A Survey of Phytoplankton Density in Three Aquatic Environments

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Genifer Maree Tarkowski

University of Notre Dame Environmental Research Center
Dr. Ronald Hellenthal

Abstract

The change in the primary productivity of phytoplankton between June and July was investigated in three aquatic environments located on the University of Notre Dame's Environmental Research Center property. Brown Lake, Crampton Lake and Forest Service Bog were the primary focuses of the this study. Each of these habitats has different physical and chemical characteristics. Dissolved oxygen profiles, temperature delineations, chemical and physical parameters of each habitat were determined by a team of three students. Assessments of the phytoplankton, zooplankton and chaoborus communities were completed individually. This study defines the dominant species of phytoplankton within each habitat. The relationships between the types of phytoplankton present and the habitats in which they thrive were also assessed.

Introduction

The majority of limnetic communities investigated at the University of Notre Dame's Environmental Research Center (U.N.D.E.R.C.) are planktonic (Berg and St. Amand 1995). As organisms subject to movement by currents, plankton can be divided into two subdivisions: phytoplankton and zooplankton. Phytoplankton, autotrophic plankton, are microscopic algae that act as the basis of the food chain. They use sunlight as energy to fix and store inorganic carbon. Over half of the world's total primary production is created by phytoplankton (Darley 1982).

The two most important requirements for algal production are light and nutrients. Phytoplankton require carbon, nitrogen and phosphorous to maintain their metabolism in conjunction with hydrogen, oxygen, calcium, manganese, iron and sodium. Other nutrients such as copper, zinc, silicon, vitamin B12, thiamine and biotin are active in cell processes, but are linked to species composition rather than productivity (Darley 1982).

In freshwater ecosystems, the primary limiting nutrients are phosphorus and nitrogen (Berg and St. Amand 1995). An increase in available phosphorous stimulates growth of phytoplankton (Vanni 1987). The level of phosphorus within a system is related to phytoplankton biomass as measured by the abundance of chlorophyll-a (Sarnelle 1992). Determination of the availability of limiting nutrients aids in characterizing the productivity of a freshwater habitat.

There are several theories involving the primary production of phytoplankton. Bergquist and Carpenter (1986) inferred that increasing the rate of nutrient cycling enables algae to fix more carbon per unit nutrient. Further investigations conducted by Hansson and Carpenter (1993) demonstrated that nutrient levels influence food chain length and the nature of trophic cascading. The activity of phytoplankton as primary producers reflects the nutrient levels and characterizes the ecosystems in which the algae live.

There is a direct correlation between the photosynthetic capacity of phytoplankton populations and the trophic status of the aquatic habitat in which samples are taken. The ecological requirements for phytoplankton growth are located within the euphotic surface waters. Suspended photoautotrophic cells must receive light to promote growth. With increasing depth, the intensity of light diminishes, thus limiting suitable space for phytoplankton to thrive. Vertical mixing from depths below the euphotic zone serves to replenish surface waters with nutrients (Darley 1992). The productivity an aquatic environment supports can be assessed by determining the concentration of dissolved oxygen, the temperature profile and abundance of nutrients. The productivity of phytoplankton can be used to evaluate different aquatic environment's ability to sustain primary producers.

Methods and Materials

Assessment of the presence and productivity of phytoplankton was conducted on Brown Lake, Crampton Lake and Forest Service Bog. Twenty-four hour sampling periods were preformed three times during May through July to determine what species of phytoplankton inhabited each environment. Samples were collected on June 20-21, July 2-3 and July 13-14. On each of these days, phytoplankton samples were collected every two hours using a Kemmerer sampler at a depth of one meter below the water's surface. Two 500ml water samples from a depth of one meter were transferred into dark labeled plastic containers along with approximately 2ml of formalin.

At the laboratory each sample was processed to concentrate the phytoplankton. First a sample was filtered through a Wisconsin net. The sample within the net was then dispensed into a 50ml centrifuge tube using distilled water. Each tube was centrifuged for ten minutes. The top 40ml of solution was siphoned off. The remaining 10ml was transferred into a labeled one dram vial. Finally, one drop of Lugol's solution was added to each vial to prevent decomposition.

Analysis of the phytoplankton was conducted by placing 1ml of solution from a dram vial into a Segdwick-Rafter counting chamber. Each chamber was viewed under a microscope and the most abundant types of algae were classified and counted. Algae identification manuals were used extensively in identifying the types of phytoplankton present (Prescott 1978).

The water analysis of each aquatic environment was conducted within seven days of a twenty-four hour sampling period. On this day, the chemical parameters, secchi depth, a temperature profile and a dissolved oxygen profile were constructed for each Lake. Water chemistry samples were collected using the Kemmerer sampler. Two 500ml samples were taken at a depth of one meter and two more 500ml samples were collected from one meter above the Lake's bottom. These four samples were used to characterize the water quality of the aquatic environments. The HACH chemistry kit was used to asses the levels of phosphate, ammonia, sulfate and nitrate within the four samples.

The secchi depth of each Lake was calculated to determine the turbidity of the water. A white disk was lowered into the water until it was barely visible. The distance of the disk from the surface of the water was determined and recorded in meters.

Water temperature and dissolved oxygen profiles were measured using an electronic probe. The apparatus was calibrated to the air temperature and then lowered into the water at one meter increments. At each meter the water temperature and dissolved oxygen concentration were recorded.

The abundance of chlorophyll-a was measured in late July. Water samples were collected from each Lake using the Kemmerer sampler at a depth of one meter. The water was then vacuum filtered using a membrane filter. The amount of water that was filtered varied from 200ml to 500ml and depended on the abundance of phytoplankton present. The filter was removed and placed in a 15ml centrifuge tube with 10ml of acetone. The tube was then gently shaken to promote suspension of the chlorophyll. Each centrifuge tube was covered with aluminum foil and placed in the refrigerator for twenty-four hours. After incubation, each tube was centrifuged for ten minutes. The bottom portion of each centrifuge tube was pipetted out and placed in a small glass cuvet. A cuvet filled with acetone was used as the blank. The absorbance of each sample was measured using a spectrophotometer. During the entire process, all flourescent lights were turned off to prevent decomposition of the sample.

A team of three students generated maps for Brown Lake, Crampton Lake and Forest Service Bog. Each map was developed by using electronic sonar equipment , a trolling motor and rough sketches. Dr. Hellenthal used the computer program Canvas to process our data into the maps located in the appendix.

Results

There were various species of phytoplankton thriving in Brown Lake, Crampton Lake and Forest Service Bog. When viewing the cells, approximately fifteen predominant species of phytoplankton, Tables 1, 2 and 3, were identified and counted for each aquatic environment. Upon analysis of the raw data, two to five inherently dominate species of phytoplankton were selected to characterize each habitat. The dominant species were analyzed in terms of their density over each twenty-four hour sampling period and their total change in density between sampling periods.

Figures 1 depicts the density of the dominant phytoplankton in each habitat. Brown Lake had the most densely populated phytoplankton community. The prominent phytoplankton varied from *Dinobyron, Anabaena* and *Fragilaria* and was dependent on the time of sampling. Crampton Lake was the least productive of each of the habitats, but sustained a wide variety of phytoplankton. Across the three sampling dates *Anabaena, Crucigenia, Dinobyron, Merismopedia* and/or *Oscillatoria* were present. Forest Service Bog's phytoplankton population was not as dense as that of Brown Lake, but was larger then Crampton Lake. Two species, Dinobyron and Merismopedia were predominant throughout each sampling period. The dominant species of phytoplankton characterized each habitat.

Table 4 presents the results of the water quality tests preformed on each aquatic habitat. Although four test were conducted, only the phosphate and nitrate data was examined in relation to each aquatic environment and the phytoplankton population it supports. Brown Lake with its dense phytoplankton community experienced high levels of phosphate and nitrate that were followed by sharp reductions of nutrients. The highest level of phosphate was recorded around the second sampling period, while high levels of nitrate were evident in the first sampling set. The nutrient level trends were observed in both the one meter and four meter depths. The secchi indicator reached its deepest level at the approximate time of the second sampling period. Crampton Lake's concentration of phosphate and nitrate increased as the summer progressed. From the first sampling era to the third, the levels of phosphate and nitrate increased at the depths of one meter and five meters. The turbidity of the water decreased with time. The secchi indicator recorded lower depths later in the summer. The water quality of Forest Service Bog was dependent on the date the sample was taken. The levels of phosphate and nitrate were at their highest point during the first sampling session. Concentrations of both phosphate and nitrate declined at approximately the second session, then increased slightly at the last date of analysis. The concentration of phosphate and nitrate trends were consistent from a depth of one meter and three meters. The secchi depth reached its lowest point at the first sampling set and progressively declined thereafter. All nutrient tests were conducted with one replicate. Therefore the results of Table 4 reflected the average concentration of nutrients.

The dissolved oxygen and temperature profiles were constructed for a single habitat on a particular day. Figures 2, 3 and 4 were constructed for Brown Lake, Crampton Lake and Forest Service Bog. Within seven days of each sampling period, these analysis were preformed. Due to unforeseeable circumstances the data was unable to be collected for Brown Lake on June 16, 1995.

The results of the chlorophyll-a analysis, Table 4, reflected the relative abundance found at a depth of one meter. Analysis of chlorophyll-a was conducted on July 22-24,1995. The data demonstrated that Brown Lake had the highest concentration of chlorophyll-a. Crampton Lake had a higher level of chlorophyll-a than Forest Service Bog. The level of chlorophyll-a was directly related to the density of phytoplankton at a depth of one meter.

The maps located in the appendix were constructed by Nick Honkamp, Ted Stets and Genifer Tarkowski. By sonar mapping each aquatic environment the depth of each habitat was determined. Crampton Lake was the deepest habitat measuring fifty feet deep. Brown Lake's deepest point reached a depth of sixteen feet, while Forest Service Bog's maximum depth was twelve feet. Samples for water quality and phytoplankton identification were taken near the deepest portion of the habitat as indicated on the maps.

Upon analysis of the chemical and physical results each habitat was characterized. Brown Lake with its high concentration of phosphate and nitrate, was able to support a large population of phytoplankton. Forest Service Bog was second in terms of its abundance of phytoplankton. The amounts of limiting nutrients, more turbid water and shallower depth made it a relatively productive phytoplankton environment. The least productive habitat was Crampton Lake. With lower nutrient availability, a vast amount of phytoplankton were unable to thrive. The results of each individual feature aided in delineating each aquatic habitat.

Discussion

Phytoplankton are microscopic algae that populate shallow depths of aquatic environments. As plants, phytoplankton are dependent on sunlight to provide energy for photosynthesis and were free floating organisms. Phosphate and nitrate were the limiting nutrients that determined the growth and productivity of algae (Sarnelle 1992). The determination of the principal phytoplankton species present in three aquatic environments aided in characterizing the basic level of three trophic systems.

The nutrients available to each system determine the productivity of each habitat. Brown Lake possessed the highest levels of phosphate and nitrate during each sampling period when contrasted to the nutrient levels in Crampton Lake and Forest Service Bog. The high density of phytoplankton in Brown Lake was directly correlated to the level of limiting nutrients available. The lower densities of phytoplankton in the other habitats corresponded to the concentration of phosphate and nitrate. The trend in the nutrient availability and phytoplankton density was witnessed during each sampling period and with each aquatic environment. The results are consistent with Vanni's (1987) conclusions that nutrient enrichment causes phytoplankton density to increase.

The alteration of different phytoplankton species as the most predominate over the coarse of three sampling eras was related to nutrient availability. Several ecologists have suggested that increasing the input of phosphorus would elevate the phytoplankton standing crop. The increase in phytoplankton abundance result in the possibility of certain species thriving better then others (Vanni 1987). Over time as each habitat's nutrient profile changed, the dominant species of algae also changed. Brown Lake initially had high densities of *Dinobyron* and *Anabaena* to later be replaced by *Fragilaria*. *Dinobyron, Anabaena* and *Oscillatoria* were the dominant phytoplankton during the first sampling period for Crampton Lake. These species remained prominent in the water column, but decreased in density as *Crucigenia* and *Merismopedia* increased their abundance over time. Forest Service Bog was at first dominated by *Dinobyron,* which was later replaced by the rise in density of *Merismopedia.* Each habitat had fluctuating nutrient availability that placed one species of phytoplankton at an advantage to others.

Phytoplankton abundance was directly related to nutrient availability and trophic level interaction. As primary producers, phytoplankton are at the basis of the food web. Zooplankton, microscopic crustaceans, are the primary predators of phytoplankton. The grazing capacities of zooplankton influenced the abundance and community structure of phytoplankton (Vanni 1987). Nick Honkamp investigated the migratory patterns of zooplankton in Brown Lake, Crampton Lake and Forest Service Bog. Figures 8, 9 and 10 illustrated the dominant species of zooplankton as found by Honkamp. When compared to the twenty-four hour plots of phytoplankton abundance (figures 5, 6 and 7) for each habitat, a general pattern appears. Zooplankton had an impact on the abundance of possible types of phytoplankton collected. At peak hours of zooplankton migration to swallower depths, phytoplankton were less abundant. Migratory patterns varied for each habitat and sampling period, but changes in the zooplankton abundance affected the species of phytoplankton present. Vanni (1987) denoted that zooplankton abundance and size structure had a substantial influence on the phytoplankton community. The presence of zooplankton in each aquatic habitat affected the density and species of phytoplankton populating each environment.

The identity of each lake was further supported by the dissolved oxygen and chlorophyll-a data. The percent saturation of dissolved oxygen was greatest in Brown Lake. From zero to two meters depth, the water was often supersaturated or highly saturated. Crampton Lake and Forest Service Bog had percentages of saturation varying from eighty to one hundred percent, but their levels were never as high as those of Brown Lake. The results suggested that the abundance of phytoplankton was greatest in Brown Lake. Phytoplankton preform photosynthesis, therefore the high levels of dissolved oxygen was produced by the algae. The chlorophyll-a results were mirror images of the dissolved oxygen data. The largest abundance of phytoplankton would yield the greatest amount of chlorophyll-a. The dissolved oxygen and chlorophyll-a-a data supported the characterization of Brown Lake, Forest Service Bog and Crampton Lake as the order of phytoplankton productivity, respectfully.

The chemical and physical parameters of an aquatic habitat determine the basis of the trophic system. Analysis of the level of nutrients, dissolved oxygen and physical characteristics of three habitats aided in explaining each environment's phytoplankton population. The conditions for phytoplankton growth of Brown Lake, Crampton Lake and Forest Service Bog supported unique planktonic communities.

Acknowledgment

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Table 1: Species of Phytoplankton Identified in Brown Lake

06/20/95	07/02/95	07/13/95
Dinobyron	Dinobyron	Dinobyron
Anabaena	Anabaena	Anabaena
Astrionella	Astrionella	Astrinella
Oscillatoria	Oscillatoria	Oscillatoria
Fragilaria	Fragilaria	Fragilaria
Staurastrum	Staurastrum	Staurastrum
Cosmarium	Cosmarium	Cosmarium
	Crucigenia	Lyngbya
	Ceratium	Ulothrix
	Lyngbya	
	Ulothrix	

Table 2: Species of Phytoplankton Identified in Crampton Lake

06/20/95	07/02/95	07/13/95
Dinobyron	Dinobyron	Dinobryon
Merismopedia	Merismopedia	Merismopedia
Anabaena	Anabaena	Anabaena
Astrionella	Astrionella	Astrionella
Oscillatoria	Oscillatoria	Oscillatoria
Fragilaria	Fragilaria	Fragilaria
Staurastrum	Staurastrum	Staurastrum
Cosmarium	Cosmarium	Cosmarium
	Crucigenia	Crucigenia
		Pediastrum

Table 3: Species of Phytoplankton Identified in Forest Service Bog

06/20/95	07/02/95	07/13/95
Dinobyron	Dinobryon	Dinobryon
Merismopedia	Merismopedia	Merismopedia
Anabaena	Anabaena	Oscillatoria
Oscillatoria	Oscillatoria	Crucigenia
Fragilaria	Fragilaria	Cosmarium
Cosmarium	Crucigenia	
	Cosmarium	

Table 4: Water Quality of Three Aquatic Habitats

Brown Lake: 1/4 meters

	Secchi(m)	Nitrate	Ammonia	Phosphate	Sulfate	Chlorophyll-a
06/16/95	----	1.6/3.0	.05/.1	.1/.11	0/0	
06/28/95	1.7	.2/.4	.03/.21	1/1	.12/.04	
07/17/95	1.4	.3/0	.19/.52	.10/.10	0/0	4.25 mg/m3

Crampton Lake: 1/5 meters

	Secchi(m)	Nitrate	Ammonia	Phosphate	Sulfate	Chlorophyll-a
06/16/95	----	.1/.2	0/.07	0/0	0/0	
06/28/95	3.3	.5/.4	.08/.06	.05/.06	0/1	
07/17/95	3.5	.4/.4	.11/.29	.05/.04	0/1	1.50 mg/m3

Forest Service Bog: 1/3 meters

	Secchi(m)	Nitrate	Ammonia	Phosphate	Sulfate	Chlorophyll-a
06/16/95	2.5	.5/.2	.04/.06	.07/.07	.002/.005	
06/28/95	2.2	.3/.3	.02/.02	.02/.07	0/0	
07/17/95	2.0	.5/.4	.02/.2	.03/.04	0/0	1.00 mg/m3

Figure 1:
The Abundance of Predominant Phytoplankton in Three Aquatic Environment.

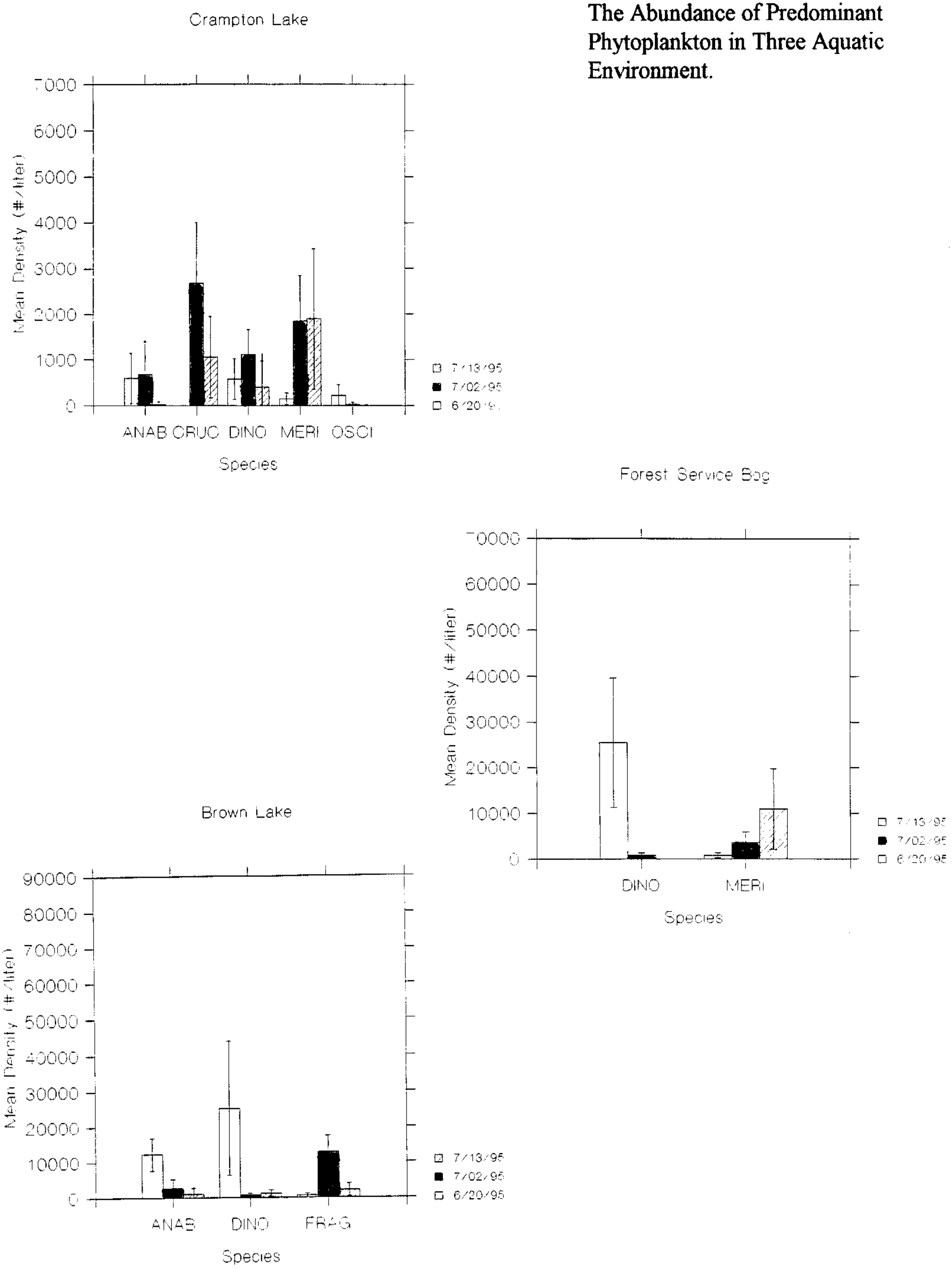
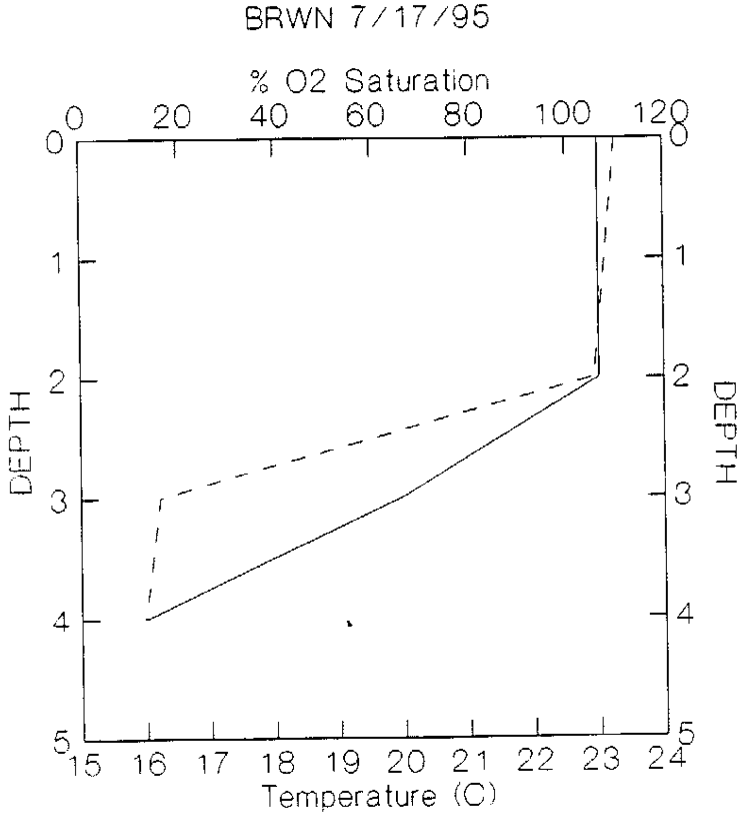


Figure 2 Dissolved Oxygen and Temperature Profiles for Brown Lake on Two Sampling Periods



Line = Temperture (C)
Dasshes = Disssolved Oxygen
Depth in meters

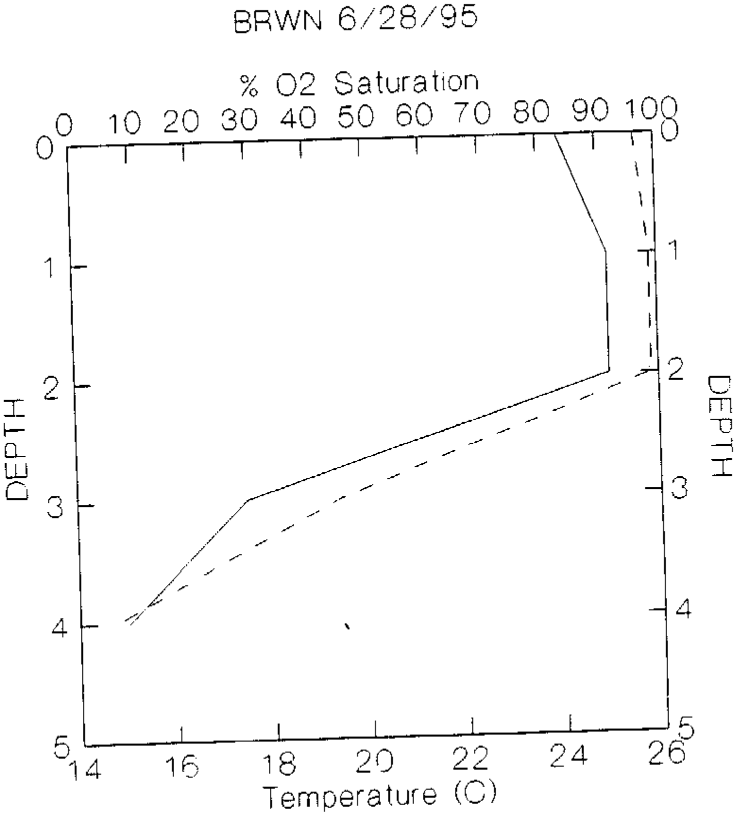
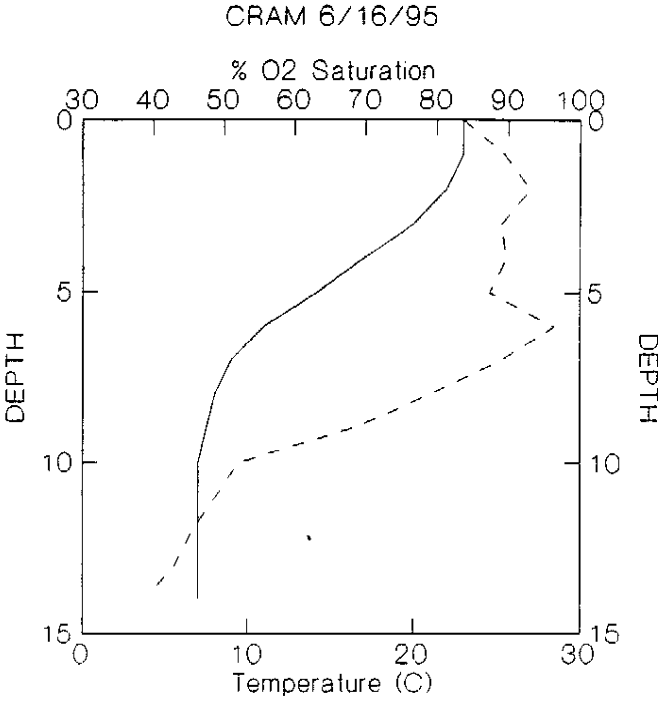
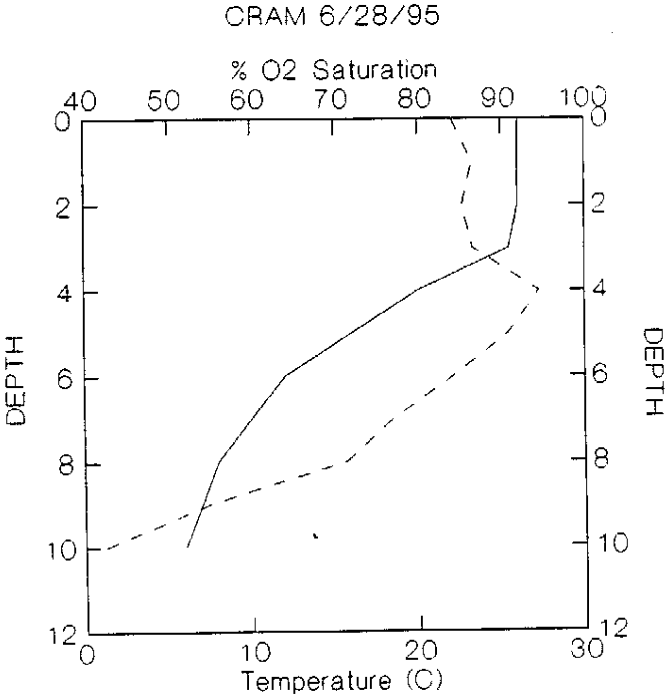
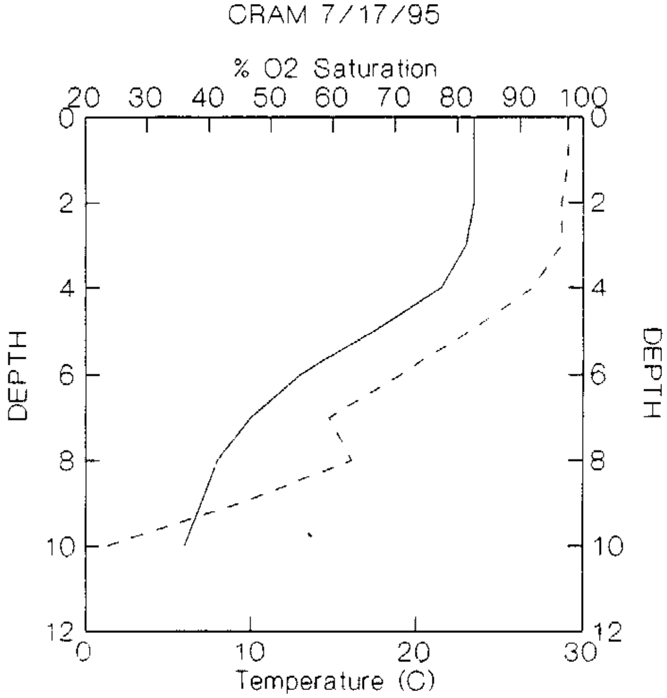


Figure 3:
Dissolved Oxygen and Termperture Profiles for Crampton Lake on Three Sampling Periods.

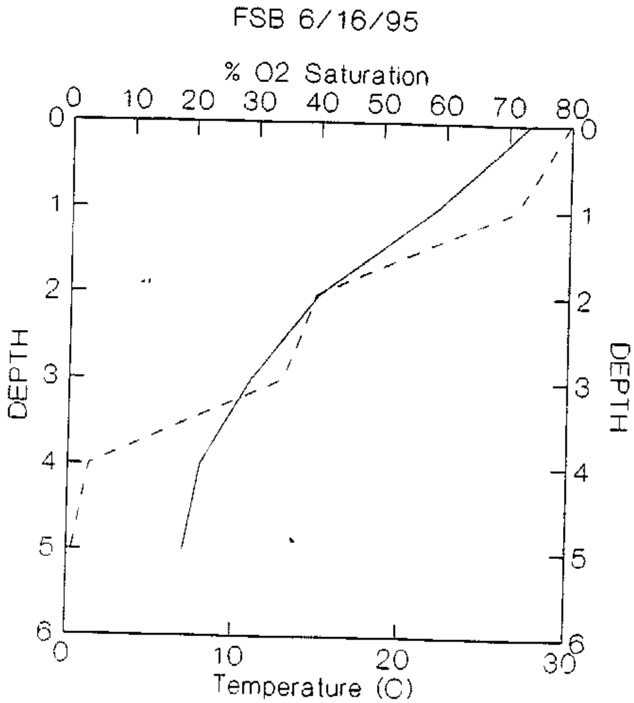


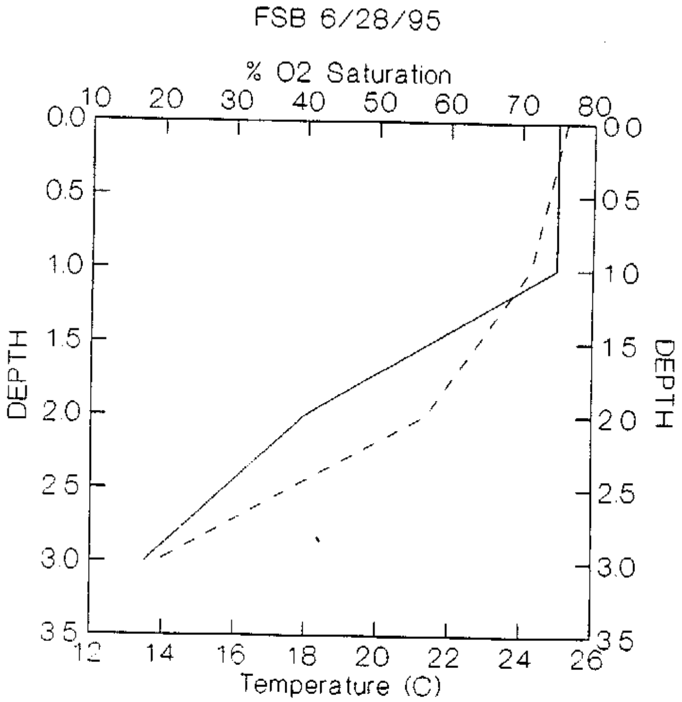


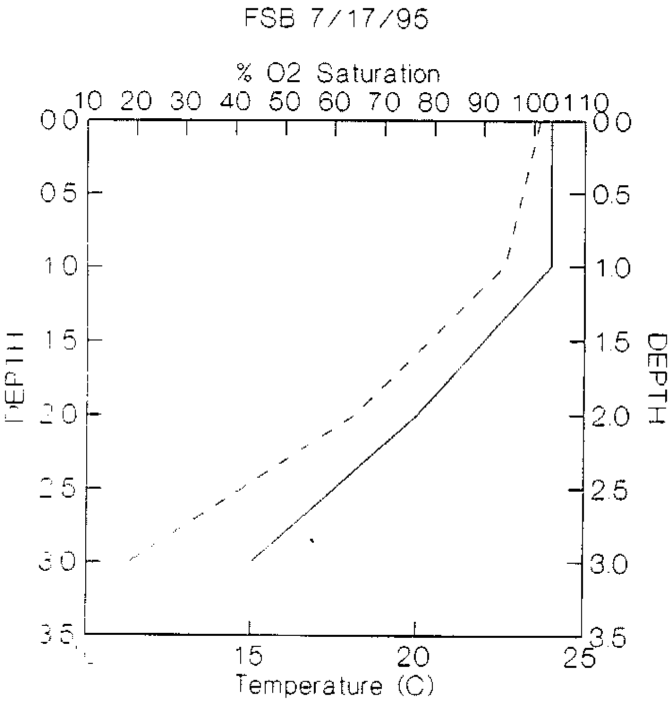


Line = Temperature (C)
Dashes = Dissolved Oxygen
Depth in meters

Figure 4:
Dissolved Oxygen and Termperature Profiles for Forest Service Bog on Three Sampling Periods.

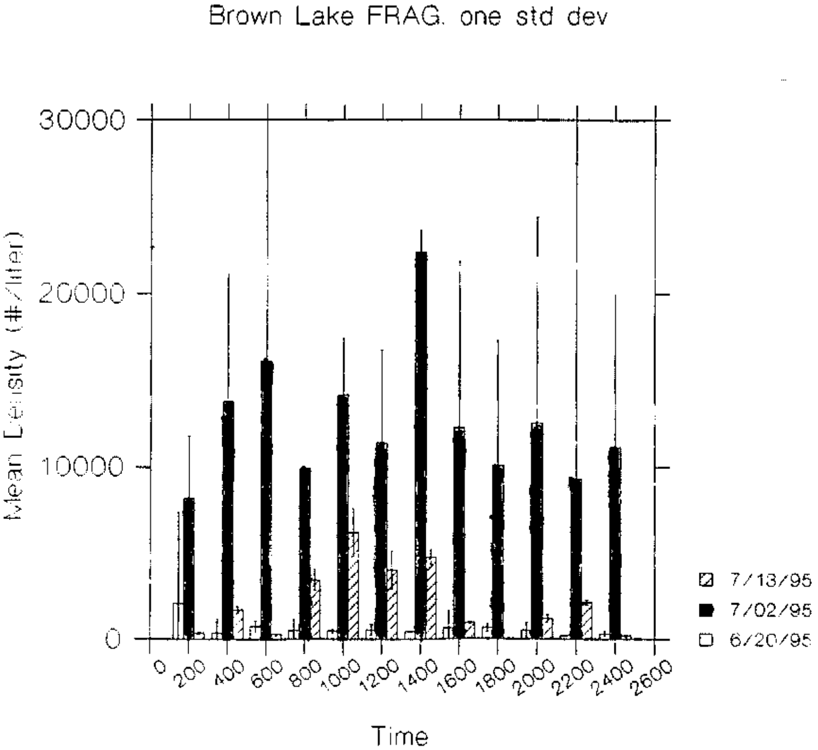




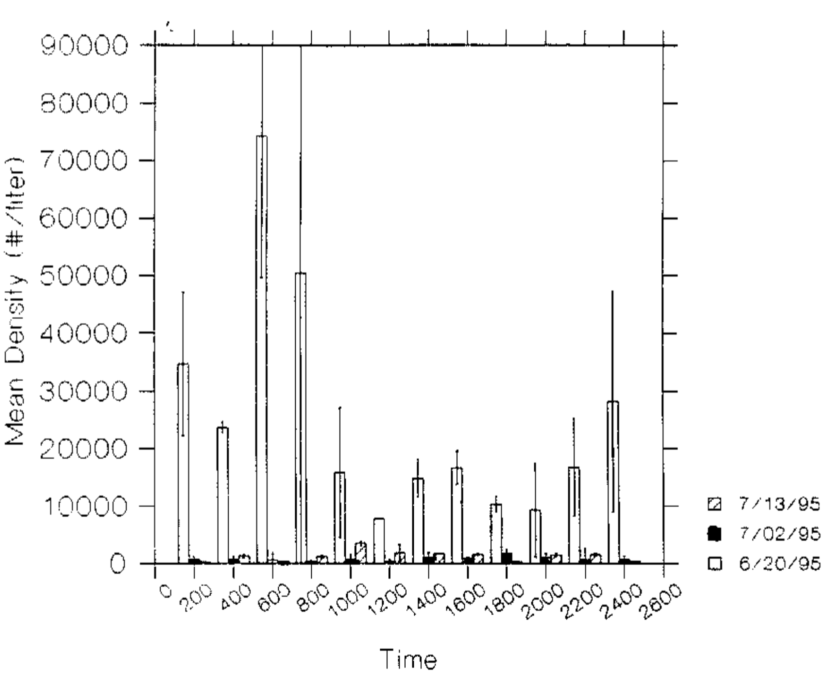


Line = Temperture (C)
Dashes = Disssolved Oxygen
Depth in meters

Figure 5:
Predominant Phytoplankton in Brown Lake Over a 24 Hour Period



Brown Lake DINO. one std dev



Brown Lake ANAB. one std dev

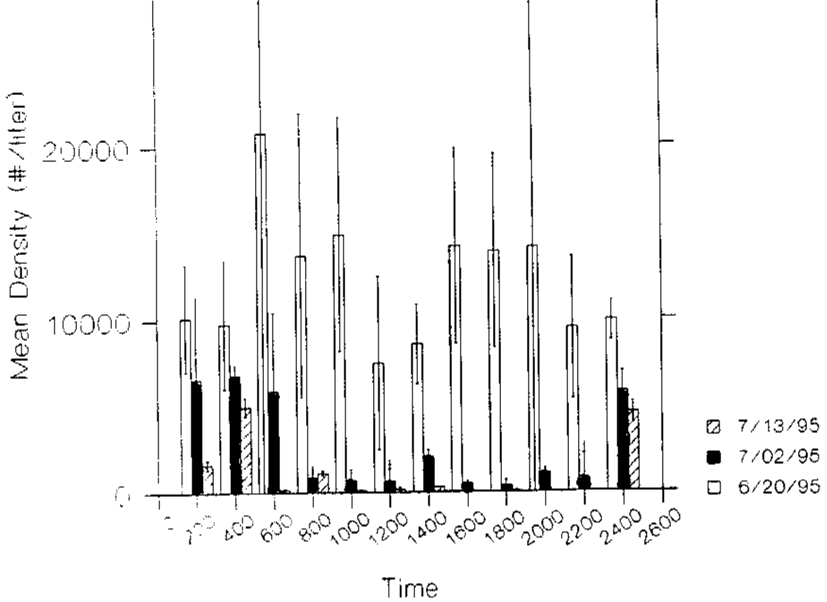
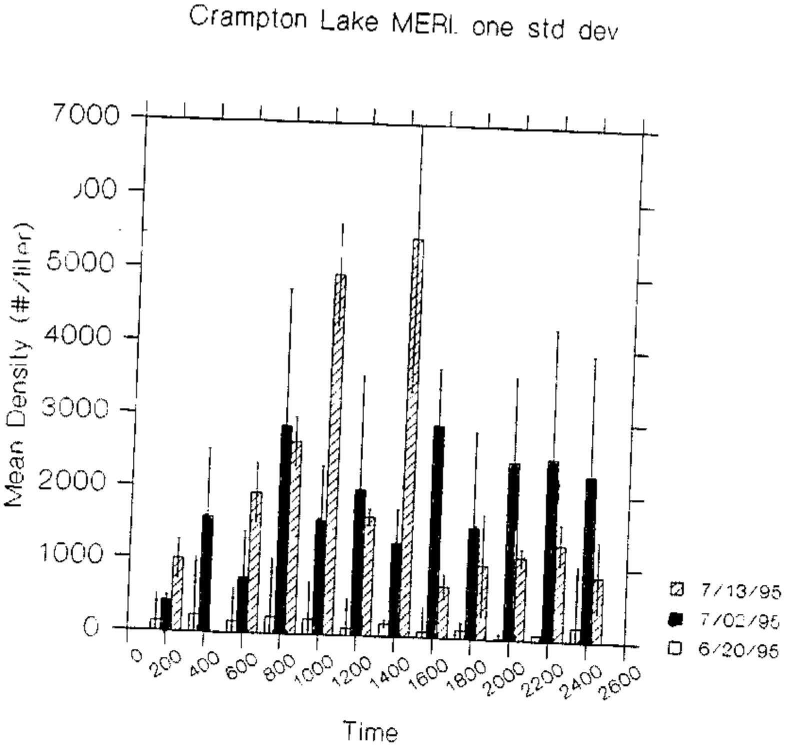
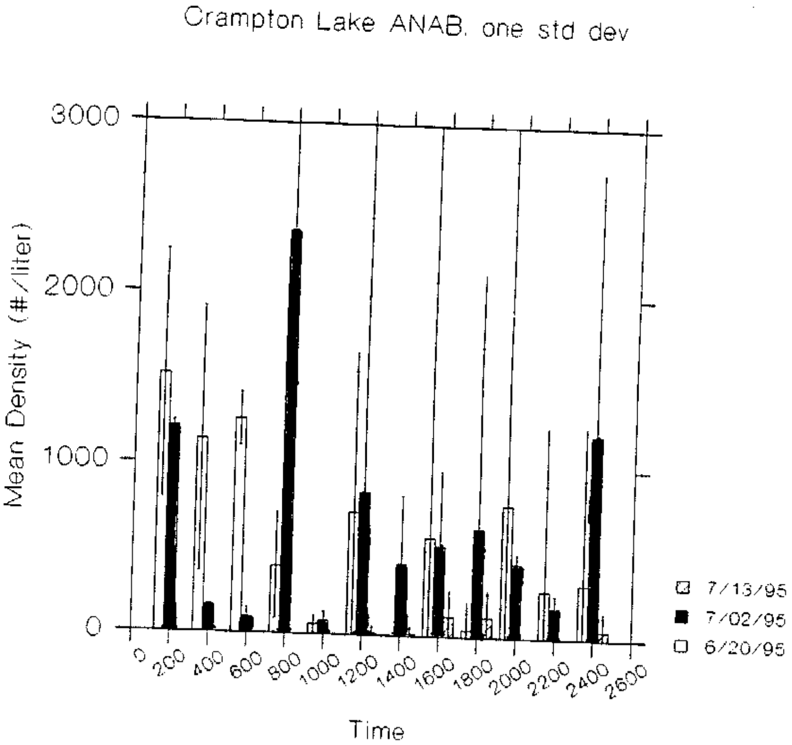


**Figure 6:
Predominant Phytoplankton in Crampton Lake Over a 24 Hour Period**





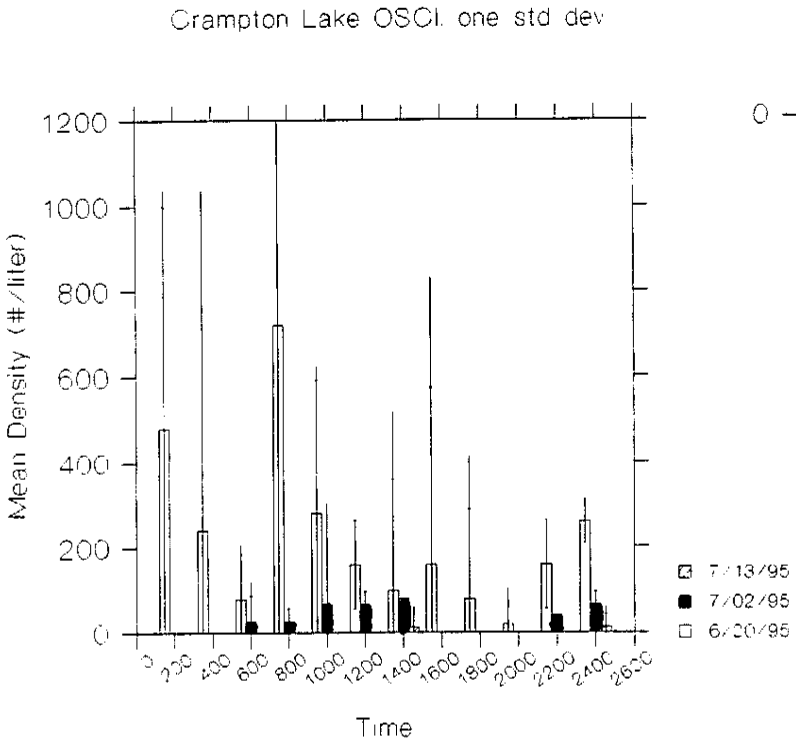
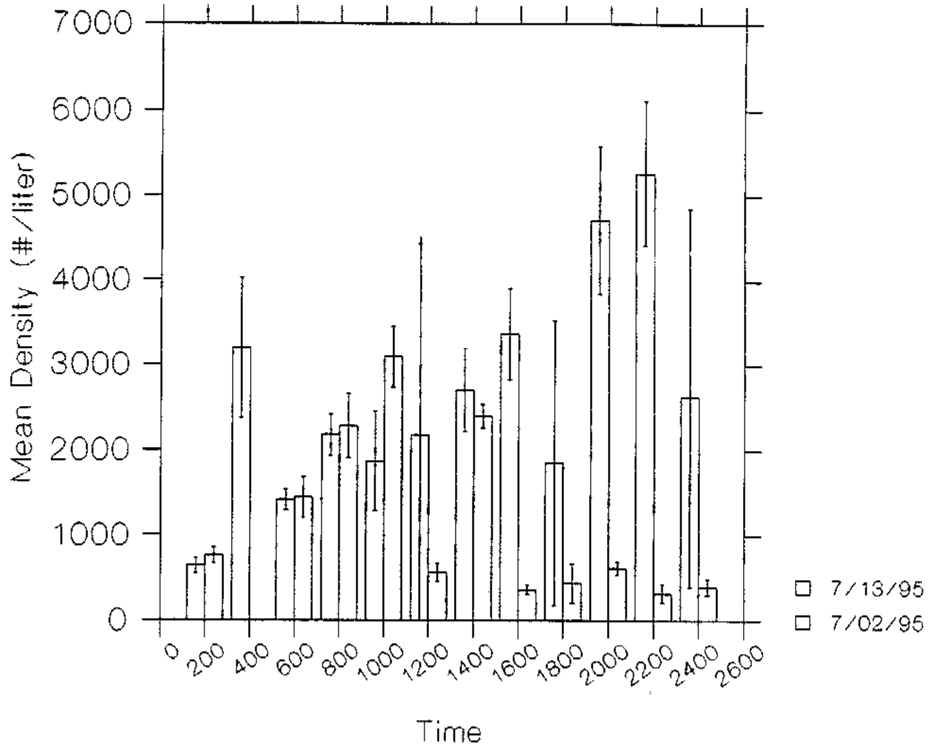


Figure 6: Predominant Phytoplankton in Crampton Lake Over a 24 Hour Period

Crampton Lake CRUC, one std dev



Line = Temperture (C)
Dashes = Disssolved Oxygen
Depth in meters

Crampton Lake DINO, one std dev

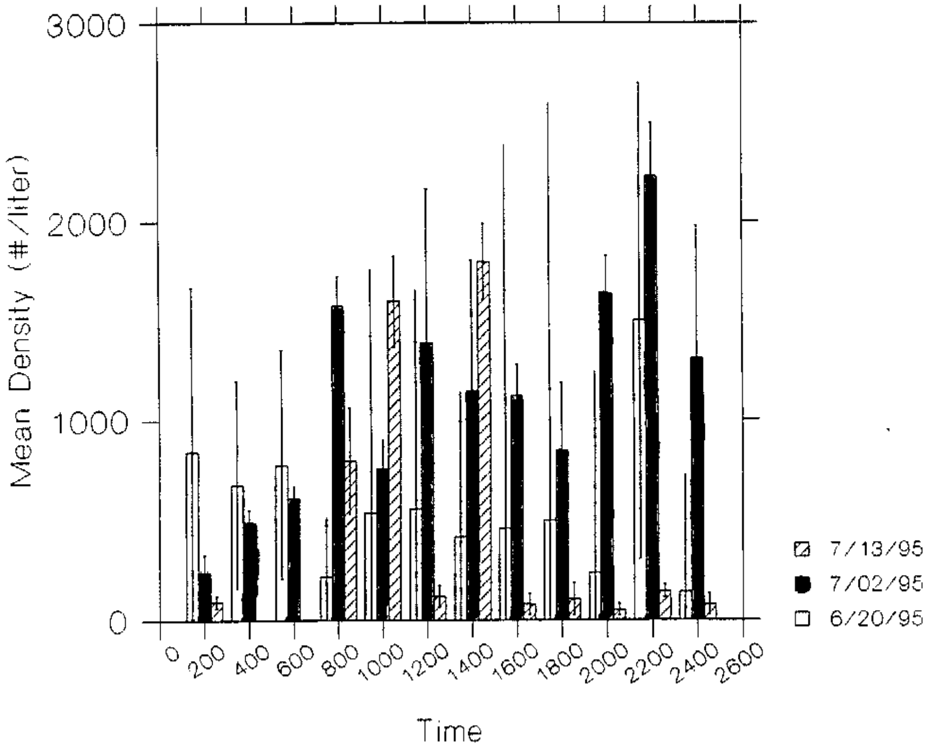
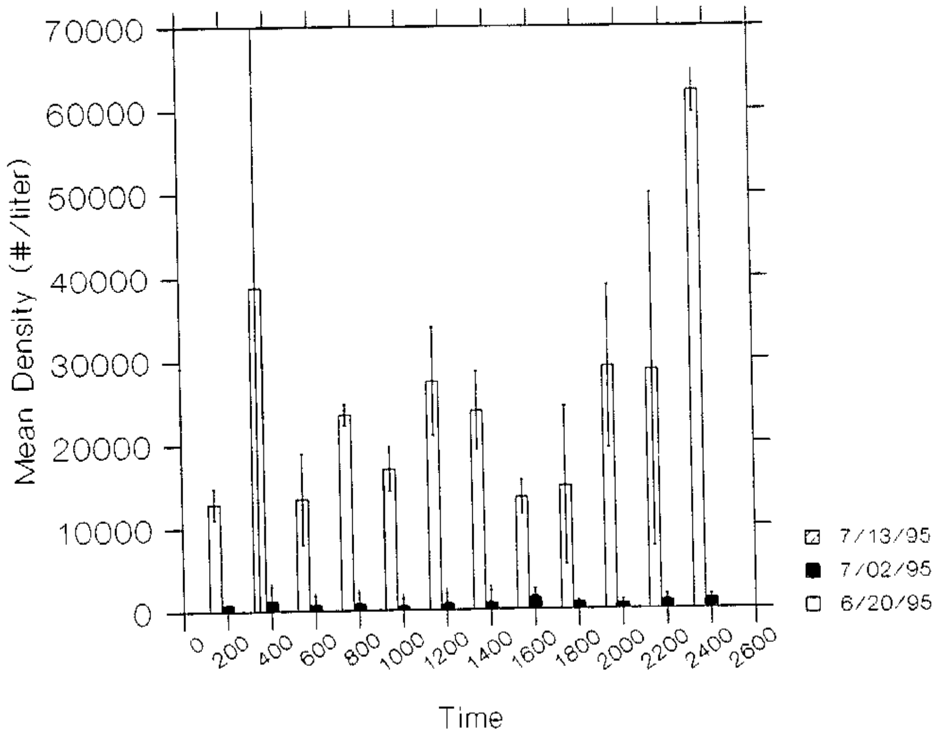
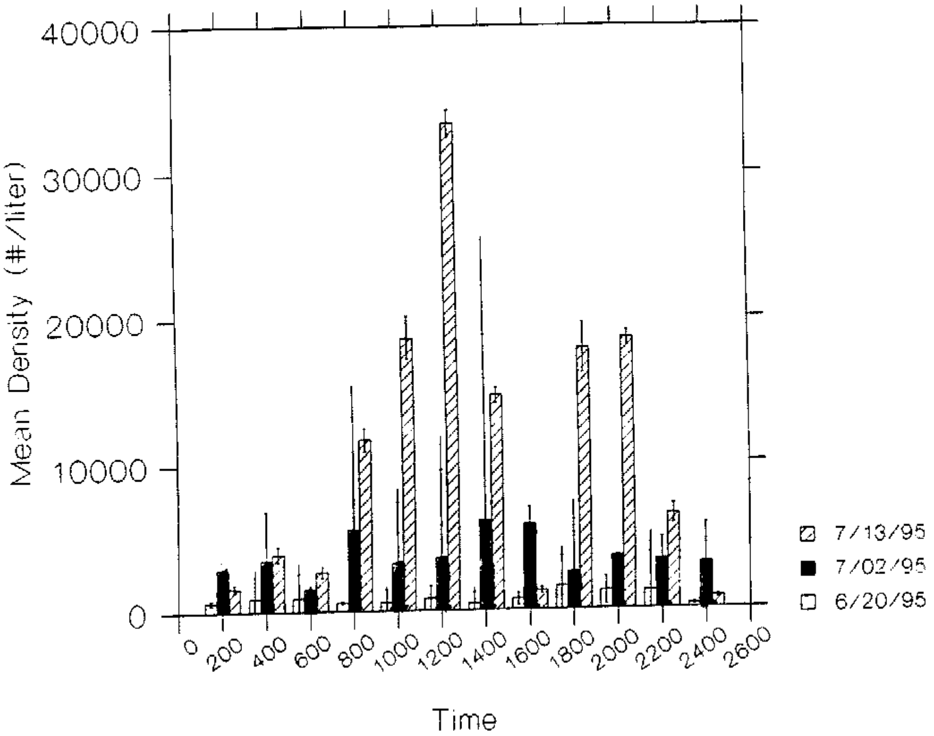


Figure 7: Predominant Phytoplankton in Forest Service Bog Over a 24 Hour Period



Forest Service Bog DINO. one std dev

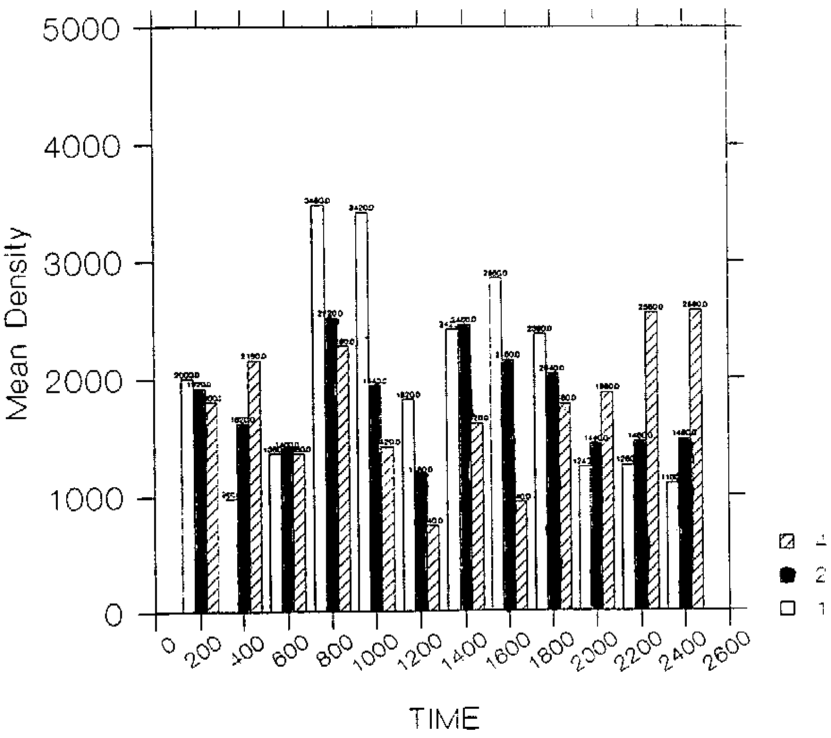
Line = Temperature (C)
Dashes = Dissolved Oxygen
Depth in meters



Forest Service Bog MERI. one std dev

Figure 8: Predominant Zooplankton in Brown Lake Over a 24 Hour Period

Date 07/17/95 Brown Lake Keratella



Mean Density (#/liters)

Date 06/20/95 Brown Lake Keratella

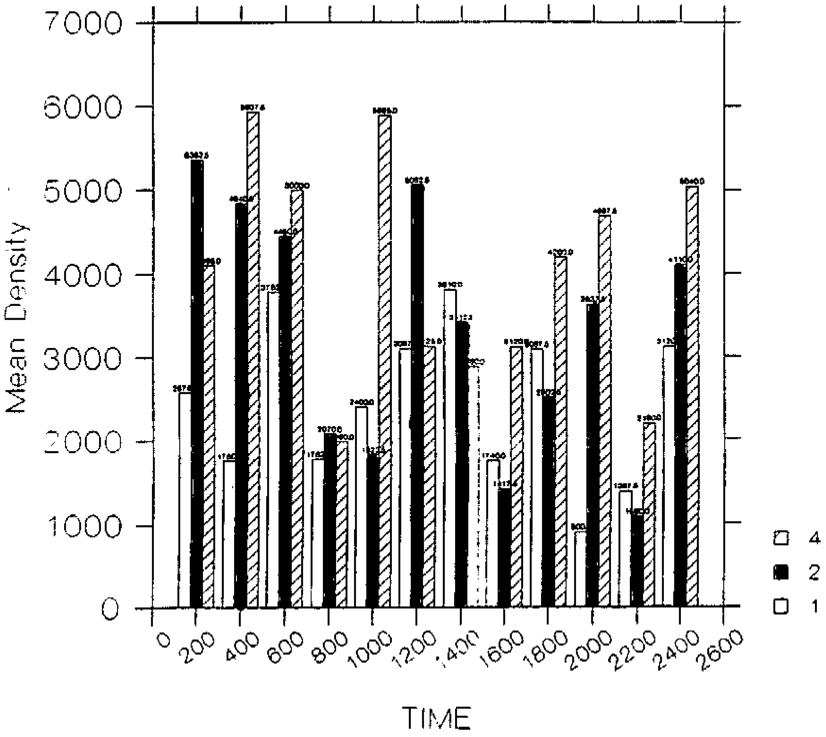
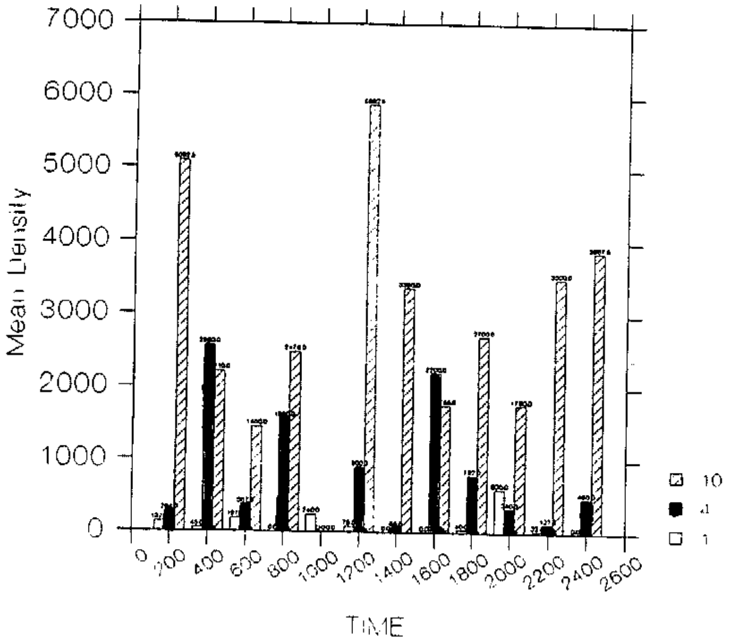
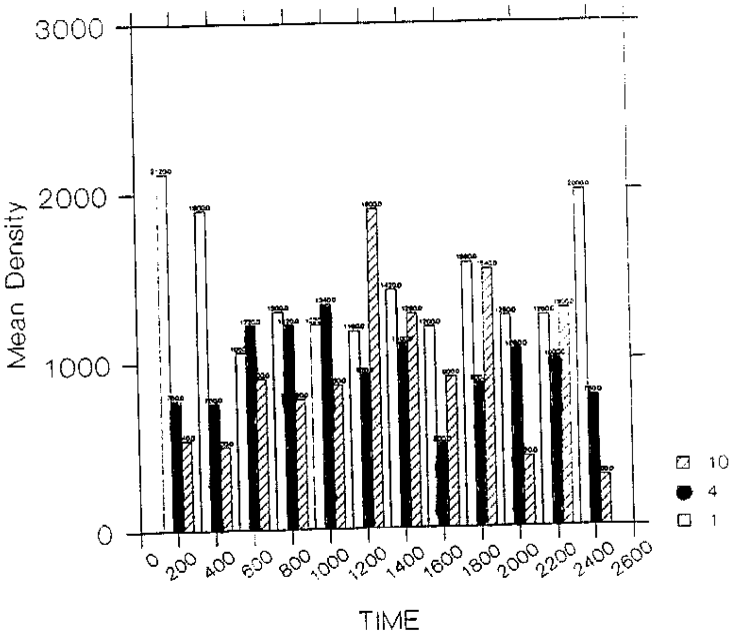


Figure 9:
Predominant Zooplankton in Crampton Lake Over a 24 Hour Period.

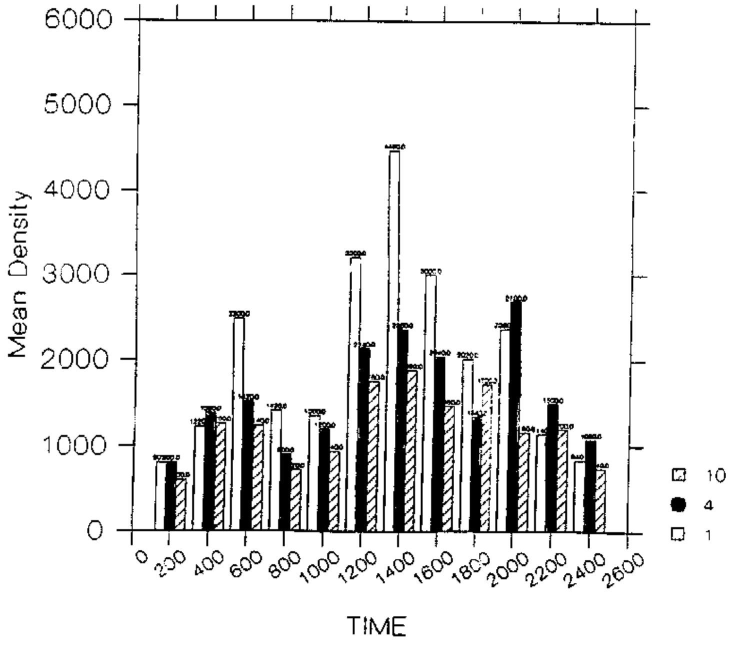
Date 06/20/95 Crampton Lake Kellicottia



Date 06/28/95 Crampton Lake Keratella



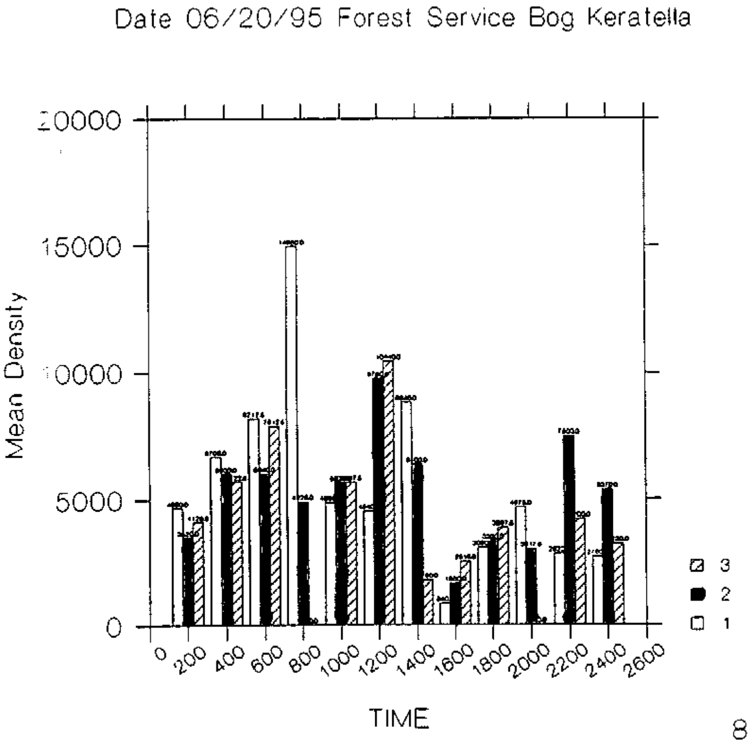
Date 07/17/95 Crampton Lake Keratella



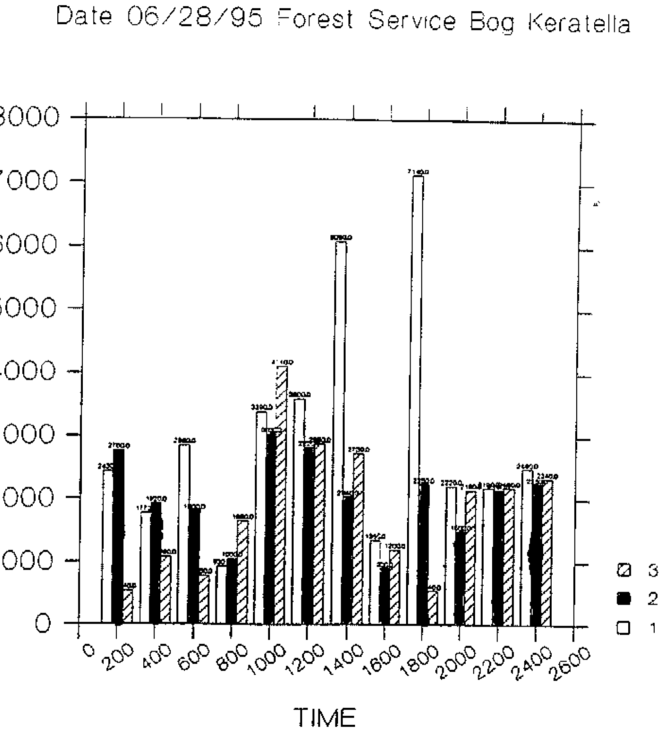
Mean Density (#/liters)

Figure 10:
Predominant Zooplankton in Forest Service Bog Over a 24 Hour Period.

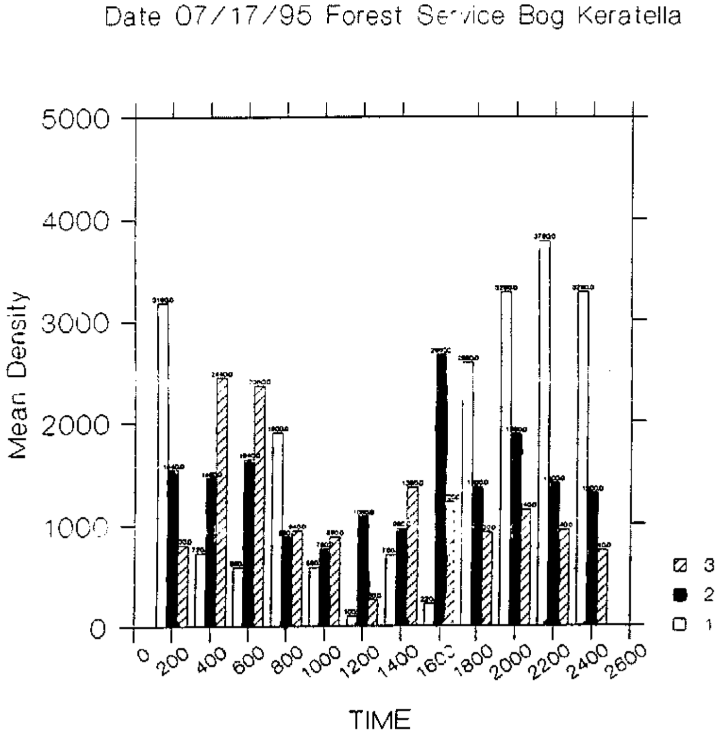
Date 06/20/95 Forest Service Bog Keratella



Date 06/28/95 Forest Service Bog Keratella



Date 07/17/95 Forest Service Bog Keratella

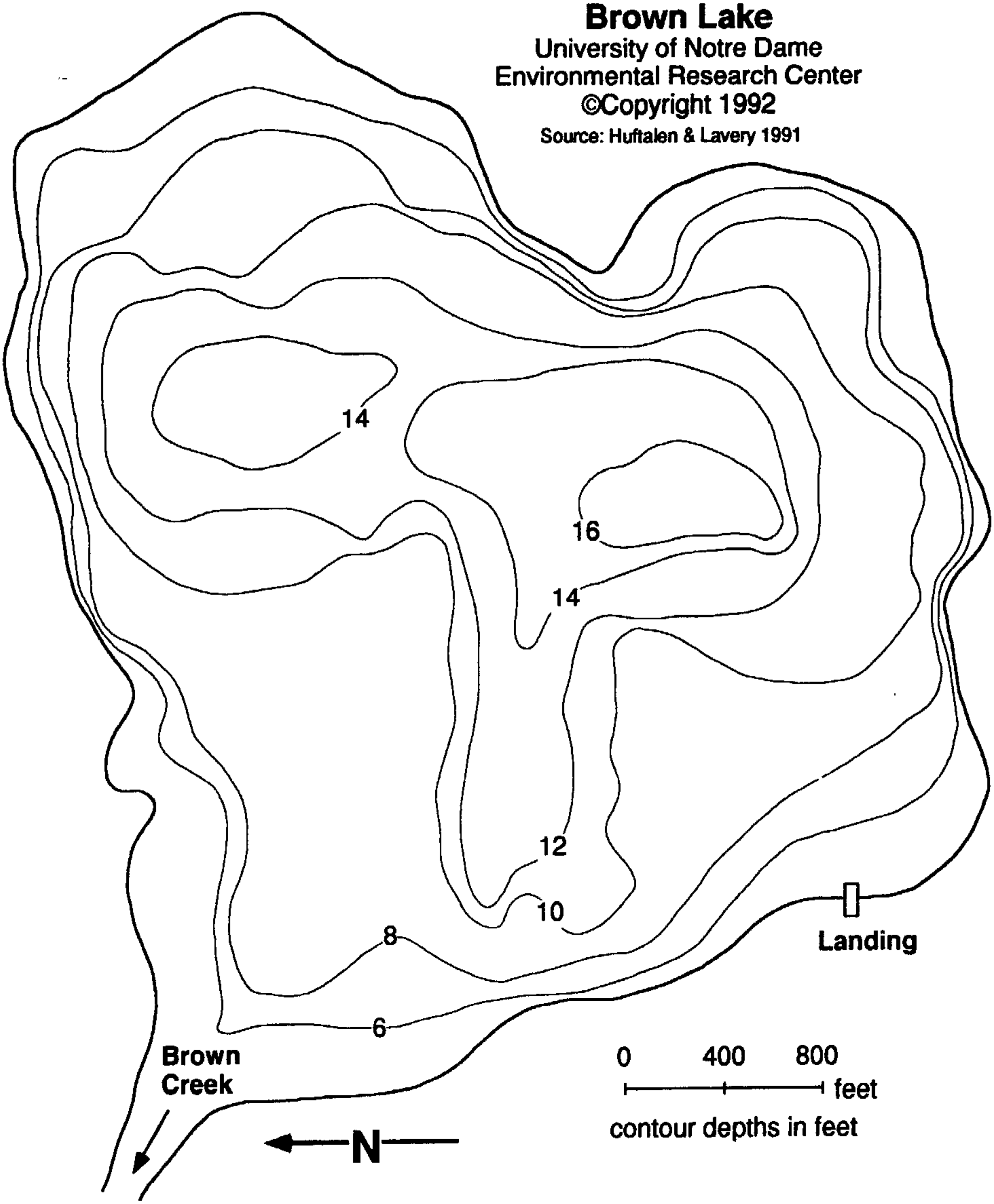


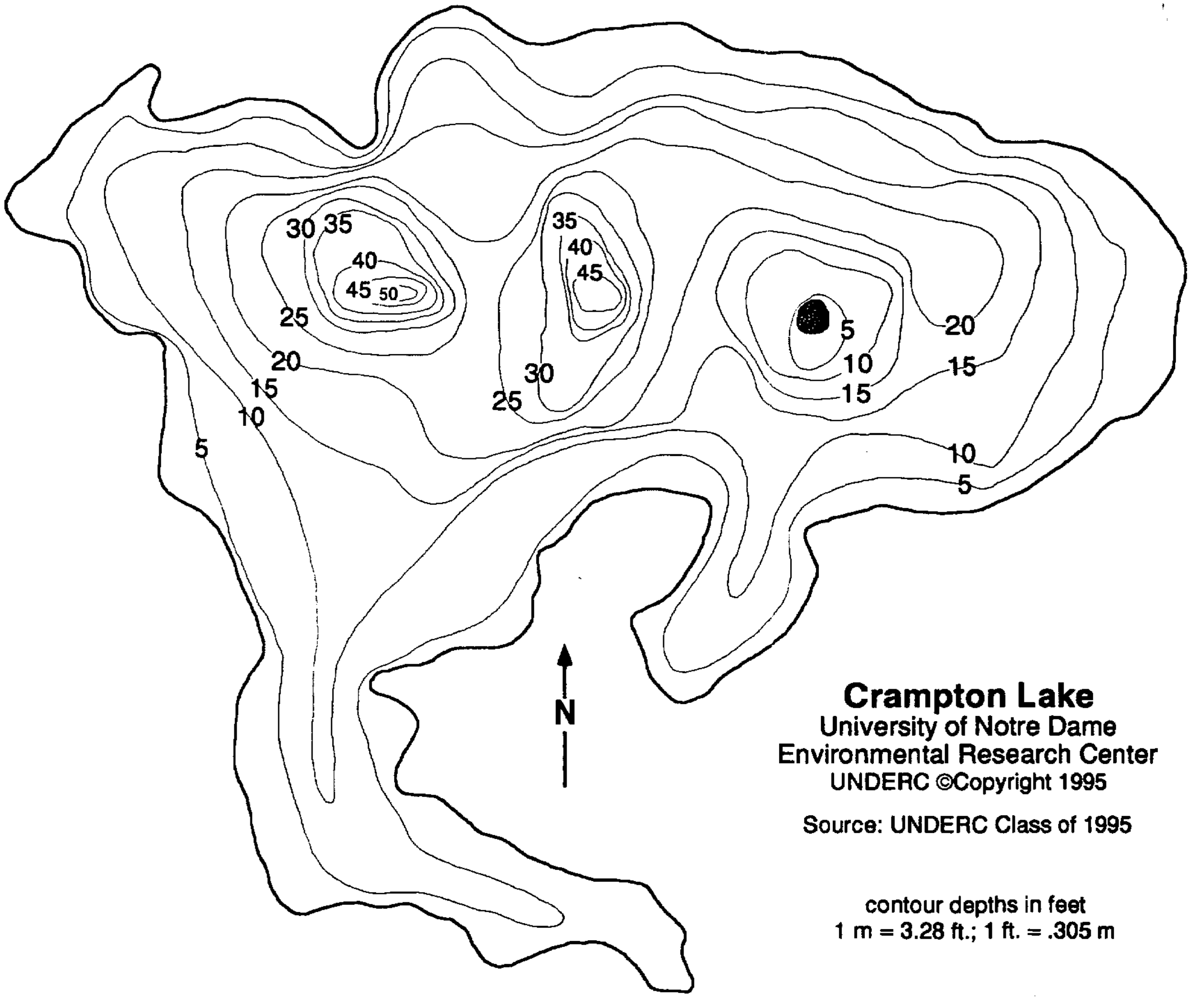
Mean Density (#/liters)

Brown Lake

University of Notre Dame
Environmental Research Center

Source: Huftalen & Lavery 1991

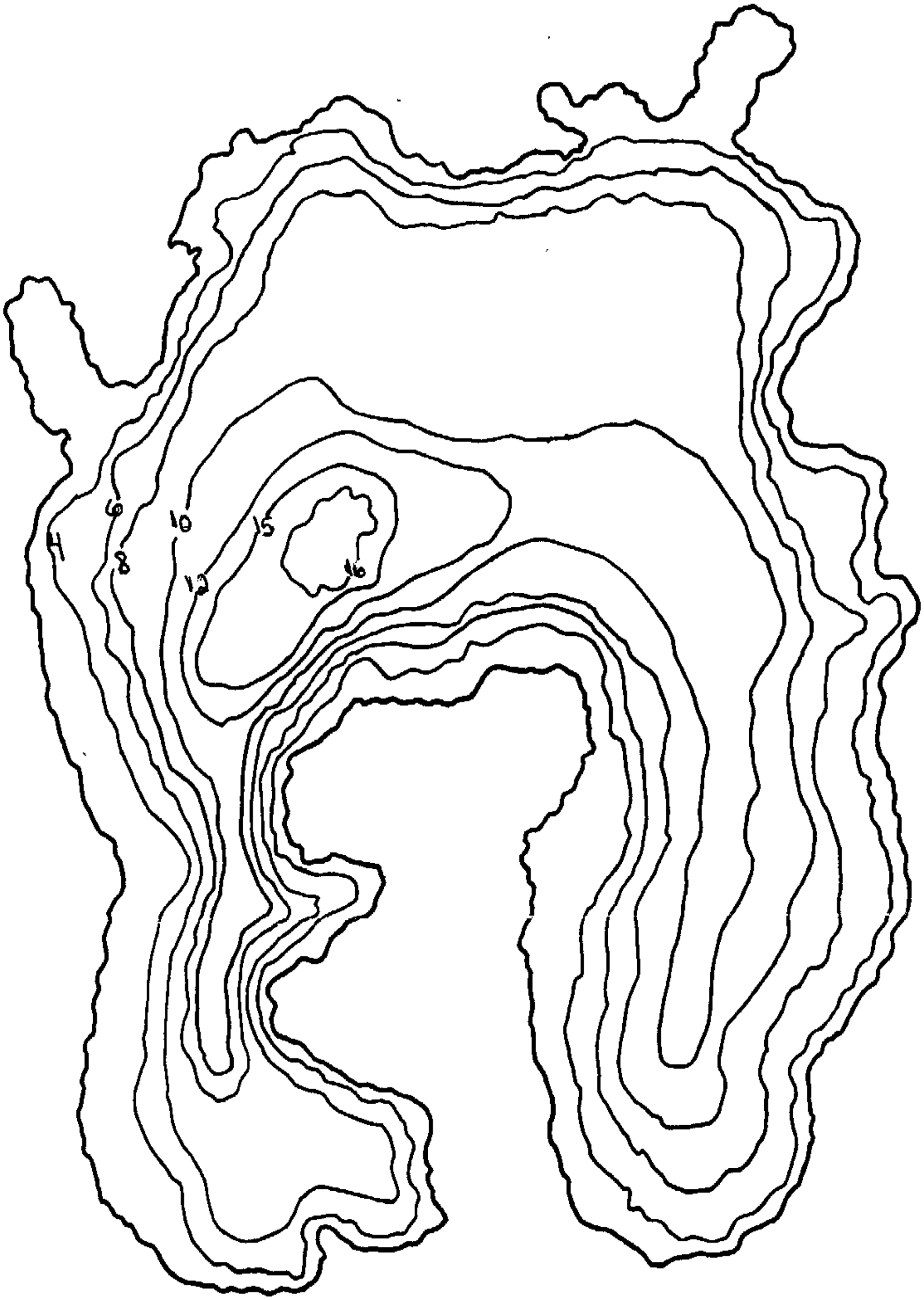




Crampton Lake
University of Notre Dame
Environmental Research Center

Source: UNDERC Class of 1995

contour depths in feet
1 m = 3.28 ft.; 1 ft. = .305 m



Forest Service Bog

University of Notre Dame Environmental Research Center

Source: Honkamp, Stets, Tarkowski

contour depths in feet
1m = 3.28 ft
1ft. = .305m