photosynthetic capacity because a high proportion of algal cells are old and beyond their peak period of photosynthesis and growth. In order to achieve high photosynthetic capacity algal cells must be in active growth mode and supplied with essential growth requirements, e.g. nutrients and light. In addition, the cells must not be subject to stress, like nutrient limitation, excessive light energy (e.g. photoinhibition or UV damage) or

temperature extremes. Since Lake Griffin is located in the sub-tropics, temperature is seldom a predominant consideration in defining the limiting factors for primary production. Similarly, incident light flux is relatively high year round , although self-shading at the high phytoplankton standing crops could lead to light limitation.

One factor that is undoubtedly important in regulating photosynthetic capacity and hence primary production in Lake Griffin is nutrient availability. Certainly the sensitivity of the lake's phytoplankton standing crops to changes in nutrient loading is a central issue in the management of the lake. From a historical perspective, it does not appear that phytoplankton standing crops are strongly correlated to total phosphorus levels. For example, total phosphorus concentrations in the lake were at equally high levels in the late 1970's and late 1990's, yet the mean annual chlorophyll a concentrations were dramatically higher during the latter period. However, the correlation between TP and chlorophyll, or the lack thereof, can be misleading in interpreting the role of phosphorus in limiting primary production because the relationship is sensitive to a wide range of factors, including differences in the bioavailability of various phosphorus-containing compounds and the influence of other limiting factors like nitrogen or light. In our current study, a positive relationship between total phosphorus and chlorophyll a was observed, but the strength of the relationship was low (Figure 12). More importantly, the results of nutrient enrichment bioassay experiments revealed phosphorus limitation on two of ten test dates. The two phosphorus–limited dates coincided with periods of low rainfall and external water inputs to the lake. The dates also fell within periods of declining or low phytoplankton standing crops. A large portion of our study period (i.e. August of 2000 to March of 2001) was characterized by drought conditions and low lake stage. During this period significant rainfall was limited to summer months and the first few months of 2002. These observations, taken together, suggest that the phytoplankton community of Lake Griffin may be sensitive to changes in external phosphorus load, at least under the drought and low lake stage conditions prevalent during our study period.

Besides the two phosphorus-limited dates encountered in the nutrient enrichment bioassays, the eight remaining dates showed nitrogen limitation of phytoplankton growth. Certainly, the apparent dominance of the nitrogen-fixing cyanobacterium

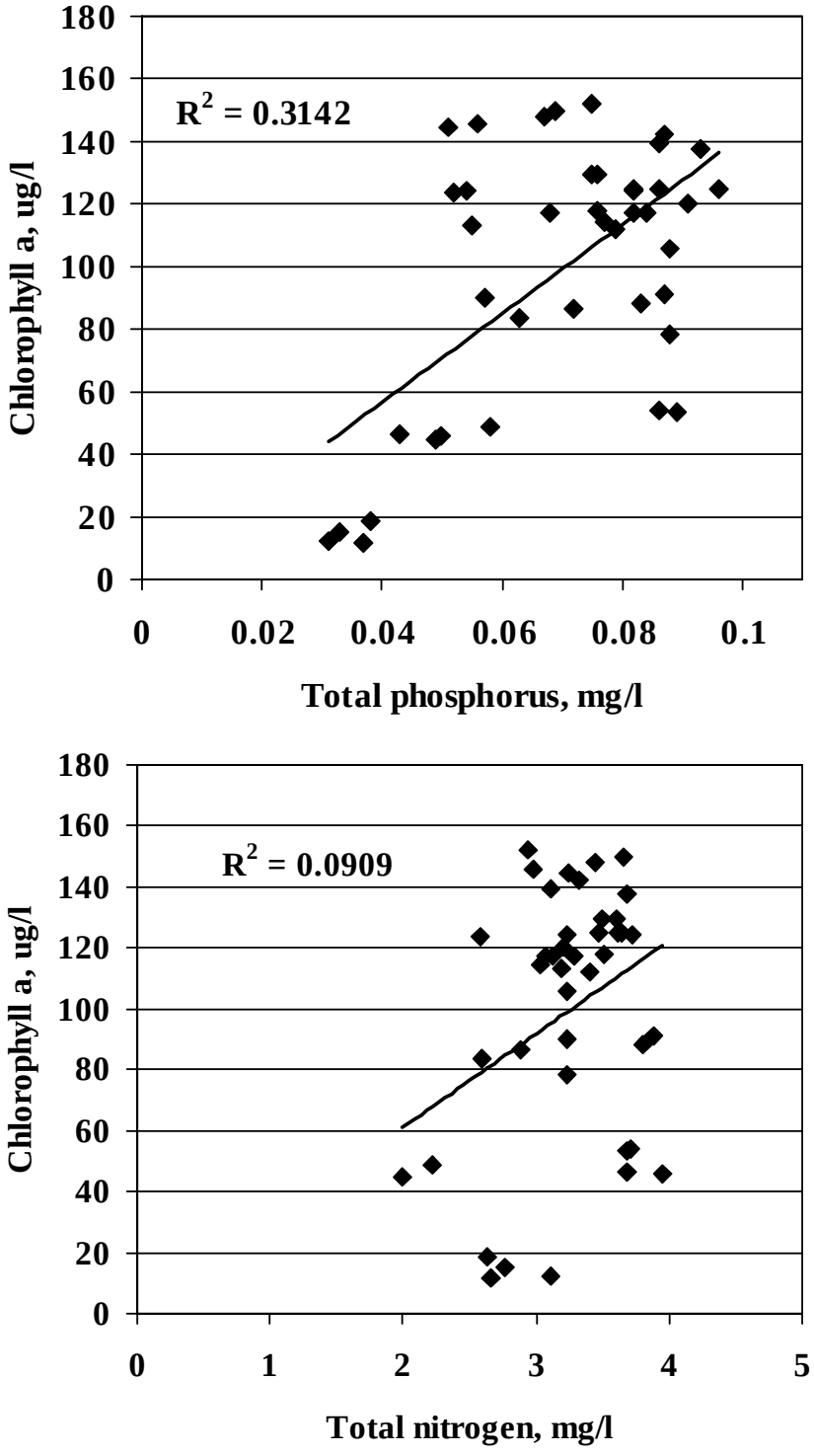

Figure 12. Total phosphorus and total nitrogen versus chlorophyll a for Lake Griffin.

Cylindrospermopsis in the lake over the past few years argues for the importance of nitrogen limitation. Historically, the increasing trend in chlorophyll concentrations in Lake Griffin since the mid-1980s has coincided with a similar trend in total nitrogen. The magnitude of the increase in nitrogen relative to phosphorus is manifested by the strong rise in TN/TP ratio during this period of time. It may be hypothesized that the dramatic rise in overall phytoplankton standing crop in the lake over the past decade is at least in part a response to increased nitrogen inputs.

The results of our nutrient limitation bioassays suggest that the nutrient-limiting status of Lake Griffin is subject to temporal variability, most probably related to the changing character of nutrient loading and utilization, particularly in terms of bioavailable forms of nitrogen and phosphorus. Variability in nutrient limitation was further indicated by changes in the ratio of bioavailable nitrogen and phosphorus (BN/BP). These ratios ranged from well above (e.g. 36) to well below (e.g. 1.6) the Redfield ratio of 7.2 (by weight), even though the ratios of TN/TP were consistently above 40. Variation in BN/BP was predominantly the result of large shifts in the amount of bioavailable nitrogen (50 to 800 :g/l), while the range of bioavailable phosphorus was by comparison small (i.e. 15 to 35 :g/l).

Due to the exceptionally low rainfall levels and lake stage conditions encountered during the current study period, it would be premature to conclude that the patterns observed for water chemistry, phytoplankton standing crop, productivity and nutrient limitation are typical of Lake Griffin under a wider range of climatic conditions. The observations made during this time period do, however, provide valuable insight into the structure and function of the lake under conditions of exceptionally low external nutrient input and low water turnover rates.

Phytoplankton Structure and the Dominance of *Cylindrospermopsis*

Cylindrospermopsis is a prominent feature of the phytoplankton community of many eutrophic lakes in temperate and subtropical latitudes around the world (Branco and Senna 1994, Fabbro and Duivenvoorden 1996, Harris and Baxter 1996, Padisak 1997). *Cylindrospermopsis* has also been identified as a major element of the phytoplankton community of Lake Griffin (Chapman & Schelske 1997). The results of

the current study provide further evidence of the importance of cyanobacteria in the phytoplankton community of the lake. As anticipated, *Cylindrospermopsis* was one of the dominant taxa found during the study. For the first nine months of the study it was the dominant phytoplankton species in terms of biovolume. In the spring of 2001, overall phytoplankton standing crops and *Cylindrospermopsis* abundance both dropped dramatically. By the following summer phytoplankton standing crops again exceeded 100 µg/liter, but the cyanobacterium identified as *Oscillatoria* took on a position of prominence, along with *Cylindrospermopsis*, which apparently diminished in relative abundance over the latter half of the sampling period. In terms of numerical abundance, the small spherical cyanobacterium *Microcystis incerta* was the dominant phytoplankton species throughout the study period. Cyanobacteria were not, however the only important elements of the phytoplankton community, certain species of diatoms also appeared in significant numbers on a periodic basis. For example, the meroplanktonic diatom *Aulacoseira* was a regular, and at times prominent, member of the community. The observation of these species in Lake Griffin supports the results of paleolimnological studies that indicate an important role for meroplankton in the ecology of Lake Griffin (Schelske 1998). The co-existence of *Cylindrospermopsis* and *Aulacoseira* in shallow polymictic lakes has been observed in other parts of the world (Harris and Baxter 1996).

The reasons for the ability of *Cylindrospermopsis* to bloom under the environmental conditions in Lake Griffin is clearly a key aspect of the ecology of the lake, particularly in light of recent concerns over the potential toxicity of this group of cyanobacteria (Chorus and Bartrum 1999). The cosmopolitan distribution of the genus *Cylindrospermopsis* indicates that it is widely successful in competing for habitat (Padisak 1997). As a heterocystous nitrogen-fixing form of algae, it clearly has an advantage in ecosystems subject to nitrogen limitation (Presing et al. 1996). Within the state of Florida it has been shown to reach bloom proportions in a number of other freshwater ecosystems subject to nitrogen limitation, including Lake Okeechobee (Cichra et al. 1995, Phlips and Ihnat 1995) and the St. Johns River (Phlips 2001). In the aforementioned ecosystems *Cylindrospermopsis* is not the only important nitrogen-fixing form of blue-green algae present, *Anabaena* and *Aphanizomenon* can also form extensive

blooms. In addition, non-heterocystous blue-green algae like *Microcystis*, *Lyngbya* and *Oscillatoria* play a major role in the plankton communities of both Lake Okeechobee and the St. Johns River.

In recent years researchers from the St. Johns River Water Management District (personal communication Rolland Fulton) and the Florida Fish and Wildlife Commission (personal communication Bill Johnson) have reported that *Cylindrospermopsis* is the dominant feature of the phytoplankton community in Lake Griffin. While there is little doubt that *Cylindrospermopsis* has been a major element of Lake Griffin's phytoplankton community over the past few years, the reasons for its success are still a matter of debate. The results of research over the past few decades provide insight into potential directions for future investigations. On first principle, it may be hypothesized that a major contributor to the success of *Cylindrospermopsis* is the ability to fix nitrogen. Since the Harris chain of lakes is subject to high rates of phosphorus loading it may be hypothesized that Lake Griffin is subject to periods of nitrogen-limitation, during which nitrogen-fixing cyanobacteria would be at a selective advantage. However, this still leaves the question of why *Cylindrospermopsis* can consistently out-compete other nitrogen-fixing blue-green algae, like *Anabaena* and *Aphanizomenon*. On a related note, the results of our recent research indicate that in the fall of 2000 and winter of 2001 *Cylindrospermopsis* dominated the phytoplankton despite the fact that significant nitrogen fixation activity was not observed during all of these time periods and the TN/TP ratios were generally high. The latter observations suggest that *Cylindrospermopsis* is not necessarily dependent on its ability to fix nitrogen to dominate the phytoplankton community of Lake Griffin. Similar observations have been made in Lake Balaton, Hungary (Padisak and Istvanovics, 1997).

The ability to fix nitrogen is not the only feature of *Cylindrospermopsis* that may be relevant to its competitive success in Lake Griffin. Another key capability is buoyancy regulation. *Cylindrospermopsis* is among the group of planktonic cyanobacteria with the ability to adjust their position in the water column through the regulation of internal gas vesicles (Reynolds et. al. 1987). In a recent study of Florida Bay, Phlips et al. (1999) observed that the cyanobacterium *Synechococcus* loses its buoyancy when P-limited and regains it under nutrient-rich conditions. Phlips et al.

(1999) hypothesized that *Synechococcus* can use buoyancy regulation to take advantage of phosphorus in Florida Bay sediments by sinking to the water-sediment interface where microaerobic conditions result in enhanced availability of soluble reactive phosphorous. A similar mechanism for obtaining phosphorous from sediments in Lake Griffin may be suggested for *Cylindrospermopsis*.

Another potentially significant observation related to the ecophysiology of *Cylindrospermopsis* is the high chlorophyll/TP ratios that have characterized the recent period of its dominance during the late 1990s. It has been suggested that this observation manifests a unique ability of *Cylindrospermopsis* to compete for and utilize limited phosphorus resources (Padisak and Istvanovics 1997). The presence of high standing crops of *Cylindrospermopsis,* even over long periods of very low soluble reactive phosphorus concentrations supports this concept. Alternatively, the high chl/TP values may reflect increases in the ratio of chlorophyll to algal biomass and not the ratio of algal biomass to TP, as implied by the previous hypothesis. It is clear that research to test these alternative hypotheses is important to defining the basis for *Cylindrospermopsis* dominance.

Beyond nutrient-related processes, there are other features of *Cylindrospermopsis* that may contribute to its success in Lake Griffin. As a potential toxin producer *Cylindrospermopsis* may be relatively resistant to grazing pressure (Rothhaupt 1991), thereby reducing the magnitude of top-down control of standing crop. From a production standpoint, the very shallow depth of Lake Griffin may pose a problem with excessive light or photoinhibition. However, it is known that certain species of cyanobacteria are exceptionally resistant to high light or UV damage. It is not known whether *Cylindrospermopsis* falls into this category.

There is clearly much that remains to be learned about the basis for the dominance of *Cylindrospermopsis* in Lake Griffin.

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Appendix 1a, Field Parameters

Appendix 1a. Field measured parameters: Dissolved Oxygen, temperature and Secchi depth.

M/D/Y	Site	Sample Type	DO	Temp	Secchi
			mg/L	C	m
08/07/00	N	0.000m	8.2	29.6	0.25
08/07/00	N	0.300m	7.5	30.0	0.25
08/07/00	N	0.600m	7.3	30.0	0.25
08/07/00	N	0.900m	6.8	29.9	0.25
08/07/00	N	1.200m	6.0	29.7	0.25
08/07/00	S	0.000m	8.4	30.3	0.25
08/07/00	S	0.200m	8.1	30.5	0.25
08/07/00	S	0.300m	7.8	30.5	0.25
08/07/00	S	0.500m	7.5	30.4	0.25
08/07/00	S	0.750m	7.0	30.3	0.25
10/11/00	N	0.300m	.	22.0	0.22
10/11/00	N	1.000m	.	22.0	0.22
10/11/00	N	1.300m	.	22.0	0.22
10/11/00	S	0.300m	.	22.0	0.22
10/11/00	S	0.500m	.	22.0	0.22
10/11/00	S	0.700m	.	22.0	0.22
12/14/00	N	0.250m	13.4	23.3	0.25
12/14/00	N	0.500m	13.2	23.1	0.25
12/14/00	N	1.00m	8.8	21.7	0.25
12/14/00	S	0.250m	9.8	20.9	0.30
12/14/00	S	0.500m	9.9	20.9	0.30
12/14/00	S	0.670m	9.9	20.8	0.30
01/17/01	N	0.000m	8.6	17.7	0.25
01/17/01	N	0.300m	6.9	16.7	0.25
01/17/01	N	0.700m	6.8	16.4	0.25
01/17/01	S	0.000m	11.6	18.8	0.25
01/17/01	S	0.300m	10.9	17.1	0.25
01/17/01	S	0.600m	9.8	16.8	0.25
02/07/01	N	Integ	11.8	17.2	0.25
02/07/01	S	Integ	11.0	15.2	0.25
02/28/01	N	0.300m	8.7	24.9	0.22
02/28/01	N	0.500m	8.6	24.9	0.22
02/28/01	N	0.675m	8.3	24.9	0.22
02/28/01	S	0.300m	6.9	22.8	0.25
02/28/01	S	0.500m	6.4	22.5	0.25
02/28/01	S	0.675m	6.0	22.4	0.25
05/07/01	N	0.000m	4.8	24.1	0.65
05/07/01	N	0.300m	4.9	24.1	0.65
05/07/01	N	0.600m	4.8	24.1	0.65
05/07/01	N	0.900m	4.8	24.1	0.65
05/07/01	N	1.200m	4.8	24.1	0.65
05/07/01	S	0.000m	4.3	23.0	0.60
05/07/01	S	0.100m	4.3	23.0	0.60
05/07/01	S	0.200m	4.3	23.0	0.60
05/07/01	S	0.300m	4.3	23.0	0.60
05/07/01	S	0.400m	4.3	23.0	0.60
05/16/01	N	Integ	5.4	29.3	0.90
05/16/01	S	Integ	5.3	26.8	0.90
07/24/01	N	Integ	8.2	26.3	0.40
07/24/01	S	Integ	8.2	27.6	0.40

Appendix 1a, Field Parameters

M/D/Y	Site	Sample Type	DO	Temp	Secchi		
			mg/L	C	m		
08/16/01	N	Integ	7.0	30.1	0.40		
08/16/01	S	Integ	8.1	30.1	0.20		
09/12/01	N	Integ	6.4	27.4	0.30		
09/12/01	S	Integ	7.6	28.6	0.30		
10/12/01	N	0.300m	7.6	23.8	0.30		
10/12/01	N	0.600m	7.2	23.7	0.30		
10/12/01	N	1.100m	6.6	23.6	0.30		
10/12/01	S	0.300m	6.4	23.8	0.30		
10/12/01	S	0.700m	6.5	23.8	0.30		
10/12/01	S	1.400m	6.4	23.8	0.30		
11/08/01	N	Integ	10.0	19.0	0.40		
11/08/01	S	Integ	14.1	20.2	0.40		
11/12/01	N	0.500m	10.5	20.8	0.40		
11/12/01	N	1.00m	10.4	20.8	0.40		
11/12/01	N	1.300m	3.5	20.9	0.40		
11/12/01	S	0.500m	9.5	20.4	0.40		
11/12/01	S	1.00m	9.6	20.3	0.40		
11/12/01	S	1.500m	9.4	20.3	0.40		
01/12/02	N	0.500m	12.4	13.8	0.40		
01/12/02	N	1.000m	10.5	13.1	0.40		
01/12/02	N	1.250m	6.4	13.1	0.40		
01/12/02	S	0.500m	10.6	11.5	0.40		
01/12/02	S	1.000m	10.4	11.0	0.40		
01/12/02	S	1.500m	10.1	10.9	0.40		
01/30/02	N	Integ	11.8	22.5	0.40		
01/30/02	S	Integ	10.2	22.2	0.40		
02/26/02	N	0.500m	10.4	18.5	0.30		
02/26/02	N	1.000m	9.2	17.2	0.30		
02/26/02	N	1.300m	5.5	17.3	0.30		
02/26/02	S	0.500m	8.9	17.0	0.30		
02/26/02	S	1.000m	7.9	16.8	0.30		
02/26/02	S	1.500m	7.9	16.8	0.30		
03/07/02	N	Integ	10.1	15.4	0.40		
03/07/02	S	Integ	10.0	15.4	0.40		
03/27/02	N	0.500m	9.4	25.0	0.30		
03/27/02	N	1.000m	8.7	24.9	0.30		
03/27/02	S	0.500m	9.2	23.8	0.30		
03/27/02	S	1.000m	8.4	23.2	0.30		
03/27/02	S	1.500m	8.3	22.8	0.30		

Appendix 1b: Field measured parameter: Light extinction.					
M/D/Y	Site	Time	Depth	Incident	Downwelling
		EST	M	m Ein/M^2/sec	m Ein/M^2/sec
08/07/00	N	15:09	0.0	1710	1412.00
08/07/00	N	15:10	0.1	1695	960.10
08/07/00	N	15:10	0.2	1677	625.30
08/07/00	N	15:11	0.5	1667	191.60
08/07/00	N	15:12	0.7	1653	88.20
08/07/00	N	15:13	1.0	1653	20.90
08/07/00	N	15:14	0.7	1648	120.00
08/07/00	S	11:52	0.0	1840	1555.00
08/07/00	S	11:53	0.1	1819	1060.00
08/07/00	S	11:56	0.2	1814	708.60
08/07/00	S	11:57	0.3	1811	420.00
08/07/00	S	11:58	0.5	1833	190.60
08/07/00	S	11:59	0.8	1849	35.70
08/07/00	S	12:00	0.5	1853	183.10
10/11/00	N	13:48	0.0	1716	1247.00
10/11/00	N	13:49	0.1	925	358.50
10/11/00	N	13:50	0.2	1535	374.60
10/11/00	N	13:51	0.3	1852	236.60
10/11/00	N	13:53	0.4	1839	134.60
10/11/00	N	13:53	0.4	1829	133.80
10/11/00	N	13:55	0.5	1823	82.14
10/11/00	N	13:56	0.3	1814	262.80
10/11/00	S	11:19	0.0	1721	1550.00
10/11/00	S	11:21	0.1	1712	983.20
10/11/00	S	11:22	0.2	1725	575.90
10/11/00	S	11:23	0.3	1730	292.30
10/11/00	S	11:25	0.4	1726	120.80
10/11/00	S	11:26	0.5	1750	90.99
10/11/00	S	11:28	1.0	1770	7.87
10/11/00	S	11:30	1.3	1743	2.48
10/11/00	S	11:31	0.4	1757	177.10
01/17/01	N	12:18	0.0	538	364.20
01/17/01	N	12:18	0.1	535	275.20
01/17/01	N	12:19	0.2	532	181.60
01/17/01	N	12:20	0.3	525	111.00
01/17/01	N	12:20	0.4	524	76.72
01/17/01	N	12:20	0.5	522	48.87
01/17/01	N	12:21	0.6	519	34.87
01/17/01	N	12:21	0.7	515	23.71
01/17/01	N	14:19	0.0	566	402.60
01/17/01	N	14:19	0.1	567	309.90
01/17/01	N	14:20	0.2	568	203.80
01/17/01	N	14:20	0.3	567	136.00
01/17/01	N	14:20	0.4	565	87.01
01/17/01	N	14:21	0.5	564	49.45
01/17/01	N	14:21	0.6	561	36.90
01/17/01	N	14:21	0.7	559	27.54
01/17/01	S	16:15	0.0	285	239.10
01/17/01	S	16:15	0.1	284	151.50
01/17/01	S	16:15	0.2	283	101.30
01/17/01	S	16:16	0.3	283	60.87

Appendix 1b, Light Extinction

M/D/Y	Site	Time	Depth	Incident	Downwelling
		EST	M	m Ein/M^2/sec	m Ein/M^2/sec
01/17/01	S	16:16	0.4	282	41.92
01/17/01	S	16:16	0.5	281	26.55
01/17/01	S	16:16	0.6	279	19.84
05/07/02	N	10:32	0.0	1727	1278.00
05/07/02	N	10:33	0.1	778	522.10
05/07/02	N	10:34	0.2	654	362.40
05/07/02	N	10:35	0.3	661	307.00
05/07/02	N	10:36	0.4	1741	141.50
05/07/02	N	10:37	0.6	1422	397.80
05/07/02	N	10:37	0.8	1263	329.00
05/07/02	N	12:36	0.0	1003	592.90
05/07/02	N	12:37	0.1	1025	735.20
05/07/02	N	12:37	0.2	1052	.
05/07/02	N	12:38	0.3	1189	632.90
05/07/02	N	12:38	0.4	1189	.
05/07/02	N	12:38	0.6	1075	325.30
05/07/02	N	12:39	0.8	1169	105.60
05/07/02	S	9:22	0.0	1390	1126.00
05/07/02	S	9:23	0.1	1430	940.80
05/07/02	S	9:24	0.2	1439	804.60
05/07/02	S	9:24	0.3	1403	591.40
05/07/02	S	9:25	0.4	1421	508.10
05/07/02	S	9:26	0.6	1441	339.60
05/07/02	S	9:27	0.8	1427	250.90
07/09/01	N	13:17	0.0	1174	679.50
07/09/01	N	13:18	0.1	1133	514.40
07/09/01	N	13:19	0.2	1113	453.40
07/09/01	N	13:19	0.3	1129	348.60
07/09/01	N	13:20	0.4	1123	253.30
07/09/01	N	13:21	0.5	1108	183.80
07/09/01	N	13:22	0.7	1114	109.60
11/12/01	N	9:02	0.5	753	19.73
11/12/01	N	9:02	0.8	748	6.86
11/12/01	N	9:03	1.0	740	2.19
11/12/01	N	11:49	0.5	1675	60.27
11/12/01	N	11:50	0.8	1685	22.86
11/12/01	N	11:50	1.0	1677	5.12
11/12/01	S	7:46	0.5	380	10.05
11/12/01	S	7:47	1.0	378	1.56
11/12/01	S	7:47	1.5	368	0.19
11/12/01	N	9:34	0.5	625	32.52
11/12/01	N	9:34	1.0	630	11.46
11/12/01	N	9:35	1.2	633	10.38
11/12/01	N	12:51	0.5	1043	63.50
11/12/01	N	12:51	1.0	469	8.42
11/12/01	S	8:31	0.5	266	14.97
11/12/01	S	8:31	1.0	295	2.45
11/12/01	S	8:31	1.5	307	0.45
11/12/01	S	8:31	2.0	303	0.06
01/12/02	N	12:22	0.5	610	37.77
01/12/02	N	12:22	1.0	620	6.82
01/12/02	N	12:22	1.3	630	1.47
01/12/02	N	14:27	0.5	83	89.49

Appendix 1b, Light Extinction

M/D/Y	Site	Time	Depth	Incident	Downwelling
		EST	M	m Ein/M^2/sec	m Ein/M^2/sec
01/12/02	N	14:27	1.0	884	16.46
01/12/02	N	14:27	1.3	810	0.31
01/12/02	S	9:04	0.5	477	44.62
01/12/02	S	9:05	1.0	477	19.11
01/12/02	S	9:05	1.3	476	0.90
02/26/02	N	12:14	0.5	1723	19.17
02/26/02	N	12:14	1.0	1708	3.22
02/26/02	N	12:14	1.3	1633	0.45
02/26/02	S	9:47	0.5	997	24.20
02/26/02	S	9:47	1.0	981	2.20
02/26/02	S	9:48	1.5	987	0.20
03/27/02	N	9:51	0.5	542	15.96
03/27/02	N	9:52	1.0	549	1.13
03/27/02	N	9:52	1.2	572	0.29
03/27/02	S	8:27	0.5	263	10.60
03/27/02	S	8:28	1.0	266	0.24
03/27/02	S	8:28	1.5	279	0.01
* Seven missing values					
-9-2001 South light data was not collected due to impending storm					

Appendix 2. Water Chemistry.													
M/D/Y	Site	Sample Type	NO2 mg/L	NO3 mg/L	NH4 mg/L	Urea mg/L	TN mg/L	SRP mg/L	PHEP mg/L	TP mg/L	SiO2 mg/L	SiO2 (B) cmg/L	POC mgC/L
08/07/00	N	0.300m	0.000	0.006	0.033	0.029	2.983	0.001	0.013	0.056	9.677	0.700	8.9
08/07/00	N	0.750m	0.000	0.002	0.030	0.039	3.001	0.000	0.015	0.055	10.059	0.472	9.5
08/07/00	N	1.400m	0.000	0.003	0.032	0.050	3.009	0.002	0.017	0.054	9.945	0.622	9.2
08/07/00	S	0.300m	0.000	0.003	0.032	0.042	3.198	0.001	0.013	0.055	9.683	0.616	9.5
08/07/00	S	0.500m	0.000	0.002	0.032	0.049	3.261	0.001	0.010	0.057	10.037	0.448	9.7
08/07/00	S	0.800m	0.000	0.005	0.035	0.062	3.249	0.001	0.011	0.061	10.037	0.459	9.8
10/11/00	N	0.300m	0.001	0.002	0.053	.	3.444	0.002	0.029	0.067	10.657	0.667	11.8
10/11/00	N	1.000m	0.000	0.003	0.042	.	3.463	0.001	0.031	0.076	10.847	0.987	17.7
10/11/00	N	1.300m	0.000	0.003	0.043	.	3.475	0.001	0.029	0.069	10.597	2.037	15.2
10/11/00	S	0.300m	0.001	0.001	0.052	.	3.506	0.001	0.026	0.076	12.006	1.067	16.1
10/11/00	S	0.500m	0.001	0.002	0.052	.	3.479	0.001	0.031	0.076	10.595	1.053	15.6
10/11/00	S	0.700m	0.001	0.001	0.046	.	3.495	0.002	0.031	0.076	10.532	1.111	15.1
12/14/00	N	0.300m	0.001	0.004	0.033	.	2.934	0.001	0.037	0.075	.	.	.
12/14/00	N	Integ	0.001	0.003	0.045	.	2.691	0.003	0.030	0.075	.	.	.
12/14/00	S	0.300m	0.001	0.030	0.121	.	3.720	0.003	0.025	0.082	.	.	.
12/14/00	S	Integ	0.001	0.005	0.082	.	3.855	0.003	0.030	0.077	.	.	.
01/17/01	N	0.300m	0.003	0.007	0.529	0.023	3.888	0.003	0.021	0.087	9.078	0.483	.
01/17/01	N	0.450m	0.003	0.006	0.561	0.021	3.914	0.002	0.022	0.086	9.394	0.666	.
01/17/01	N	0.700m	0.003	0.006	0.576	0.017	4.005	0.001	0.022	0.088	9.225	0.717	.
01/17/01	S	0.300m	0.003	0.012	0.397	0.021	3.800	0.004	0.018	0.083	8.796	0.033	.
01/17/01	S	0.450m	0.003	0.011	0.398	0.019	3.692	0.003	0.019	0.079	8.739	0.027	.
01/17/01	S	0.600m	0.003	0.013	0.394	0.041	3.701	0.005	0.017	0.080	8.848	0.082	.
02/07/01	N	Integ	.	.	.	.	3.470	.	.	0.086	.	.	16.2
02/07/01	S	Integ	.	.	.	.	3.320	.	.	0.087	.	.	15.9
02/28/01	N	0.300m	0.001	0.004	0.035	.	3.436	0.003	0.032	0.088	7.014	1.554	.
02/28/01	N	0.500m	0.001	0.002	0.030	.	3.432	0.001	0.034	0.085	7.315	1.608	.
02/28/01	N	0.850m	0.001	0.003	0.036	.	3.468	0.002	0.032	0.080	6.682	1.605	.
02/28/01	S	0.300m	0.001	0.002	0.084	.	3.623	0.003	0.029	0.082	7.793	2.007	.
02/28/01	S	0.500m	0.001	0.002	0.092	.	3.770	0.003	0.036	0.092	7.829	1.794	.
02/28/01	S	0.700m	0.001	0.003	0.075	.	3.539	0.003	0.029	0.087	7.881	1.731	.
05/07/01	N	0.300m	0.001	0.002	0.763	0.022	2.657	0.003	0.019	0.037	7.537	0.933	.
05/07/01	N	0.600m	0.001	0.002	0.789	0.023	2.623	0.003	0.018	0.038	7.463	0.837	.
05/07/01	N	1.100m	0.001	0.002	0.774	0.022	2.623	0.003	0.018	0.038	7.452	0.789	.
05/07/01	N	0.300m	0.001	0.001	0.664	0.021	2.638	0.005	0.017	0.038	7.940	0.921	
05/07/01	S	0.600m	0.001	0.001	0.664	0.020	2.639	0.003	0.020	0.040	7.867	0.926	
05/07/01	S	1.000m	0.001	0.001	0.693	0.020	2.664	0.004	0.020	0.038	7.998	0.932	
05/16/01	N	Integ	.	.	.	.	3.117	.	.	0.031	.	.	3.9
05/16/01	S	Integ	.	.	.	.	2.769	.	.	0.033	.	.	3.5
07/09/01	N	0.300m	0.001	0.001	0.036	0.021	2.219	0.001	0.031	0.058	8.166	0.834	13.0
07/09/01	N	0.600m	0.001	0.003	0.045	0.038	2.229	0.002	0.030	0.059	8.351	0.836	.
07/09/01	N	0.850m	0.001	0.001	0.039	0.024	2.215	0.001	0.031	0.059	8.693	1.089	.
07/09/01	N	Integ	.	.	.	.	.	0.004	.	.	8.700	.	.
07/09/01	S	0.300m	0.000	0.002	0.044	0.031	1.998	0.003	0.027	0.049	8.504	0.830	12.9
07/09/01	S	1.000m	0.000	0.004	0.046	0.026	2.021	0.002	0.027	0.048	8.993	0.763	.
07/09/01	S	1.900m	0.001	0.000	0.040	0.033	2.031	0.002	0.025	0.049	8.591	0.763	.
07/09/01	S	Integ	.	.	.	.	.	0.004	.	.	8.700	.	.
07/24/01	N	Integ	.	.	.	.	3.227	0.008	.	0.088	12.451	.	17.6
07/24/01	S	Integ	.	.	.	.	2.881	0.005	.	0.072	11.914	.	16.8
08/16/01	N	Integ	.	.	.	.	3.238	0.002	.	0.057	11.299	1.981	13.9
08/16/01	S	Integ	.	.	.	.	3.227	0.003	.	0.054	11.711	2.219	16.2
08/20/01	N	Integ	.	.	.	.	3.007	0.000	.	0.061	12.866	.	15.6

Appendix 2, Nutrient Concentration

M/D/Y	Site	Sample	NO2	NO3	NH4	Urea	TN	SRP	PHEP	TP	SiO2	SiO2 (B)	POC
		Type	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cmg/L	mgC/L
08/20/01	N	0.300m	0.001	0.002	0.031	0.013	2.594	0.003	0.042		8.166	1.688	.
08/20/01	N	0.500m	0.001	0.002	0.028	0.013	2.540	0.002	0.041		8.351	1.710	.
08/20/01	N	0.850m	0.001	0.002	0.031	0.017	2.587	0.002	0.042		8.693	2.114	.
08/20/01	S	Integ	.	.	.	.	3.040	0.000	.	0.062	8.500	.	15.9
08/20/01	S	0.300m	0.001	0.003	0.037	0.011	2.582	0.006	0.057	.	8.504	2.044	.
08/20/01	S	1.000m	0.001	0.003	0.030	0.010	2.638	0.004	0.042	.	8.993	1.890	.
08/20/01	S	2.400m	0.001	0.002	0.028	0.011	2.624	0.003	0.046	.	8.591	2.022	.
09/12/01	N	Integ	.	.	.	.	3.281	0.003	.	0.068	8.946	.	16.4
09/12/01	S	Integ	.	.	.	.	3.247	0.003	.	0.051	9.305	.	16.5
10/12/01	N	Integ	.	.	.	.	3.065	0.003	.	0.069	10.920	.	16.6
10/12/01	N	0.300m	0.002	0.000	0.020	.	3.027	0.002	.	0.077	11.679	2.641	17.3
10/12/01	N	0.600m	0.002	0.000	0.002	.	3.028	0.002	.	0.084	11.360	2.310	17.2
10/12/01	N	1.100m	0.001	0.000	0.001	.	3.036	0.002	.	0.085	11.749	2.321	17.5
10/12/01	S	Integ	.	.	.	.	3.056	0.003	.	0.086	11.409	2.081	18.1
10/12/01	S	0.300m	0.001	0.000	0.039	.	3.112	0.003	.	0.086	11.879	2.001	17.1
10/12/01	S	0.700m	0.001	0.007	0.049	.	3.379	0.002	.	0.098	11.480	1.990	17.4
10/12/01	S	1.400m	0.001	0.029	0.001	.	3.286	0.003	.	0.089	11.606	2.104	17.8
11/08/01	N	Integ	.	.	.	.	3.204	0.002	.	0.091	10.324	.	.
11/08/01	S	Integ	.	.	.	.	3.076	0.003	.	0.084	10.885	.	.
11/12/01	N	Integ	0.000	0.000	0.066	.	3.287	0.006	.	0.088	11.498	.	8.7
11/12/01	N	0.300m	0.000	0.000	0.064	.	3.236	0.004	.	0.088	11.303	.	10.0
11/12/01	N	0.750m	0.000	0.000	0.061	.	3.225	0.004	.	0.089	11.127	.	10.3
11/12/01	N	1.300m	0.000	0.000	0.060	.	3.287	0.007	.	0.092	11.951	.	10.4
11/12/01	S	Integ	0.000	0.000	0.050	.	3.157	0.004	.	0.079	11.014	.	.
11/12/01	S	0.300m	0.000	0.000	0.054	.	3.129	0.004	.	0.082	11.053	.	8.1
11/12/01	S	0.900m	0.000	0.000	0.065	.	3.041	0.004	.	0.079	10.759	.	8.6
11/12/01	S	1.500m	0.000	0.000	0.057	.	3.058	0.005	.	0.081	10.726	.	8.7
01/12/02	N	Integ	0.004	0.014	0.431	0.030	3.638	0.004	0.052	0.080	8.845	.	14.3
01/12/02	N	0.300m	0.002	0.008	0.467	0.018	3.689	0.002	0.053	0.089	6.299	.	13.8
01/12/02	N	0.750m	0.003	0.012	0.172	0.009	3.579	0.002	0.051	0.077	8.081	.	13.9
01/12/02	N	1.300m	0.002	0.007	0.285	0.010	3.808	0.002	0.055	0.091	7.465	.	16.4
01/12/02	S	Integ	0.002	0.011	0.302	0.031	3.626	0.001	0.056	0.071	6.909	.	14.1
01/12/02	S	.0300m	0.002	0.009	0.261	0.034	3.716	0.001	0.053	0.086	7.711	.	13.9
01/12/02	S	0.900m	0.002	0.008	0.241	0.016	3.524	0.002	0.056	0.075	8.779	.	13.4
01/12/02	S	1.500m	0.002	0.009	0.239	0.043	3.819	0.002	0.058	0.072	9.099	.	14.1
01/30/02	N	Integ	.	.	.	.	3.682	0.003	.	0.093	7.016	.	.
01/30/02	S	Integ	.	.	.	.	3.603	0.002	.	0.076	6.730	.	.
02/26/02	N	Integ	0.002	0.009	0.043	0.001	3.536	0.004	0.256	0.087	5.147	.	.
02/26/02	N	30cm	0.001	0.016	0.050	0.004	3.401	0.003	0.259	0.079	5.610	.	.
02/26/02	N	70cm	0.001	0.010	0.020	0.017	3.451	0.003	0.256	0.081	5.452	.	.
02/26/02	N	1.300m	0.001	0.008	0.030	0.007	3.584	0.002	0.247	0.079	5.580	.	.
02/26/02	S	Integ	0.001	0.003	0.028	0.010	3.452	0.003	0.260	0.106	5.580	.	.
02/26/02	S	30cm	0.001	0.025	0.025	0.004	3.500	0.003	0.230	0.075	5.482	.	.
02/26/02	S	75cm	0.002	0.009	0.025	0.014	3.427	0.002	0.250	0.074	5.659	.	.
02/26/02	S	1.5m	0.001	0.007	0.032	0.003	3.432	0.002	0.234	0.078	6.170	.	.
03/07/02	N	Integ	.	.	.	.	3.644	0.000	.	0.096	4.852	.	16.0
03/07/02	S	Integ	.	.	.	.	3.661	0.000	.	0.069	4.709	.	15.3
03/27/02	N	Integ	0.002	0.001	0.054	0.009	.	0.025	0.043	.	5.553	.	17.5
03/27/02	N	30cm	0.002	0.000	0.057	0.005	.	0.026	0.042	.	5.846	.	18.8
03/27/02	N	70cm	0.001	0.000	0.062	0.002	.	0.021	0.043	.	6.077	.	18.7
03/27/02	N	1.300m	0.002	0.000	0.058	0.007	.	0.021	0.050	.	5.448	.	23.8
03/27/02	S	Integ	0.052	0.000	0.057	0.015	.	0.017	0.039	.	5.620	.	16.8
03/27/02	S	30cm	0.003	0.000	0.060	0.017	.	0.029	0.037	.	5.546	.	17.3
03/27/02	S	75cm	0.002	0.001	0.059	0.019	.	0.030	0.036	.	5.439	.	17.2

Appendix 2, Nutrient Concentration

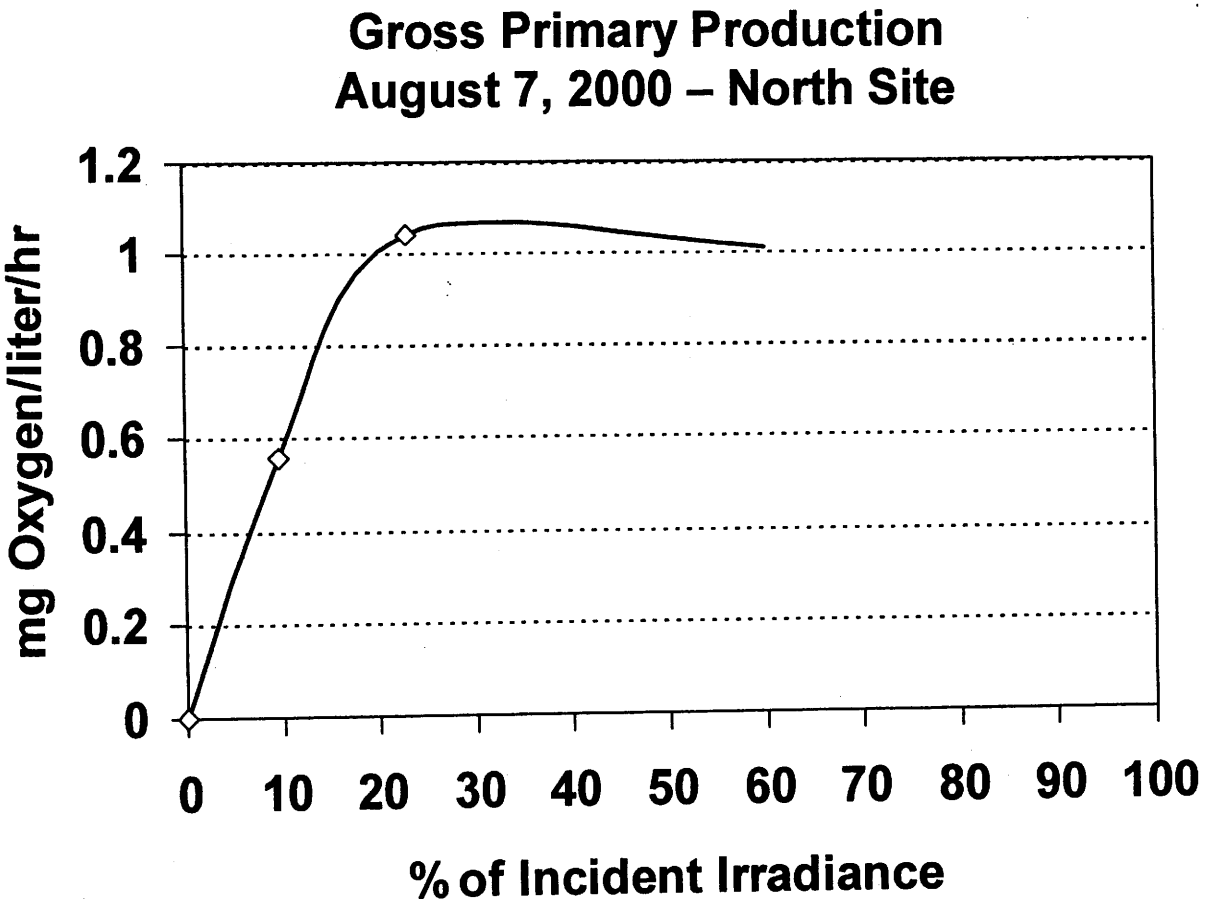
M/D/Y	Site	Sample	NO2	NO3	NH4	Urea	TN	SRP	PHEP	TP	SiO2	SiO2 (B)	POC
		Type	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cmg/L	mgC/L
03/27/02	S	1.5m	0.002	0.002	0.076	0.031	.	0.028	0.035	.	5.660	.	16.8

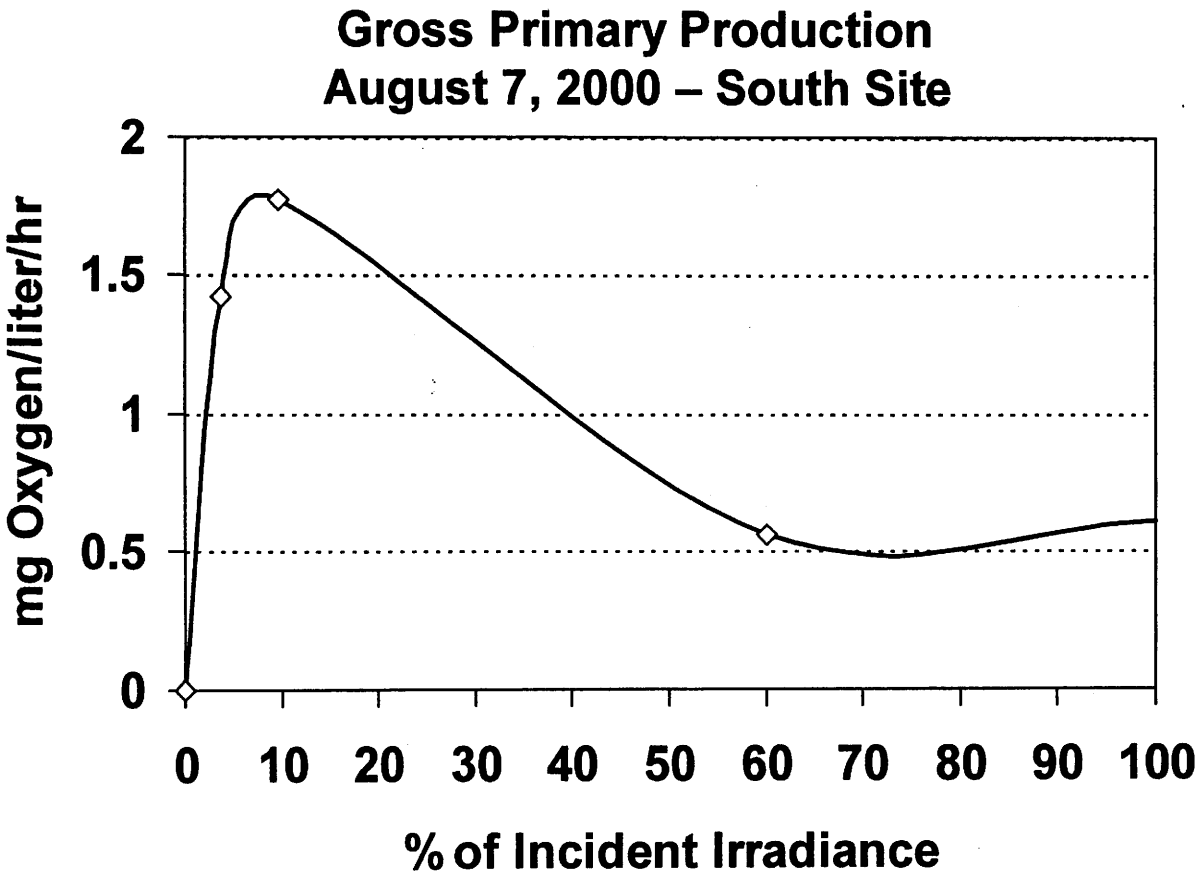
Appendix 3. Chlorophyll a concentrations.					
M/D/Y	Site	Sample Type	Chl-a	Phe-a	Uncorrected
			mg/m3	mg/m3	Chl a
08/07/00	N	0.000m	4.0	.	.
08/07/00	N	0.750m	3.0	.	.
08/07/00	N	1.400m	7.0	.	.
08/07/00	N	Integ	133.0	26.9	146.1
08/07/00	S	0.500m	6.0		
08/07/00	S	0.800m	80.0		
08/07/00	S	Integ	101.7	22.6	112.9
10/11/00	N	0.300m	5.0	.	.
10/11/00	N	1.000m	21.0	.	.
10/11/00	N	1.300m	20.0	.	.
10/11/00	S	0.300m	31.0	.	.
10/11/00	S	0.500m	20.0	.	.
10/11/00	S	0.700m	21.0	.	.
12/14/00	N	Integ	134.1	34.9	151.7
12/14/00	S	Integ	109.5	28.1	123.7
02/07/01	N	Integ	112.3	24.9	124.6
02/07/01	S	Integ	131.8	22.2	142.3
02/28/01	N	0.300m	126.0	.	.
02/28/01	N	0.500m	145.0	.	.
02/28/01	N	0.850m	130.0	.	.
02/28/02	N	0.300m	116.0	.	.
02/28/02	S	0.500m	108.0	.	.
02/28/01	S	0.700m	106.0	.	.
05/07/01	N	0.000m	7.0	17.6	16.9
05/07/01	N	0.300m	8.9	4.7	11.5
05/07/01	N	0.600m	7.8	5.5	10.8
05/07/01	N	1.100m	8.9	4.7	11.5
05/07/01	S	0.000m	22.1	14.9	30.2
05/07/01	S	0.300m	14.5	7.2	18.4
05/07/01	S	0.600m	17.9	3.4	19.5
05/07/01	S	1.000m	16.2	6.3	19.5
05/16/01	N	Integ	10.7	3.1	12.3
05/16/01	S	Integ	13.0	4.6	15.4
07/09/01	N	0.300m	43.6	10.7	49.0
07/09/01	N	0.600m	48.0	10.3	53.1
07/09/01	N	0.850m	46.9	10.2	52.0
07/09/01	N	Integ	65.9	7.7	69.2
07/09/01	S	0.300m	40.2	9.3	44.8
07/09/01	S	1.000m	39.7	10.2	44.8
07/09/01	S	1.900m	44.7	10.0	49.7
07/09/01	S	0.300m	49.7	10.0	54.6
07/24/01	N	Integ	68.9	18.5	78.3
07/24/01	S	Integ	81.2	12.1	86.7
08/16/01	N	Integ	81.8	17.1	90.2
08/16/01	S	Integ	114.2	20.7	124.1
08/20/01	N	Integ	77.9	16.8	86.2
08/20/01	N	0.300m	75.4	16.7	83.7
08/20/01	N	0.500m	75.4	12.7	81.4
08/20/01	N	0.850m	73.2	14.1	80.0
08/20/01	S	Integ	120.1	24.9	132.3
08/20/01	S	0.300m	114.0	20.8	123.9

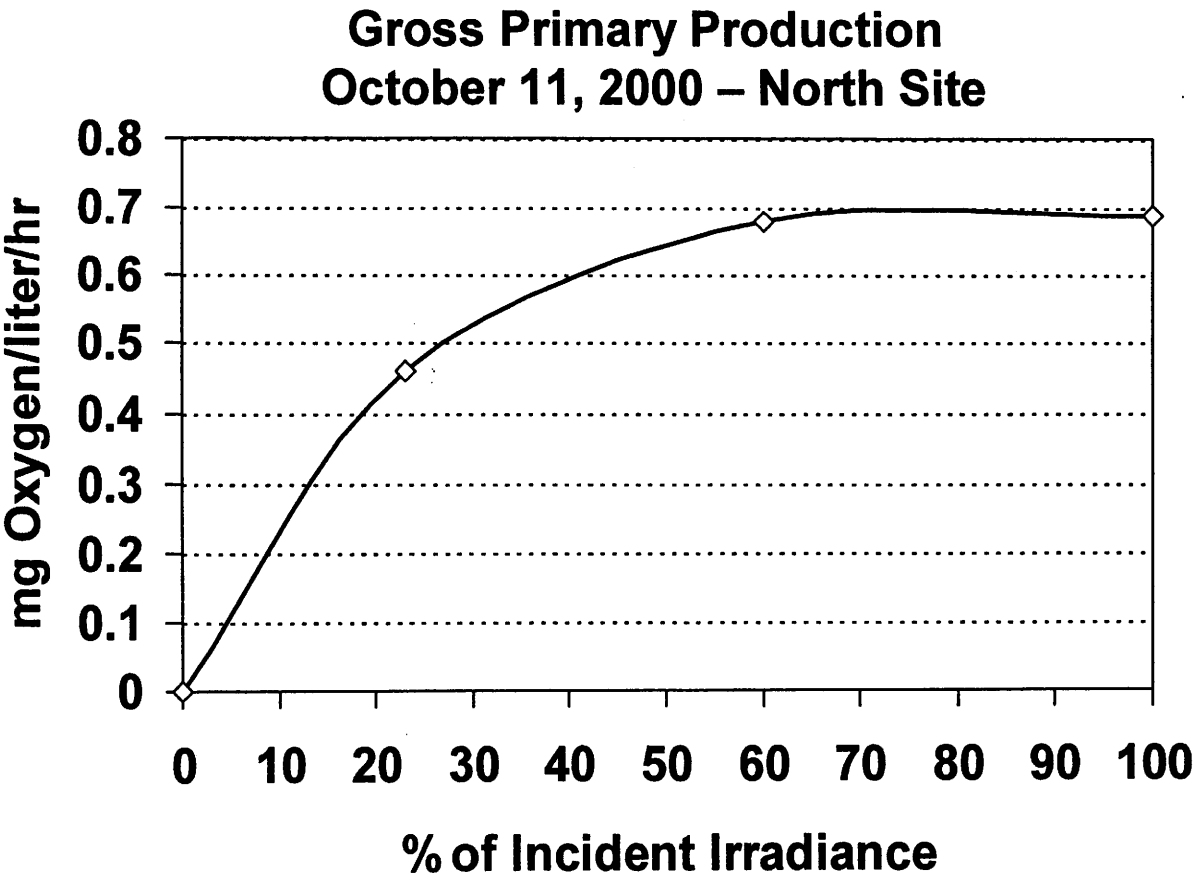
Appendix 3, Chl

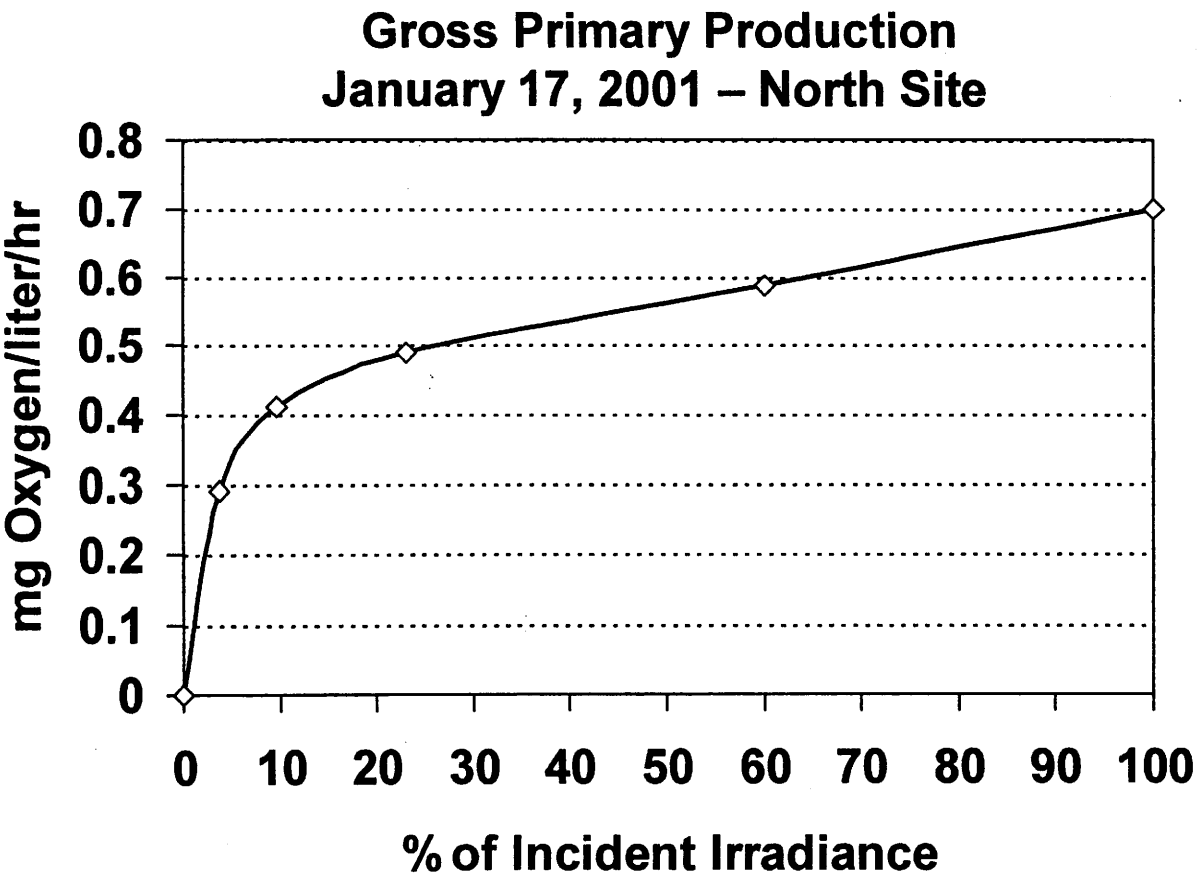
M/D/Y	Site	Sample Type	Chl-a	Phe-a	Uncorrected
			mg/m3	mg/m3	Chl a
08/20/01	S	1.000m	119.5	18.8	128.3
08/20/01	S	2.400m	122.3	22.5	133.1
09/12/01	N	Integ	109.1	17.9	117.5
09/12/01	S	Integ	134.4	21.9	144.7
10/12/01	N	Integ	118.4	23.1	129.7
10/12/01	N	0.300m	103.3	22.1	114.3
10/12/01	N	0.600m	106.1	19.4	115.4
10/12/01	N	1.100m	105.0	21.7	115.6
10/12/01	S	Integ	127.9	27.3	141.4
10/12/01	S	0.300m	127.9	24.1	139.5
10/12/01	S	0.700m	124.6	25.9	137.2
10/12/01	S	1.400m	131.8	24.2	143.4
11/08/01	N	Integ	112.1	17.7	120.3
11/08/01	S	Integ	109.1	21.5	117.2
11/12/01	N	Integ	105.6	16.9	113.4
11/12/01	N	0.300m	96.9	18.5	105.9
11/12/01	N	0.750m	104.2	18.7	113.1
11/12/01	N	1.300m	91.1	19.4	100.6
11/12/01	S	Integ	112.8	20.7	122.8
11/12/01	S	0.300m	107.3	20.5	117.1
11/12/01	S	0.900m	113.1	20.8	123.1
11/12/01	S	1.500m	110.1	17.5	118.2
01/12/02	N	Integ	45.0	20.0	55.6
01/12/02	N	0.300m	44.1	17.6	53.4
01/12/02	N	0.750m	45.5	13.6	52.5
01/12/02	N	1.300m	53.1	14.3	60.3
01/12/02	S	Integ	63.1	16.3	71.4
01/12/02	S	.0300m	48.3	11.4	54.0
01/12/02	S	0.900m	58.1	16.1	66.3
01/12/02	S	1.500m	63.7	18.6	73.2
01/30/02	N	Integ	112.6	46.7	137.4
01/30/02	S	Integ	104.5	46.6	129.3
02/26/02	N	Integ	108.4	26.4	121.6
02/26/02	N	30cm	98.0	27.0	111.8
02/26/02	N	70cm	91.1	28.6	105.9
02/26/02	N	1.300m	88.5	28.7	103.4
02/26/02	S	Integ	106.1	28.0	120.3
02/26/02	S	30cm	110.3	36.7	129.4
02/26/02	S	75cm	119.5	41.3	141.1
02/26/02	S	1.5m	114.0	32.4	130.6
03/07/02	N	Integ	117.3	23.3	128.6
03/07/02	S	Integ	137.7	10.9	141.6
03/27/02	N	Integ	136.3	31.2	151.8
03/27/02	N	30cm	134.6	33.3	151.4
03/27/02	N	70cm	137.4	29.3	151.8
03/27/02	N	1.300m	140.2	34.3	157.5
03/27/02	S	Integ	156.7	40.6	177.2
03/27/02	S	30cm	152.8	42.7	174.6
03/27/02	S	75cm	160.0	43.1	182.0
03/27/02	S	1.5m	156.7	44.6	179.5

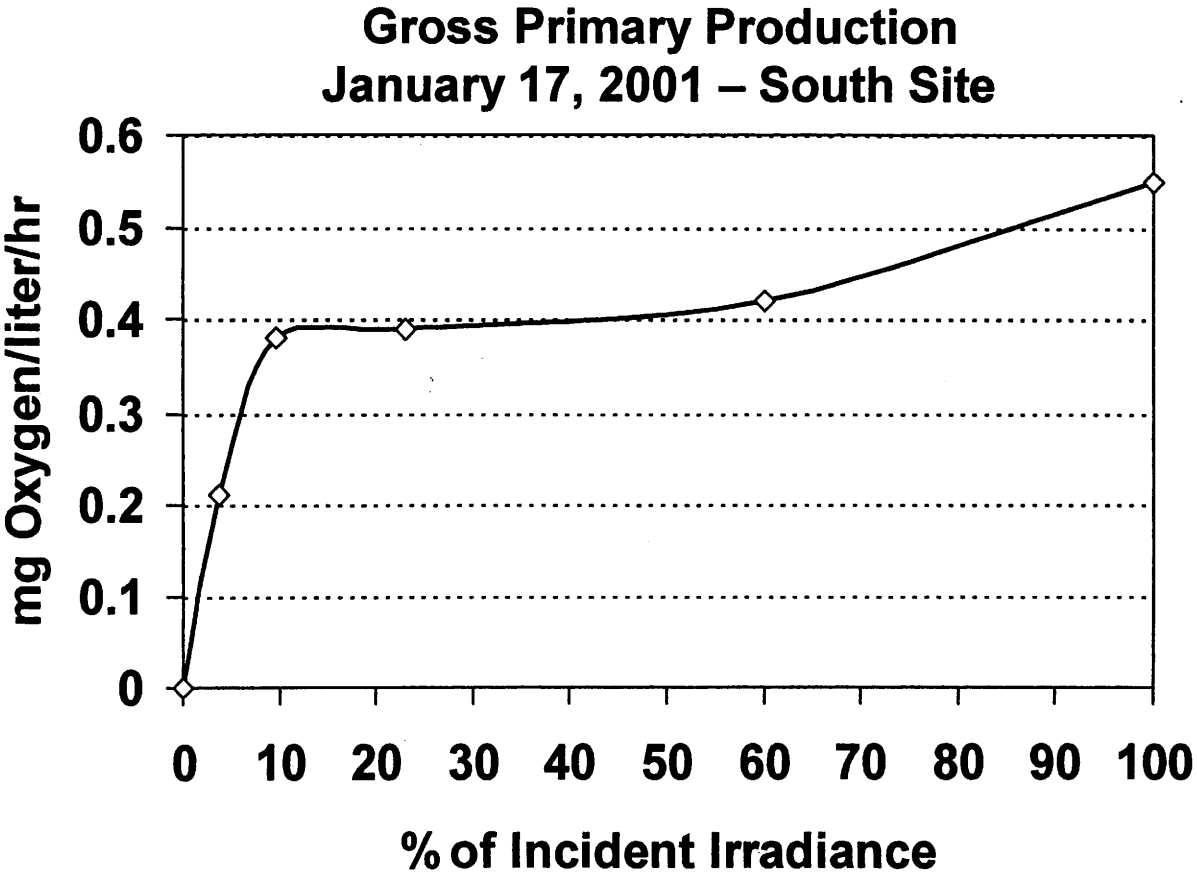
Appendix 4. Irradiance X gross primary production. Zero irradiance values were Obtained from curve fit estimates of dark respiration.

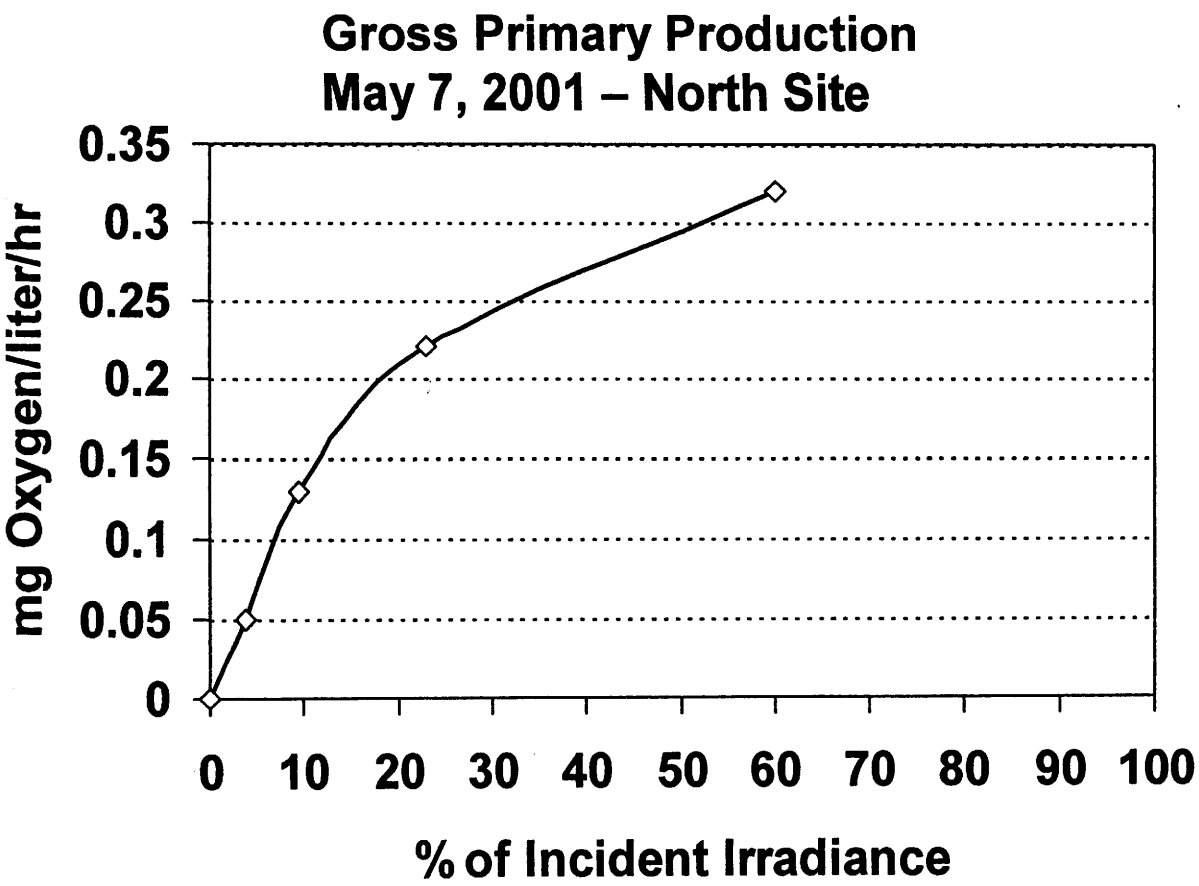


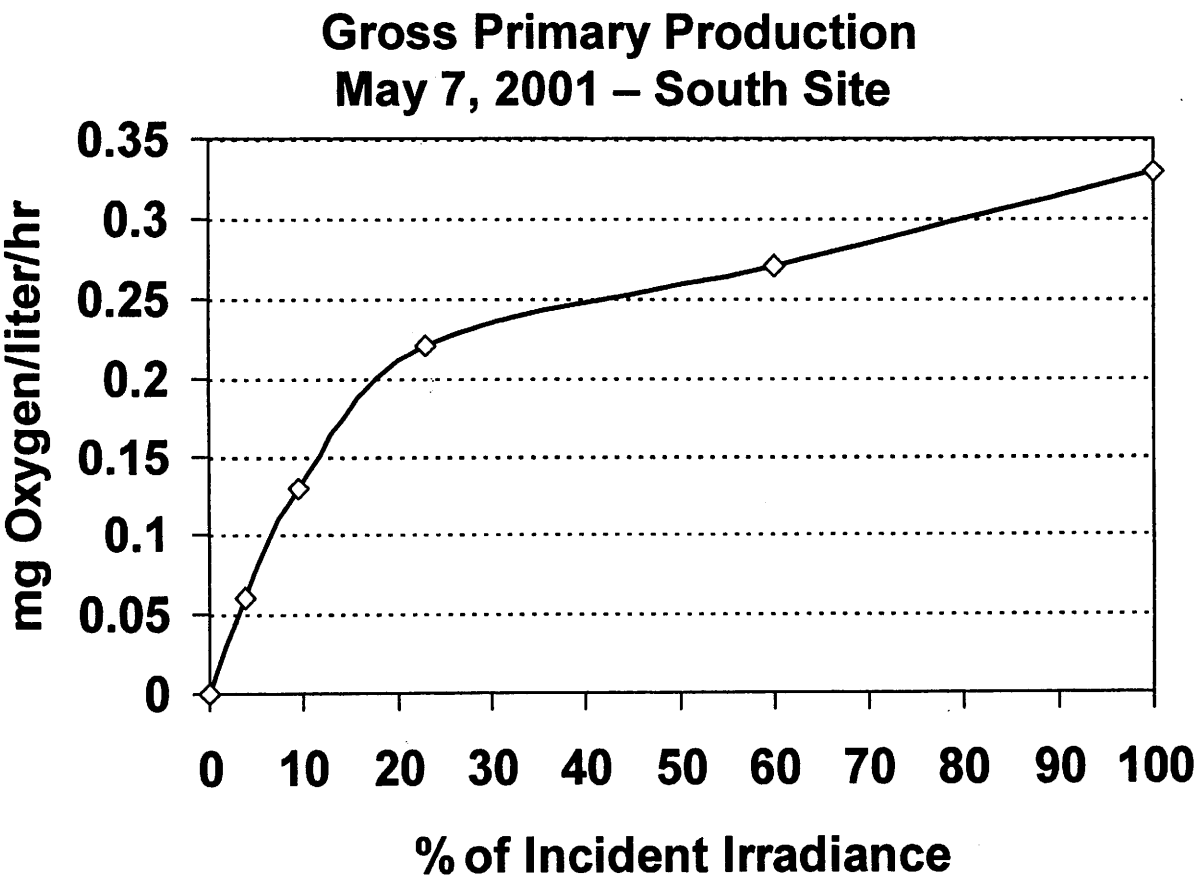

Gross Primary Production
August 7, 2000 – South Site
mg Oxygen/liter/hr
2
1.5
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

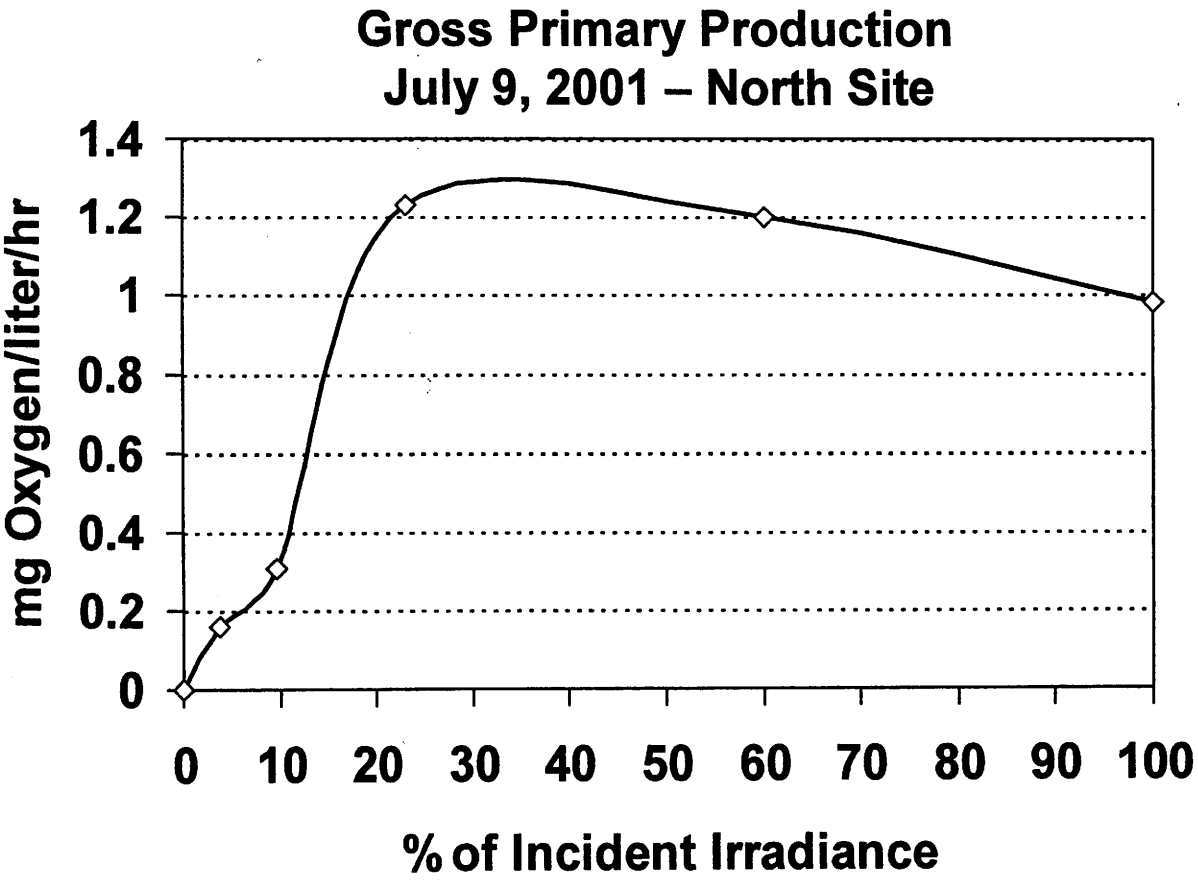

Gross Primary Production
October 11, 2000 – North Site
mg Oxygen/liter/hr
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

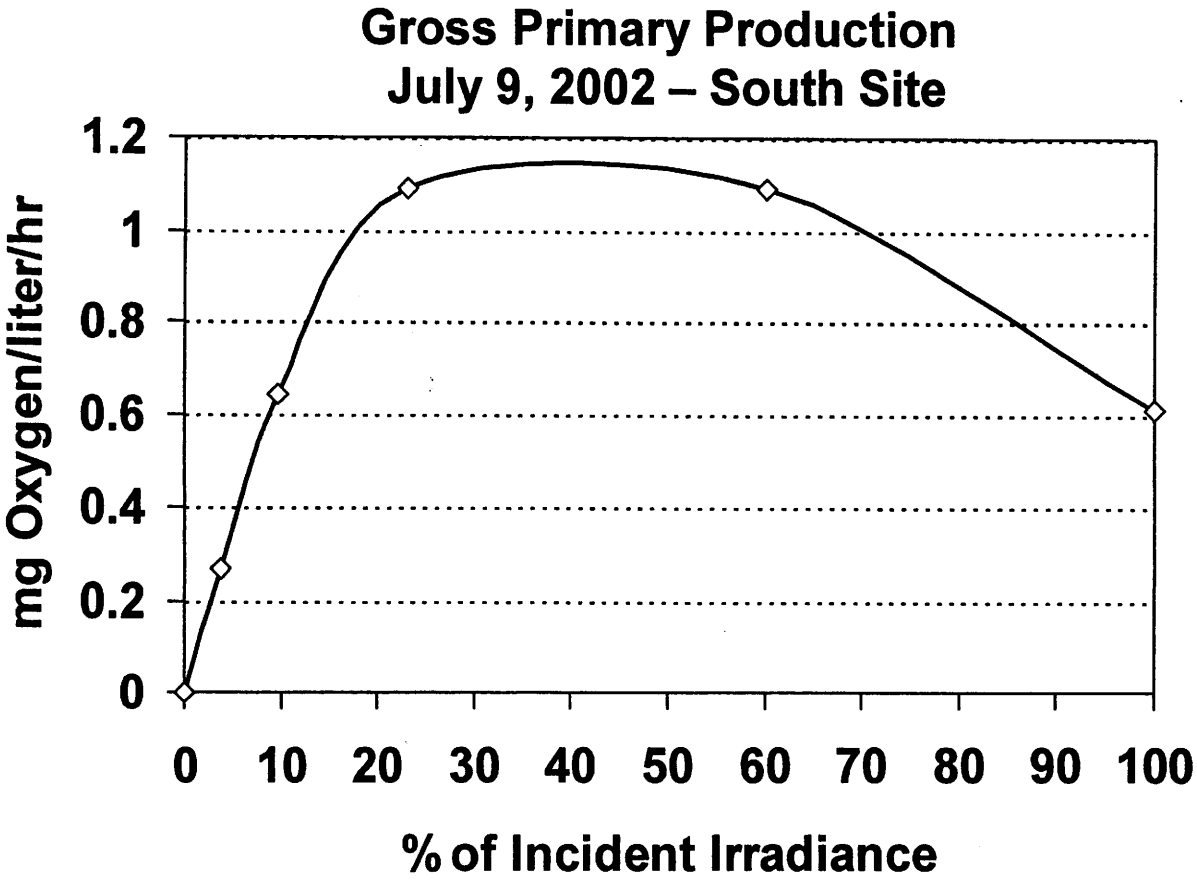

Gross Primary Production
January 17, 2001 – North Site
mg Oxygen/liter/hr
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

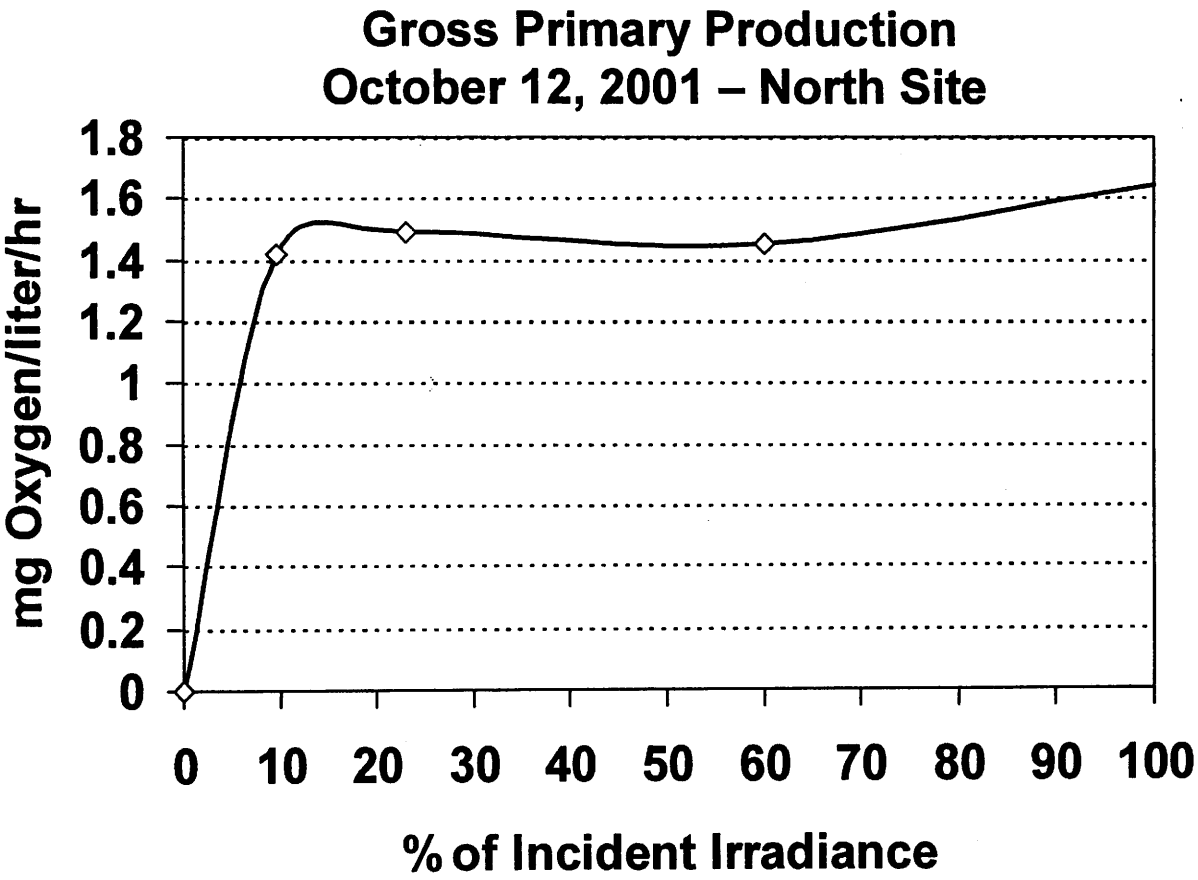

Gross Primary Production
January 17, 2001 – South Site
mg Oxygen/liter/hr
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

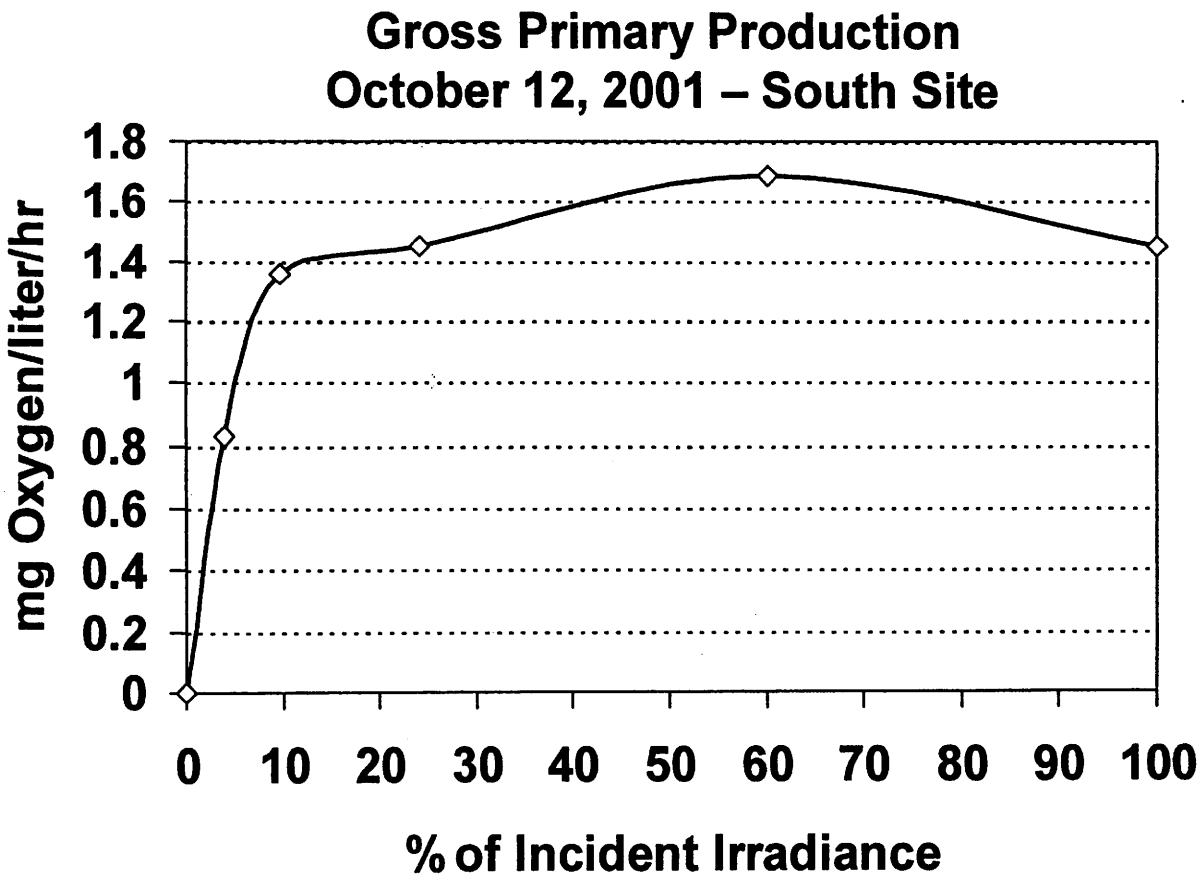

Gross Primary Production
May 7, 2001 – North Site
mg Oxygen/liter/hr
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

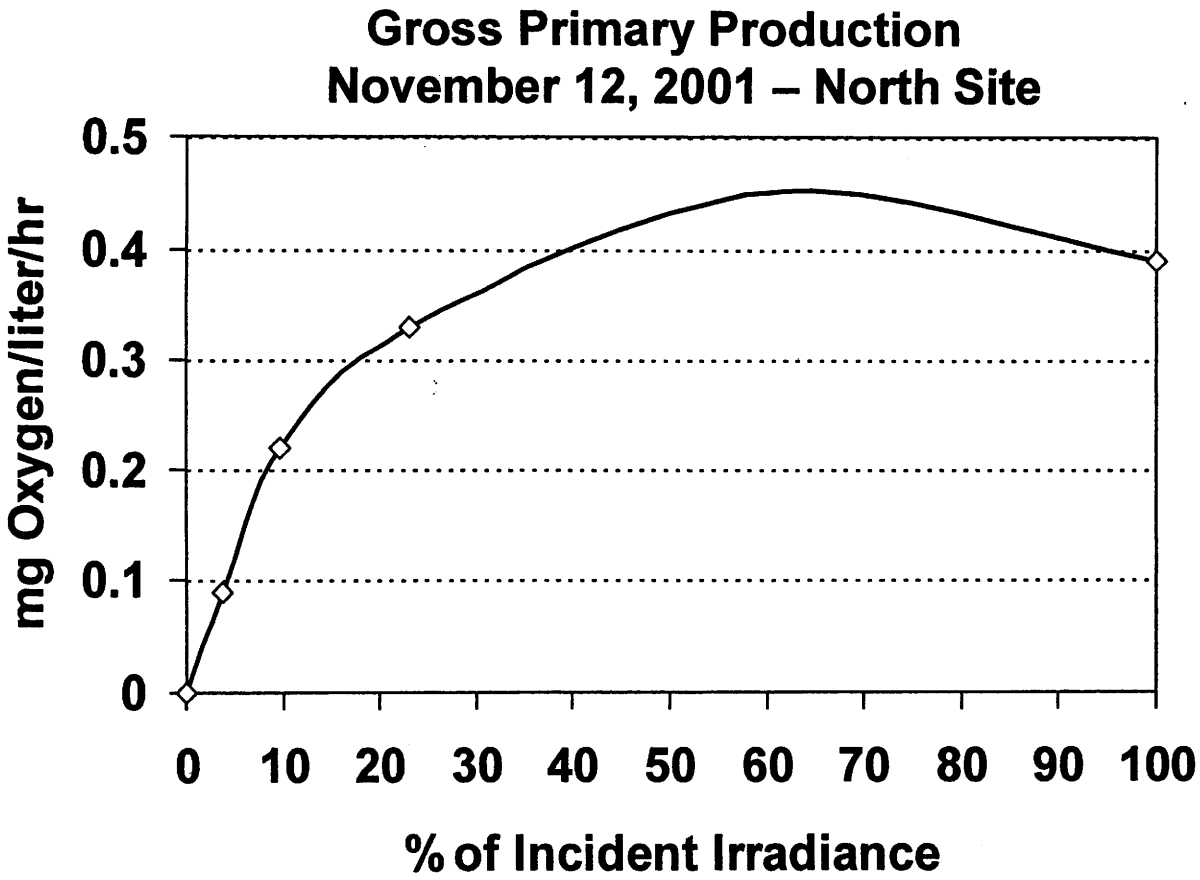

Gross Primary Production
May 7, 2001 – South Site
mg Oxygen/liter/hr
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

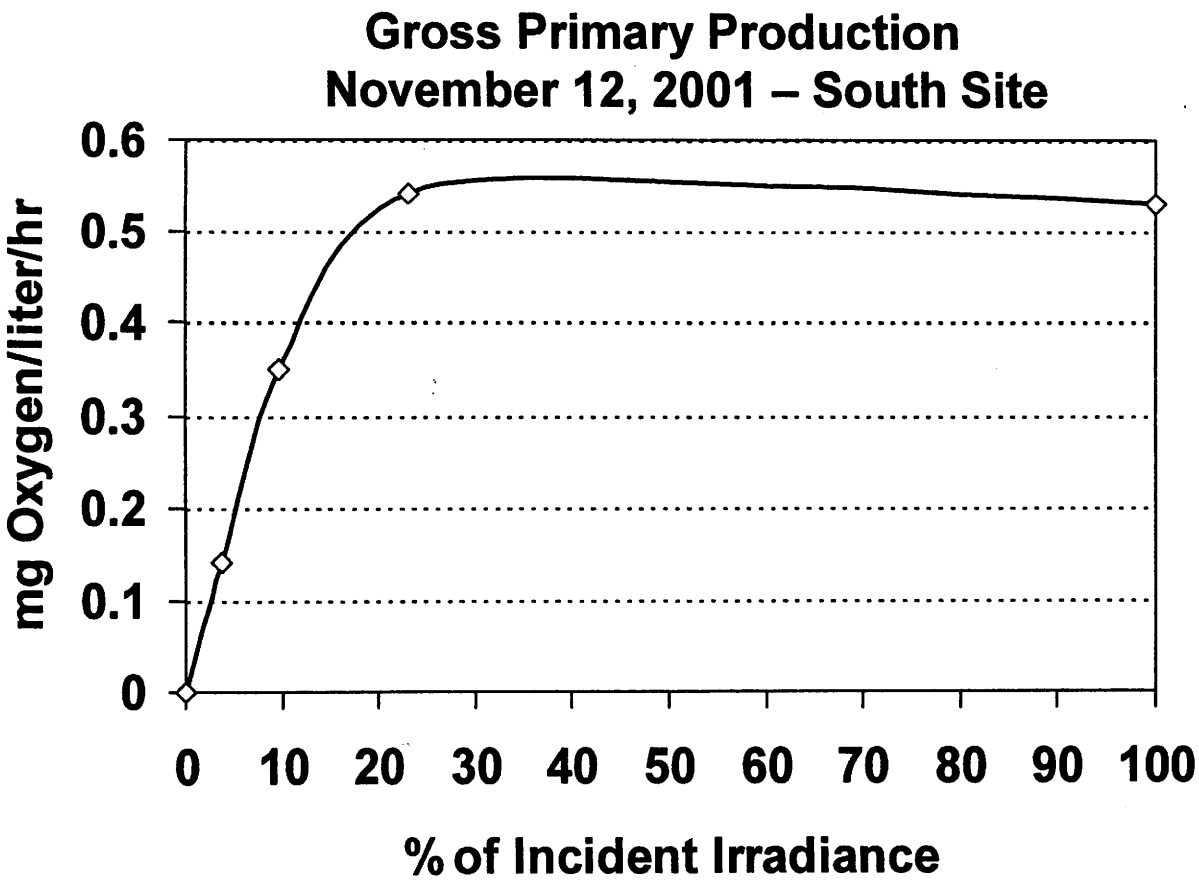

Gross Primary Production
July 9, 2001 – North Site
mg Oxygen/liter/hr
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

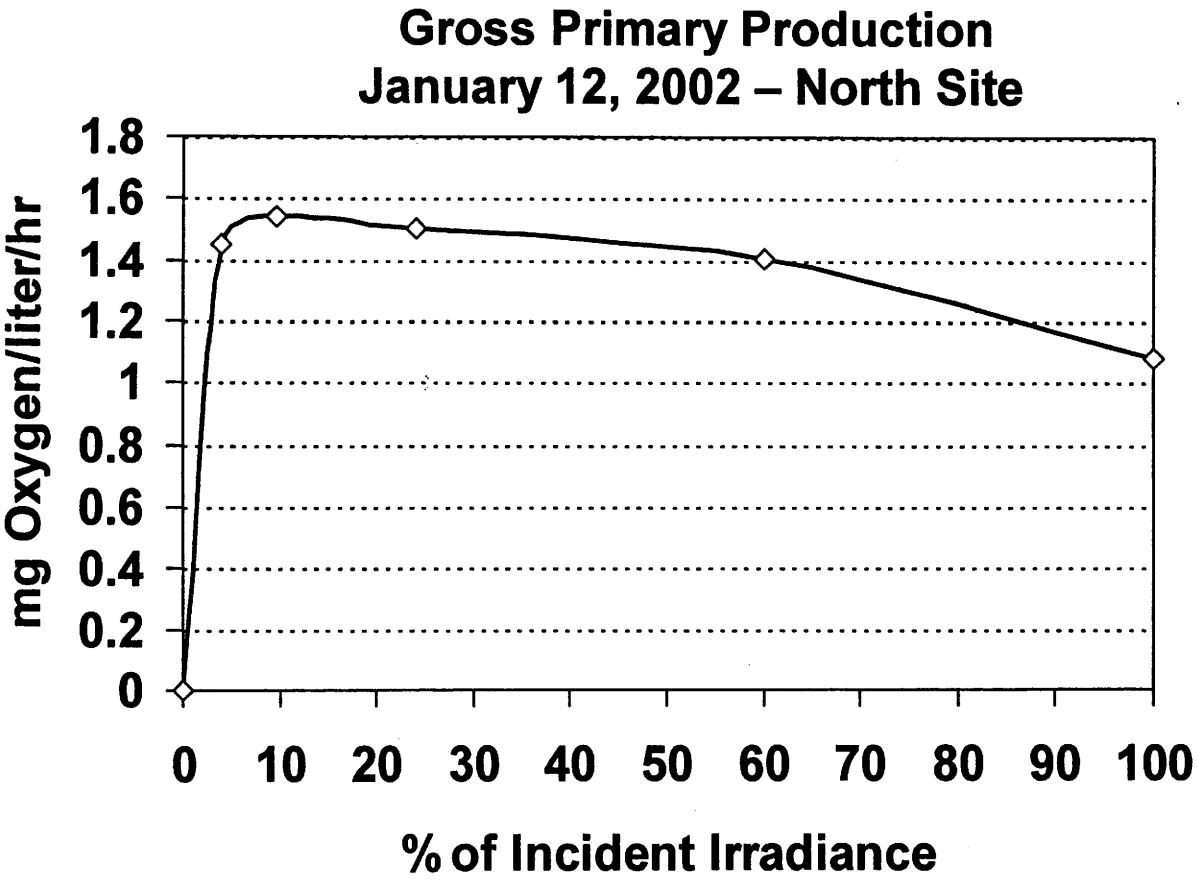

Gross Primary Production
July 9, 2002 – South Site
mg Oxygen/liter/hr
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

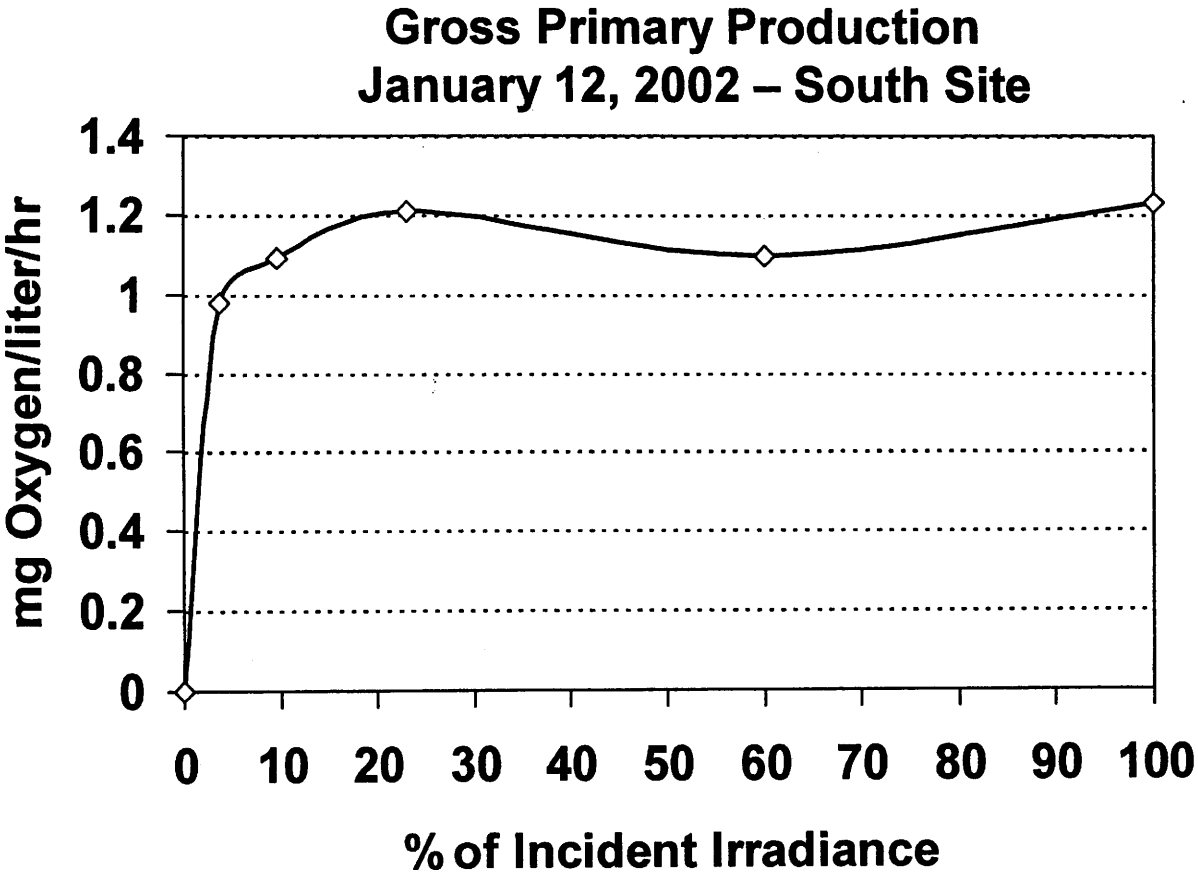

Gross Primary Production
October 12, 2001 – North Site
mg Oxygen/liter/hr
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

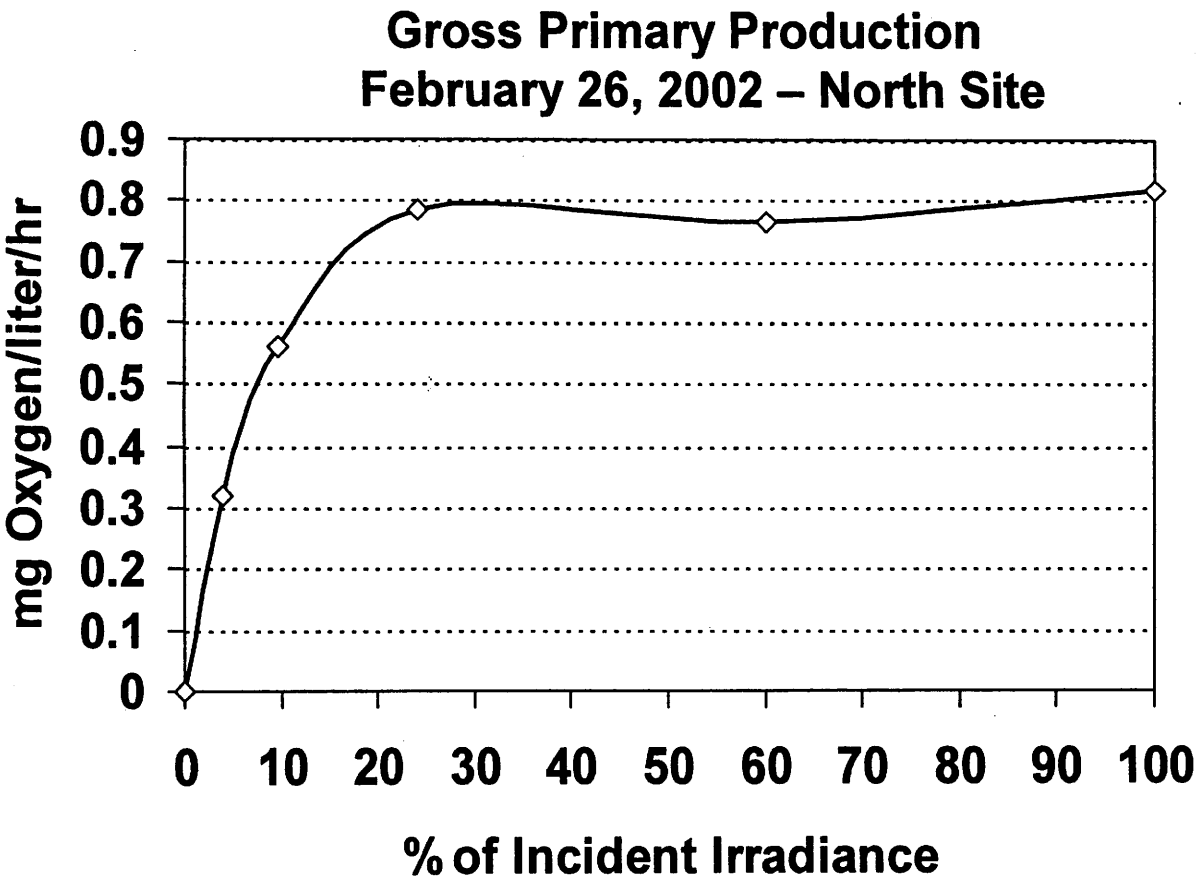

Gross Primary Production
October 12, 2001 – South Site
mg Oxygen/liter/hr
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

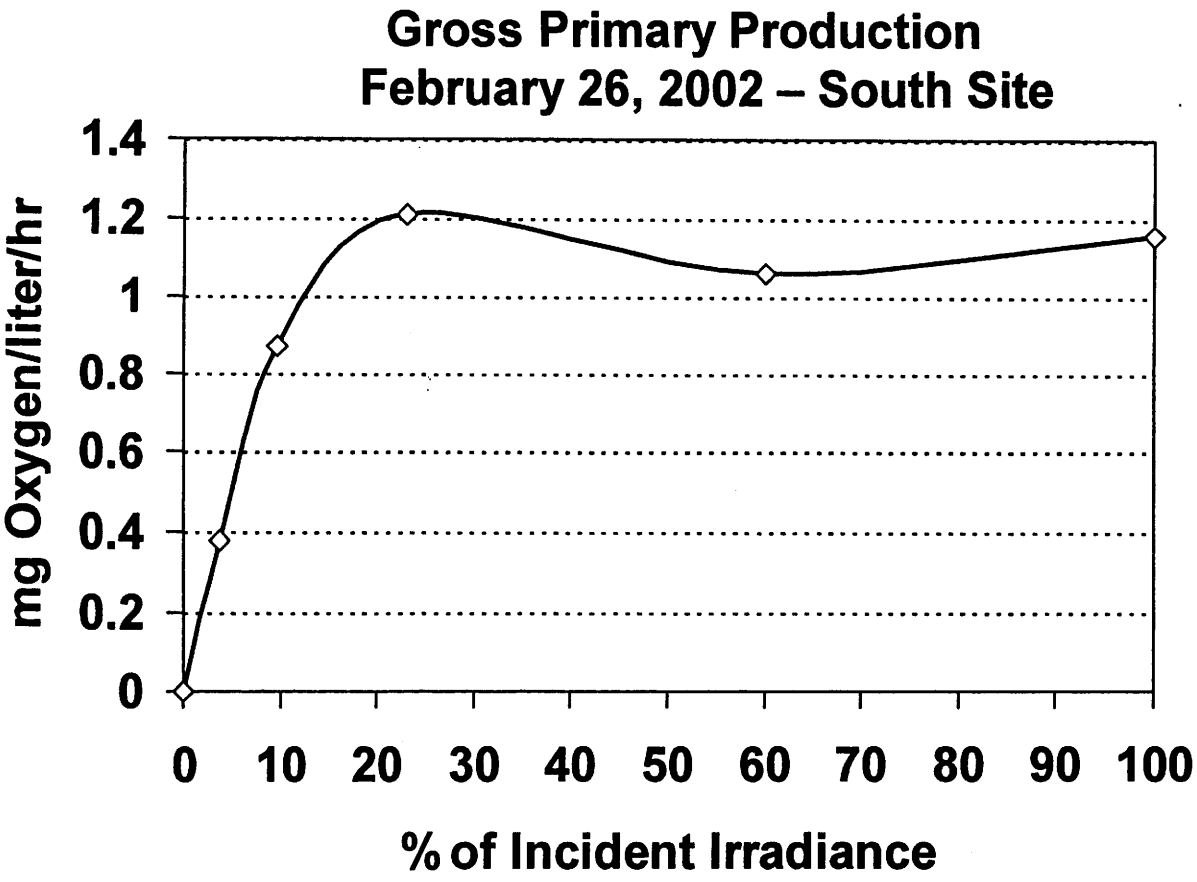

Gross Primary Production
November 12, 2001 – North Site
mg Oxygen/liter/hr
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

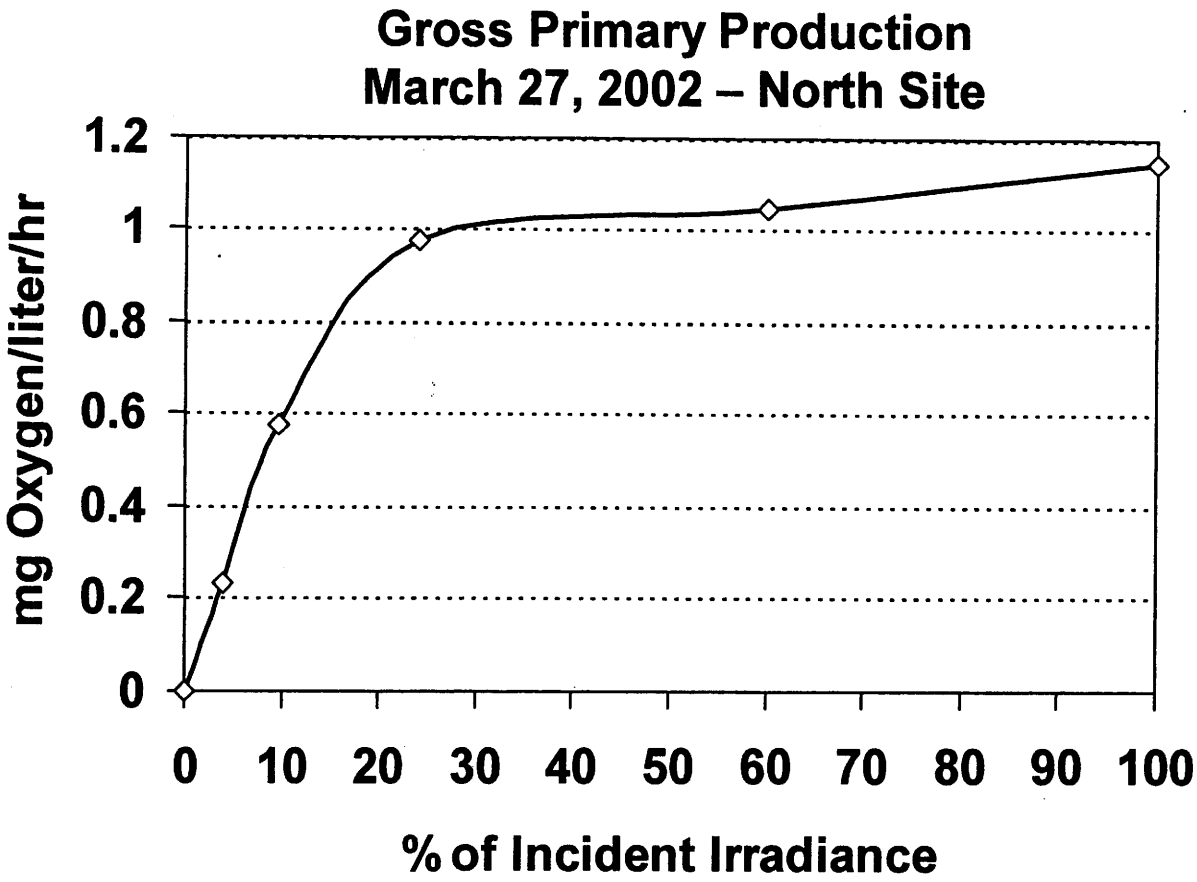

Gross Primary Production
November 12, 2001 – South Site
mg Oxygen/liter/hr
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

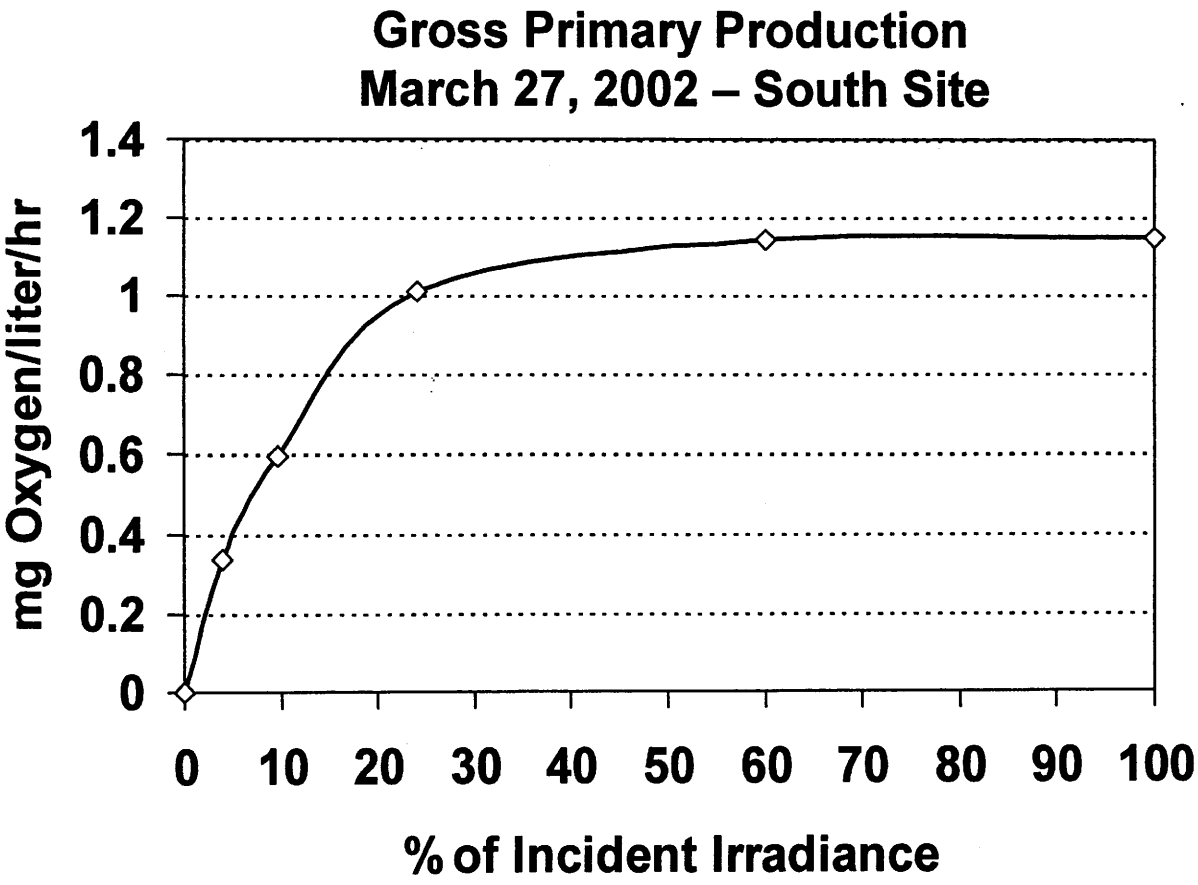

Gross Primary Production
January 12, 2002 – North Site
mg Oxygen/liter/hr
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance


Gross Primary Production
January 12, 2002 – South Site
mg Oxygen/liter/hr
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

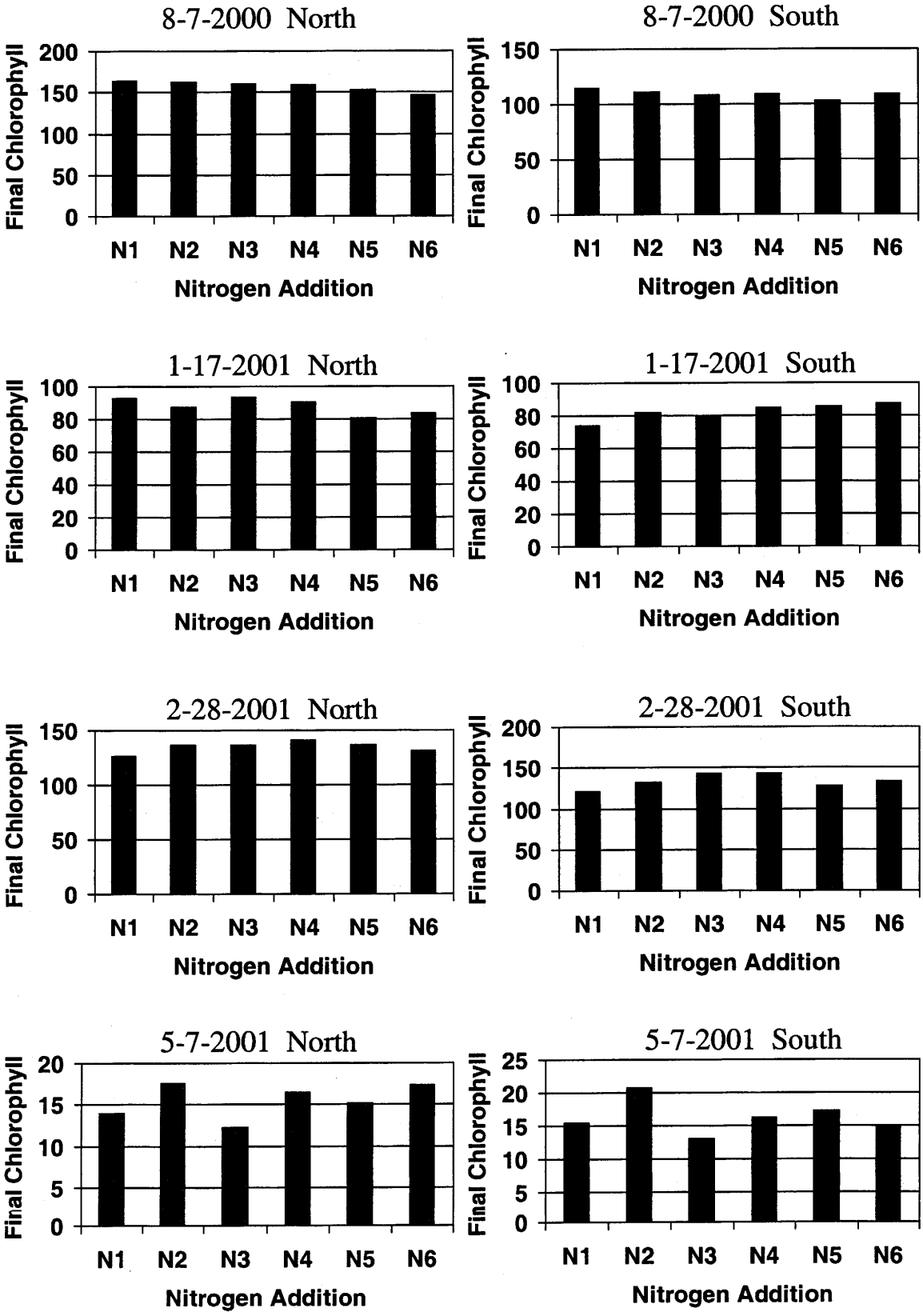

Gross Primary Production
February 26, 2002 – North Site
mg Oxygen/liter/hr
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance


Gross Primary Production
February 26, 2002 – South Site
mg Oxygen/liter/hr
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

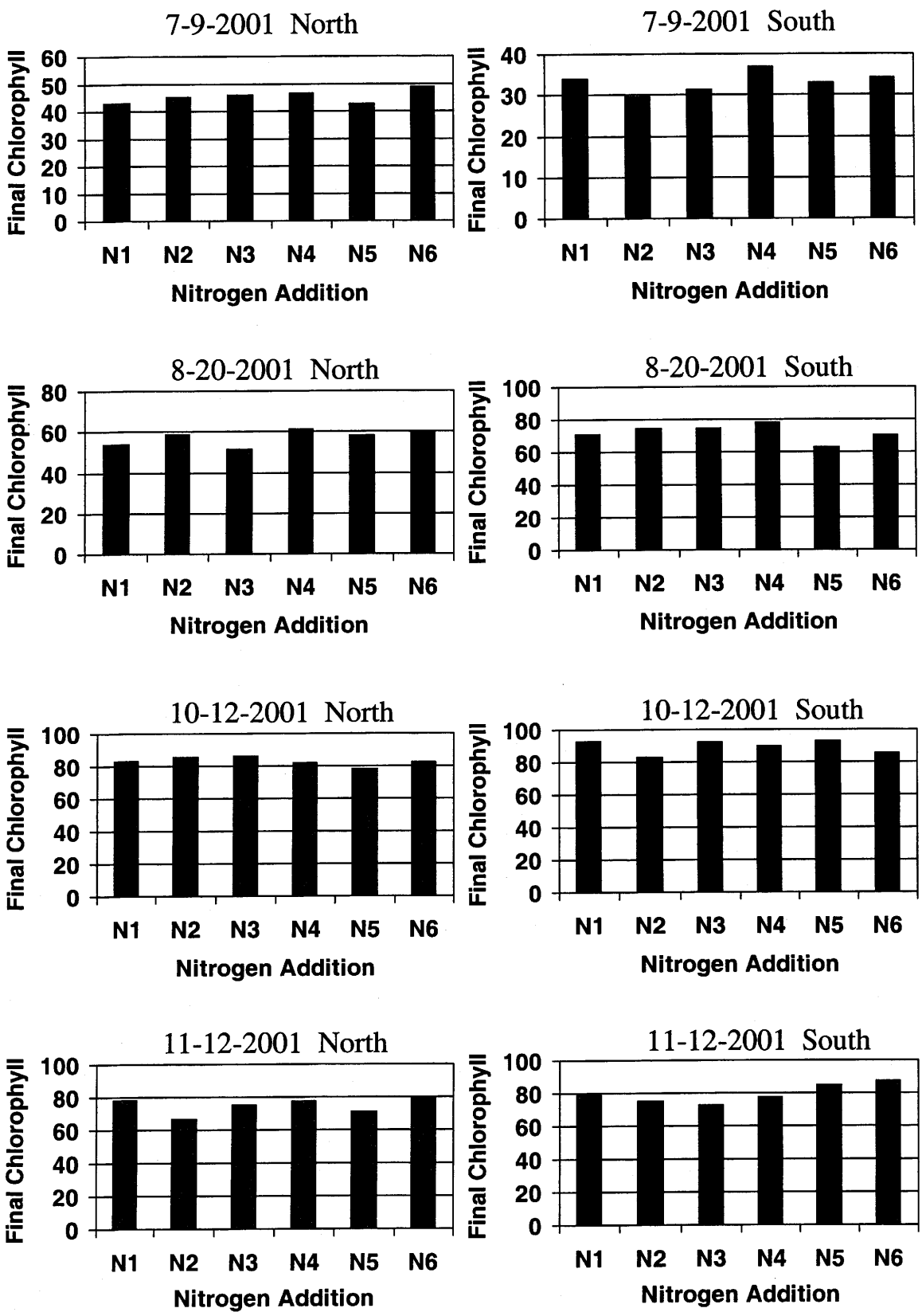

Gross Primary Production
March 27, 2002 – North Site
mg Oxygen/liter/hr
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100
% of Incident Irradiance


Gross Primary Production
March 27, 2002 – South Site
mg Oxygen/liter/hr
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90 100
% of Incident Irradiance

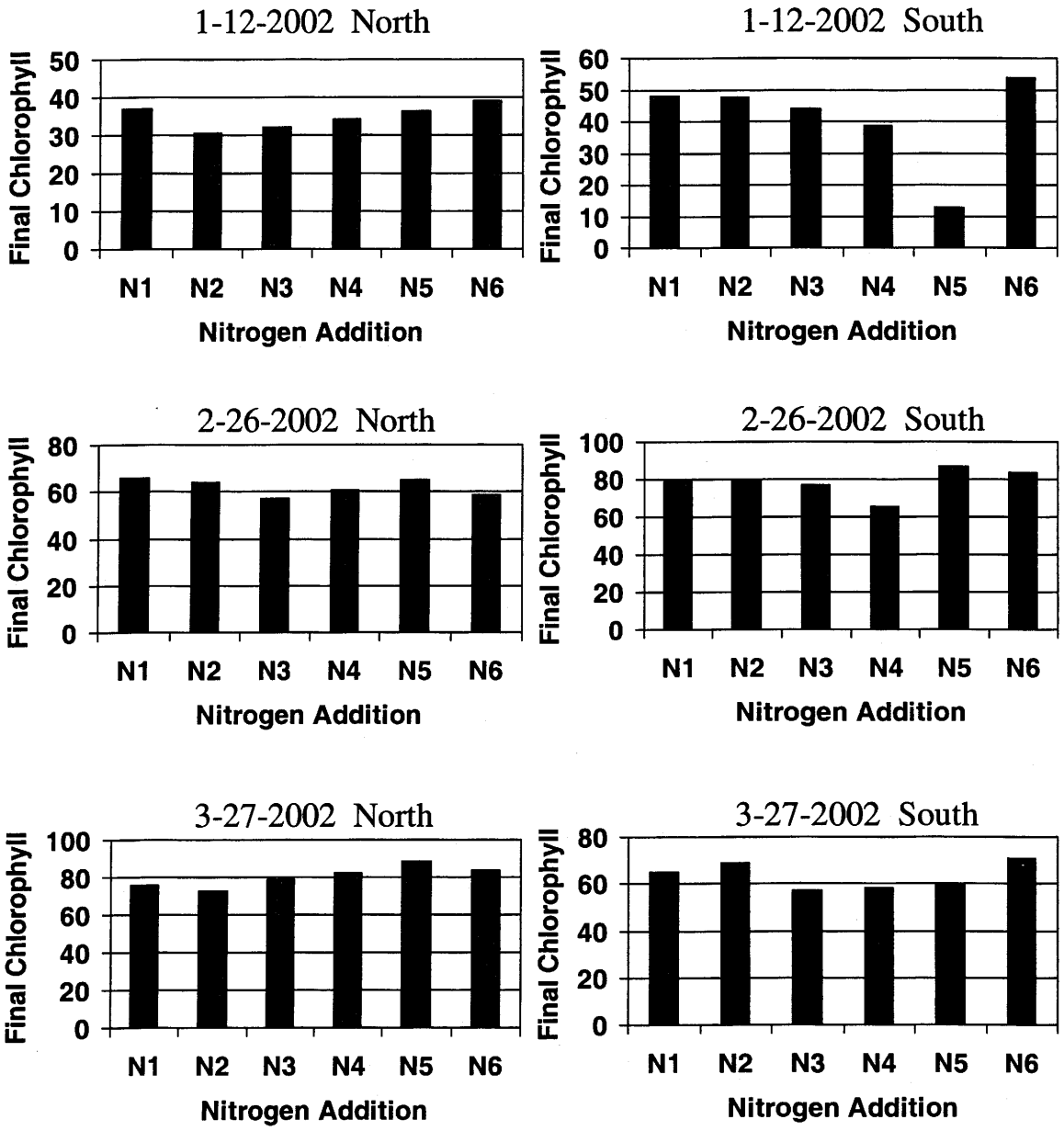
Appendix 5. Response of phytoplankton standing crop to the addition of six different concentrations of nitrogen spike. Chlorophyll is given as μg/liter. Values for 8-7-2000 And 2-28-2001 are based on fluorescence values, while the remainder are based on extracted chlorophyll values (corrected for phaeophytin). N1 is the mean of two replicates.



Appendix 5, continued



Appendix 5, continued



Appendix 6. Comparison of phytoplankton biovolumes (million cubic microns/ml) for the final day of nutrient limitation bioassays. The eight experiments included in these analyses were all from the south sampling site.

	Initial			Final – Control			Final - +NPSi		
Date	Total	Cyano	Diatoms	Total	Cyano	Diatom	Total	Cyano	Diatom
1-17-01	16.7	14.3	2.1	14.3	10.4	3.8	15.0	13.9	1.8
5-7-01	17.8	16.9	0.7	7.7	5.1	2.6	5.4	1.6	1.6
7-9-01	12.1	10.0	1.7	14.3	12.8	1.5	8.6	6.4	2.1
8-20-01	10.2	8.7	1.4	11.3	10.7	0.6	9.3	6.6	2.6
11-12-01	16.5	13.6	2.7	11.8	11.4	0.2	11.8	7.3	4.5
1-12-02	11.0	9.2	1.6	20.3	16.5	3.7	10.9	9.1	1.7
2-26-02	15.6	14.2	0.9	14.3	13.5	0.8	7.1	5.0	2.1
3-27-02	11.9	10.8	0.9	12.8	12.4	0.3	89.9	87.2	2.7

Appendix 7: Lake Griffin Phytoplankton Species List (Code)

Division Chlorophyta (100s & 200s)
- Ankistrodesmus convolutus (101.01)
  - falcatus (101.02)
  - nannosolene (101.03)
  - sp. (101.00)
- Chlamydomonas (103)
- Chlorogonium (104)
- Closterium (106)
- Coelastrum sphaericum (107.02)
- Cosmarium (108)
- Crucigenia crucifera (109.02)
  - tetrapedia (109.01)
- Dictyosphaerium ehrenbergianum (110.02)
- Elakatothrix (112)
- Golenkinia (115)
- Kirchneriella contorta (117.02)
  - subsolitaria (117.05)
  - sp. (117.00)
- Oocystis (122)
- Pediastrum boryanum var. longicorne (124.13)
  - duplex var. gracilimum (124.02)
  - duplex var. reticulatum (124.07)
  - simplex var. duodenarium (124.04)
- Scenedesmus acuminatus (127.01)
  - bijuga (127.05, 127.06)
  - dimorphus (127.14)
  - quadricauda (127.03, 127.04)
  - quadricauda var. maximus (127.13)
  - sp. (127.00)
- Schroederia (128)
- Selenastrum minutum (126.03)
- Staurastrum (129)
- Tetraedron gracile (130.09)
  - incus (130.06)
  - minimum (130.02)
- Sphaerellopsis (145)
- unidentified forms $\leq 5\mu$ (295.00)

Division Euglenophyta (300s)
- Euglena (300)

Division Pyrrhophyta (400s)
armored dinoflagellates (400.00)

Ceratium hirundinella (402.01)

Division Cryptophyta (500s)

Division Chrysophyta (600s)
non-diatoms (600-609)
diatoms
centrics spp. 5-15µ (610.04–610.06)
Melosira/ Aulacoseira (613.00)
granulata var. angustissima (613.02)
Pennates spp. (630s)
Navicula (651)
Plagiotropis (665)

Cyanobacteria (700s)
Anabaena circinalis (700.01)
spp. (700.00)
Aphanothece (704)
Chroococcus prescotti (706.05)
spp. (706)
Cylindrospermopsis (722)
cf Dactylococcopsis (738)
Merismopedia tenuissima (710.01)
spp. (710)
Microcystis aeruginosa (711.03)
incerta (711.01)
Oscillatoria (714)
Raphidiopsis (715)
Un-identified singles ~ 5µ (718.02)
Un-identified singles and doubles $\leq 2\mu$ (718.03)

Appendix 8. Quality Assurance/Quality Control Report.

Field Collections, Preservation and Storage of Samples

All sample collections were carried out according to the methods prescribed in our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157) and the Project Quality Assurance Plan (QAPP #200064). Samples were processed and kept under chilled conditions in the field according to our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157) and the Project Quality Assurance Plan (QAPP #200064). Samples were returned to the laboratory within the same day as sampling and stored in accordance with the guidelines set forth in our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157) and the Project Quality Assurance Plan (QAPP #200064).

Analyses of Samples

All chemical analyses were carried out within the time frame prescribed for each analyte in our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157) and the Project Quality Assurance Plan (QAPP #200064).

All of the chemical analyses were performed in accordance with our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157) and the Project Quality Assurance Plan (QAPP #200064). The phosphorus and silica analyses were carried out using spectrophotometric analyses of digested and undigested water samples. Nitrogen analyses were performed on a Braun-Lubbe autoanalyzer. Samples were run against a standard curve generated from designated dilutions of standard solutions. Standard curves had to meet strict quality criteria before they were used, i.e. r^2 >0.95 and y-intercepts within accuracy targets of the origin. Check standards (matrix spikes), reagent blanks and duplicate samples were performed every ten samples. The values obtained for the standards, blanks and duplicates associated with all of the chemical analyses fell within the accuracy targets set for each of the parameters tested, as specified below. If the results for these standard and blanks fell outside of the prescribed

targets the results for that particular analytical run were rejected and the samples re-run. If sufficient sample was not available for a re-run a missing value, '.', was placed in the data table. QC check Standards had precision targets with an $R^2 = 0.95$ of the standard curve.

Specific Methods Used For Chemical Analyses That Fell Under QA/QC

Phosphorus samples were processed according to the methods listed in Table 5.2 of our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157), dated 8/28/98. Phosphorus detection methods followed the procedures described in section SM 4500P, B.5 of Standard Methods (APHA 1989). The matrix for this procedure is H2O with a precision target of 25% to 10%. Accuracy Targets are between 85% to 109% and the method detection limit is 0.002mg/L.

Nitrogen samples were processed according to the methods listed in Table 5.2 of our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157), dated 8/28/98. Nitrogen detection methods followed the procedures described in section SM 4500NO^{3-}F of Standard Methods (APHA 1989). The matrix for this procedure is H2O with a precision target of 10% to 25%. Accuracy Targets are between 80 and 120% and the method detection limit is 0.07mg/L.

Silica samples were processed according to the methods listed in Table 5.2 of our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157), dated 8/28/98. Silica detection methods followed the procedures described in section SM 4500Si-F of Standard Methods (APHA 1989). The matrix for this procedure is H2O with a precision target of 10% to 25%. Accuracy Targets are between 80 and 120% and the method detection limit is 0.047mg/L.

Chlorophyll samples were processed according to the methods listed in Table 5.2 of our DEP-approved Comprehensive Quality Assurance/Quality Control Plan (#910157), dated 8/28/98. Chlorophyll detection methods followed the procedures described in section SM 1002G of Standard Methods (APHA 1989). The matrix for this procedure is H2O with a precision target of 10%. Accuracy Targets are between 90 and 110% and the method detection limit is 0.01mg/L.