DEVELOPMENT AND ASSESSMENT OF MODELS FOR PREDICTING THE PHYTOPLANKTON ASSEMBLAGE PATTERNS IN LAKE KEMP

by

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TABLE OF CONTENTS

CHAPTER

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Phytoplankton are an essential component of aquatic ecosystems (Cole, 1983). Despite their microscopic size, these organisms are responsible for the majority of primary production that takes place in lakes and reservoirs (Goldman, 1969; Kimmel et al., 1990). This also means that they are responsible for regulating the trophic state of the aquatic ecosystem (Reynolds, 2000; Reynolds et al., 2000). Phytoplankton abundance typically undergoes regular population patterns from year to year, in much the same manner as terrestrial plant communities (Elser et al., 1995). Phytoplankton communities typically reach their greatest abundance in the summer months and their lowest abundance during the winter months. Possibly the most important factors that determine phytoplankton abundance are available nutrients, and as phytoplankton populations increase over the growing season, certain nutrients may become limited. The potential for nutrient limitation and the perception that lakes and reservoirs are homogeneous environments suggests that certain species that have different nutrient requirements would enable selected species to dominate the community structure in that environment (Interland and Kilham, 2001). However, complete dominance by a single phytoplankton species is rare within the phytoplankton communities of lakes and reservoirs (Sommer, 1996). Quite often there will be several species of phytoplankton that will be present in high numbers, many species that will be present in moderately high numbers, and a few that will be very uncommon. This phenomenon, known as the “Paradox of the Plankton,” was first described by G. E. Hutchinson (Hutchinson, 1967).

The “Paradox of the Plankton” was explained by showing that an aquatic ecosystem that appears to be homogeneous at the macroscopic scale, is actually highly heterogeneous at the microscopic scale. This heterogeneity allows a variety of phytoplankton species to thrive in very small areas, but not dominate throughout the entire aquatic system. The small size of the phytoplankton and their short generation times enable phytoplankton to be studied in small containers and ecological effects can be observed over much shorter periods than in larger organisms (Rojo and Alvarez-Cobelas, 2000).

Disturbance, which can be defined as any sudden change in the aquatic environment is also responsible for determining the high degree of diversity in phytoplankton communities (Gaedeke and Sommer, 1986; Roxburgh et al., 2004). Examples of these disturbances are temperature changes, influx of nutrients, influx of freshwater, storm events, wind, and chemical fluctuations (Padisak, 1993).

Various models have been developed for understanding mechanisms that drive phytoplankton community structure and for predicting the composition of phytoplankton communities as a result of changes in the environment (Reynolds, 2000). Models that deal with the mechanics of community structure dynamics usually are vague as to specific cause-and-effect explanations. The Plankton Ecology Group model (PEG model) is commonly cited in limnological textbooks and is used as a descriptive model to illustrate how and why phytoplankton community dynamics change throughout the growing season. This model explains how different regulating factors account for and predict general trends in phytoplankton community structure and how succession progresses throughout the season (Sommer, 1996). A number of other models have been developed to predict the specific environmental characteristics that are important to community composition (Downing et al., 2001). These models typically predict phytoplankton biomass, abundance, community structure and phytoplankton blooms based on biologically important environmental parameters (Keller, 1989; Makulla and Sommer, 1993; Moisan et al., 2002). Environmental parameters typically studied include total nitrogen concentration, total phosphorus concentration, ratio of total nitrogen to total phosphorus, temperature, available light, dissolved oxygen, pH, and the water column mixing regime.

There are several problems associated with phytoplankton prediction. At the species level, prediction is very difficult if not impossible because of the highly stochastic environment (Rojo and Cobelas, 2000) present at the scale that phytoplankton inhabit (Reynolds, 2000). Predicting the successional and assemblage patterns is more difficult to predict than single species patterns because interspecies interactions must also be taken into consideration (Rojo et al., 2000). Although variation of species-level abundance is still not well understood, prediction of phytoplankton biomass, abundance, and productivity have been more accurately achieved when phytoplankton species are studied as functional groups such as with the PEG model (Sommer, 1986).

Understanding mechanisms responsible for changes in phytoplankton communities and being able to predict when these changes will occur is an important aspect for ecological modelers, water quality managers, and fishery managers in central

Texas as well as worldwide (Moestrup, 1994). The main objective of this project was to use environmental parameters to develop and evaluate models for predicting phytoplankton abundance and phytoplankton community composition in Lake Kemp, a central Texas reservoir.

CHAPTER II

METHODS

Study area

Lake Kemp is a temperate, monomictic reservoir located 64 km southwest of Wichita Falls, Texas and 13 km north of Seymour, Texas. The reservoir was formed in 1922 by impoundment of the Wichita River at river kilometer 228, in north-central Baylor County. The main purposes of this reservoir are flood control and water for irrigation. The reservoir is administered jointly by the U. S. Army Corps of Engineers, Tulsa District and the City of Wichita Falls. Lake Kemp has a surface area of 6,314 ha (15,590 acres) and a volume of 0.432 km^3 (268,000 acre-feet). Mean depth of Lake Kemp is 9.6 m (Ground and Groeger, 1994) and maximum depth is 17 m (Wilde, 1997).

Mean daily air temperature of Baylor County in July is 36º C and -3º C in January (Ramos, 1995). Annual rainfall is 69 cm per year (Ramos, 1995) and Lake Kemp has an evaporation rate of 152 cm per year (Joerns, 1961). Prevailing winds are out of the north in the winter and the south in spring and summer (Ramos, 1995).

Extensive deposits of chlorides occur within the watershed of Lake Kemp and are responsible for high concentrations of chlorides present in the ground water. Surface springs are responsible for contributing high concentrations of chlorides to streams and tributaries of Lake Kemp. Since 1987, chloride control projects implemented by the Army Corps of Engineers have reduced the quantity of dissolved chlorides that reach

Lake Kemp (USACOE, 1994) to provide higher quality irrigation and drinking water for the cities of Wichita Falls and Seymour, Texas (Joerns, 1961). These chloride control projects that use inflatable weirs and diversion canals, have removed approximately 33% of the chlorides that previously entered the lake (Wilde, 1997).

Field Collection

Thornton et al. (1982) described reservoirs as having characteristics of both lakes and rivers. This requires some consideration for developing a sampling protocol that includes sites from lacustrine zones, transition zones, and riverine zones because the lacustrine sites that are closest to the dam stratify more readily, contain less allochthonous material, and are usually more insulated from environmental temperature (Thornton et al., 1982). The transition sites possess characteristics of both lacustrine and riverine zones, including more allochthonous material and less stability with respect to thermal stratification. The riverine zones contain the most allochthonous material and rarely stratify thermally. There were five sampling sites on Lake Kemp (Figure 1). Sites K1 and K2 were closest to the dam, the most lacustrine sites, and were the only sites that underwent stratification with a summer thermocline established at a depth of approximately 8-10 m (Wilde, 1997). K3 and K4 are located in the transition zone between the riverine and limnetic areas of the lake and did not stratify. Site K5 is located in the most riverine environment and never stratified thermally during the study period.

Field sampling was conducted twice a month during in June and July and once a month during the remainder of the study. Phytoplankton samples were taken by inverting 250 ml bottles at a depth of 0.5 m from the surface. Three replicate phytoplankton samples were taken at each of the five sites and preserved in Lugol's solution. Water samples for total nitrogen and total phosphorus analysis were taken at 0.5 m from the surface and 0.5 m from the bottom using a hose and a water pump. These samples were stored on ice until they were processed. Temperature, dissolved oxygen, and pH were measured with a Hydrolab instrument at 1.0 m intervals from the surface to a depth 0.5 m from the bottom. Photosynthetically active radiation (PAR) was measured with a Licor light sensor from the surface to the depth at which only 1% of the surface radiation was measured, light measurements were made in depth increments of 0.5 m to 1 m.

Preserved phytoplankton samples were counted in the laboratory using an Olympus IX-51 inverted microscope according to an adapted Utermöhl counting method (Paxinos and Mitchell, 2000). Samples were prepared by settling a measured volume of the phytoplankton onto a microscope slide (Furet and Benson-Evans, 1982). Each slide was then examined using the microscope and each phytoplankton cell was counted until either 200 cells of an individual species were counted or twenty fields of view of the microscope had been examined. When a filamentous phytoplankton or colonial group of phytoplankton cells continued past the edge of the field of view, all cells in filaments of colonies were counted including those outside of the field of view. The concentration, as cells per milliliter, was estimated by determining the total area of the microscope slide, the total number of microscope fields of view per slide, and the number of cells in the field of view. Using the total number of cells per slide and the volume of water on the slide, the density of phytoplankton is calculated. The total area of the slide was determined using a micrometer that is accurate to 0.05 mm and the field of view area was determined with a slide micrometer. The numbers of cells in a field of view was counted and the volume of sample on the slide was determined using a 0.5 ml pipette.

Water samples were transported in ice coolers at 4º C from Lake Kemp, Texas to Advanced Analysis Laboratories in Lubbock, Texas where nutrients (total phosphorus and total nitrogen) were analyzed according to Environmental Protection Agency standard techniques (APHA, 1996; AWWA, 1990).

Model Development

Prediction of phytoplankton community succession and abundance at the species level is inaccurate and impractical, but prediction of phytoplankton functional groups has been shown to be useful and consistent when predicting abundance and community succession (Reynolds, 2000). Therefore, I used the total cell counts for each of the five Lake Kemp sites and composited them into five different phytoplankton groups. The most abundant orders present in Lake Kemp were cyanobacteria (B), chryptophytes (C), diatoms (D), euglenoids (E), and green algae (G) order. These orders made up over 99% of the total phytoplankton assemblage. No differences in cell counts between the five sample sites were found using analysis of variance (Table 1.1). Therefore I averaged cell counts so results would be applicable to the whole lake. Means of each phytoplankton group were log transformed to satisfy assumptions of normality and were compared to the best predictor variables (total nitrogen concentration, total phosphorus concentration, and temperature) individually using the partial least squares regression procedure in SAS software. The variables that I used were consistent with those used in other studies of phytoplankton prediction. Downing et al. (2001) found that total phosphorus and total nitrogen were the best predictors of cyanobacteria biomass and the formation of blooms in northern European lakes. Keller (1989) was able predict primary productivity using principal component regression of temperature, light, total phosphorus and total nitrogen. I also developed models containing two and three variables using partial least squares regression methods. Partial least squares regression analysis is a multiple linear regression method that allows simultaneous prediction of several various phytoplankton groups from several independent variables (environmental parameters) (Xu, 2001).

Model selection was performed using the Akaike Information Criterion (AIC) likelihood (Akaike, 1973; Burnham and Anderson, 1998). This method is useful for evaluating my models because it allows comparisons of models with differing numbers of parameters. Assuming normally distributed errors, the AIC can be calculated using the sum of squares of the deviations between the predicted and observed values (Burnham and Anderson, 1998). The model with the lowest absolute value AIC is considered the best predictor of the observed data.

CHAPTER III

RESULTS

Phytoplankton enumeration

Phytoplankton cell counts at all sites exhibited similar population trends throughout the study period and growing season (Table 1.1). Mean phytoplankton cell counts were slightly over 155,000 cells ml^{-1} (± 19,917 cells ml^{-1}) for both August and September to a cell count of 35,000 cells ml^{-1} (± 3,874 cells ml^{-1}) in May (Figure 6). Phytoplankton cell counts were low in the early spring and increased linearly until September after which cell counts followed a generally linearly downward trend.

Species Composition

The cyanophyte group was the most abundant phytoplankton group on each date during the study period. May and January were the only months that the cyanophyte group made up less than 50% of total, when the total cell counts were 48% and 43% respectively. The cyanophyte group was between 60% and 81% of total cell counts throughout the rest of the season with the greatest percentage occurring in August when they composed 81% of the phytoplankton community. The cryptophyte group was second most common group for this study period and represented between 7% to 22% during November and July, respectively. The chlorophyte group represented 25% of the phytoplankton community composition during January and 6% of the composition in

August. The diatom group made up 8% of the phytoplankton community composition in January and 3% in July. Euglenoids abundance was low throughout the year and only during May did this group represent more than 1% of the phytoplankton composition (Figure 7).

Within the cyanophyte group, the most common genera were *Pseudanabaena*, *Oscillatoria*, *Anacystis*, and *Lyngbya* with 29%, 26%, 17%, and 13% of the total phytoplankton assemblage respectively. Within the cryptophyte group, the most common genera were *Cryptomonas*, *Ochromonas*, *Chrysochromulina*, and *Rhodomonas* with 27%, 25%, 21% and 20% respectively. Within the chlorophyte group, the most common genera were *Oocystis, Carteria*, *Chlorocapsa*, and *Tetraedron* with 21%, 15%, 12%, and 12% respectively. The most common genera within the diatom group were *Cyclotella*, *Cocconeis*, *Achnanthes*, *Chaetocerus*, and *Navicula* with 24%, 24%, 15%, 12% and 11% respectively. Within the euglenophyte group, the most common genera were *Lepocinclis*, *Phacus*, and *Euglena* with 52%, 35%, and 11% respectively (Appendix B). These results were typical of other Texas reservoirs according to previous studies (Harris and Silvey, 1940).

Surface physical and chemical limnology

Surface temperatures in Lake Kemp ranged from 28.3° C (± 0.29° C) and 28.5° C (± 0.16° C) in July and August, respectively, to 5.7° C (± 0.22° C) in January (Figure 2). Surface temperatures increased slightly through the summer months from May until August when surface temperatures dropped steadily until January. Photosynthetically active radiation was slightly over 1927 µE (± 85.4µE) in May and 272 PAR (± 58.9µE) in August (Figure 2). The photosynthetically active radiation dropped steadily from May until December with two months that did not coincide with this downward, linear trend (Figure 2). Photosynthetically active radiation in August that was much lower than expected may have been caused by high turbidity following a storm event. Photosynthetically available radiation in January was much higher than the yearly trend would suggest. This month may not follow the linear trend because seasonal radiation may have started to increase. Total nitrogen concentration was 0.55 mg l^{-1} ($\underline{+}$ 0.09 mg l^{-1}) in June and 0.073 mg l^{-1} ($\underline{+}$ 0.025 mg l^{-1}) in July (Figure 4). Most months had total nitrogen concentrations between 0.2 and 0.4 mg l^{-1} with no apparent trend that emerged. Total phosphorus concentration was slightly less than .0001 mg l^{-1} in September and 0.48 mg l^{-1} ($\underline{+}$ 0.22 mg l^{-1}) in December with all but two months less than 0.05 mg l^{-1} ($\underline{+}$ 0.001 mg l^{-1}) (Figure 5).

Analysis

Partial least squares (PLS) regression analysis of the environmental parameters and phytoplankton cell counts was conducted to develop predictive models. Of the seven models, three were single variable models (total nitrogen concentration, total phosphorus concentration, and temperature). There were also three models with two variables (total nitrogen concentration with total phosphorus concentration, total nitrogen concentration with temperature, and total phosphorus concentration with temperature). The seventh model included all three variables (Figure 8).

Models developed with partial least squares regression were evaluated according to the Akaike Information Criterion likelihood statistic. The model containing temperature, total phosphorus, and total nitrogen had an AIC of -30.7 and therefore was the best predictor of phytoplankton abundance. The three models containing two variables all equally predicted phytoplankton abundance. All three of the two variable models had an AIC of -32.9. The three single variable models had the highest scores. The total nitrogen model had an AIC of -35.3. The total phosphorus model had an AIC of -35.1, and the temperature model had an AIC of -35.0.

CHAPTER IIII

DISCUSSION

The phytoplankton community is an important component of aquatic systems and is studied for both scientific and socio-economic reasons. One of the main scientific reasons for studying phytoplankton is that it makes up the base of the food web and therefore are responsible for regulating the productivity of aquatic ecosystems (Goldman, 1969). One socio-economic reason for studying phytoplankton is that certain cyanobacterial blooms are responsible for causing foul tasting drinking water. Understanding what ecological conditions must be present in order to form these blooms could be used to prevent or reduce these unpleasant blooms (Moestrup, 1994).

For many years now, phytoplankton ecologists have been pleading for a more ecological approach to studying phytoplankton assemblage patterns (Rojo and Alvarez-Cobelas, 2000). Prediction of phytoplankton assemblage composition in particular has been especially overlooked (Duarte and Agusti, 1992; Sommer, 1996). This is not an easy task because of the vast number of relative environmental variables in aquatic environments as well as temporal and spatial scales that can be highly variable (Gaedeke and Sommer, 1986). Previous studies of phytoplankton assemblage patterns have either focused at the level of the individual phytoplankton group (Dokulil, and Teubner, 2000; Downing et al., 2001) or at the system level (Fox, 2004). In order to identify the important patterns in phytoplankton abundancy and composition, we must understand the individual and population such as nutrient requirements, growth rates, metabolic rates, and distributions as well as community traits such as competition, predation, and community dynamics (Anderson, 1993; Elser et al. 1995; Fox, 2004; Interland and Kilham, 2001; Keller, 1989; Nozaki, 2001; Rojo and Alvarez-Cobelas, 2000). These factors have been included in the plankton ecology group (PEG) model (Sommer et al., 1986), notably important for combining phytoplankton population ecology and aquatic community ecology in a way that explains the spatio-temporal dynamics of the phytoplankton and zooplankton communities (Holzmann, 1993; Makulla and Sommer, 1993; Reynolds et al., 2000; Roxburgh et al. 2004; Vanni and Layne, 1997). The scope of the PEG model is the primary reason that it is not feasible for use as a predictive model. The numerous variables that are present in an aquatic system, and the vast number of combinations of variables possible would make the PEG model useless as a predictive model (Sommer et al. 1986). Even if a model could be developed using all of the relevant variables, the measurement and collection of the variables would not be feasible (Reynolds, 2000).

The most successful models that I constructed included three of the environmental variables. The model containing temperature, total nitrogen concentration, and total phosphorus concentration was the best predictor of phytoplankton assemblage. This is consistent with previous studies that have predicted the maximum growth rates of phytoplankton populations using temperature (Moisan et al. 2002). Other studies have also used total nitrogen concentration and total phosphorus concentration to predict phytoplankton growth and also for describing successional patterns in lakes (Duarte and Agusti, 1992; Interland and Kilham, 2001; Keller, 1989; Reigman and Mur, 1986).

Among the variables that were not useful in predicting the composition were chloride, conductivity, light and pH (Anderson, 1993; Falkowski et al., 1985). These variables may not have been as useful for several reasons. Perhaps the range of values exhibited was not sufficient to cause a significant change in the phytoplankton community. Alternatively, variables, such as light intensity were only measured once a month, but light changes significantly over a twenty-four hour period. This variation would not be detected because of the monitoring regime and therefore makes these variables less useful for developing predictive models than variables that change at a more seasonal rate (Anderson, 1993).

Previous phytoplankton modeling studies have concentrated on either single species prediction, single group prediction, or predictions of primary productivity (Dokulil and Teubner, 2000; Downing et al., 2001; Keller, 1989; Moestrup, 1994; Moisan et al. 2002). These studies were primarily focused on identifying environmental conditions useful in predicting the triggering mechanisms that cause certain phytoplankton to increase explosively, forming blooms (Sommer, 1988). Prediction of single species populations does not allow the prediction of populations of several differet species (Downing et al., 2001; Duarte and Agusti, 1992). When interspecific interactions are included, the single species models become less useful (Rojo et al. 2000; Sommer, 1988). Community assemblage has usually been studied using groups of similar phytoplankton species, such as at the order level. When individual species characteristics are not important to the final model, then grouping according to order makes more sense because species belonging to the same order are very likely to possess many of the same individual traits such as nutrient requirements, growth rates, and occupy many of the same niches and serve many of the same ecological roles as other members of the same order (Goldman, 1969; Sandusky and Horne, 1978). Herein, I have predicted the phytoplankton assemblage of Lake Kemp, as a whole, not just as a collection of single order predictions. This is a novel approach to phytoplankton community assemblage prediction that could be used in future studies of community structure assemblage.

REFERENCES

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. Pages 267-281 *in* Petrov, B. N., and F. Csaki, editors. Second International Symposium on Information Theory. Akademiai Kiado, Budapest.

American Public Health Association (APHA). 1996. Standard methods for the examination of water and wastewater, 24th edition. American Public Health Association, Inc. New York, New York.

American Water Works Association (AWWA). 1990. Water quality and treatment: A handbook of community water supplies, 4 th Edition. McGraw-Hill, New York, New York.

Anderson, T. R. 1993. A spectrally averaged model of light penetration and photosynthesis. Limnology and Oceanography 38:1403-1419.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and multimodel inference, 2nd edition. Springer, New York, New York.

Cole, G. A. 1983. Textbook of limnology, 3rd Edition. Waveland Press Inc. Prospect Heights, Illinois.

Dokulil, M. T., and K. Teubner. 2000. Cyanobacterial dominance in lakes. Hydrobiologia 438:1-12.

Downing, J. A., S. B. Watson, and E. McCauley. 2001. Predicting cyanobacteria dominance in lakes. Canadian Journal of Fisheries and Aquatic Sciences 58:1905-1908.

Duarte, C. M., and S. Agusti. 1992. Patterns in phytoplankton community structure in Florida lakes. Limnology and Oceanography 37:155-161.

Elser, J. J., F. S. Lubnow, E. R. Marzolf, M. T. Brett, G. Dion, and C. R. Goldman. 1995. Factors associated with interannual and intraannual variation in nutrient limitation of phytoplankton growth in Castle Lake, California. Canadian Journal of Fisheries and Aquatic Sciences 52:93-104.

Falkowski, P. G., Z. Dubinsky, and K. Wyman. 1985. Growth-irradiance relationships in phytoplankton. Limnology and Oceanography 30:311-321.

Fox, J. W. 2004 Effects of algal and herbivore diversity on the partitioning of biomass within and among trophic levels. Ecology 85:549-559.

Furet, J. E., and K. Benson-Evans. 1982. An evaluation of the time required to obtain complete sedimentation of fixed algal particles prior to enumeration. British Phycological Journal 17:253-258.

Gaedeke, A., and U. Sommer 1986. The influence of the frequency of periodic disturbances on the maintenance of phytoplankton diversity. Oecologia 71:25-28.

Goldman, C. R. 1969. Primary productivity in aquatic environments. University of California Press, Berkley, California.

Ground, T. A., and A. W. Groeger. 1994. Chemical classification and trophic characteristics of Texas reservoirs. Lake and Reservoir Management 10:189-201.

Harris, B. B., and J. K. Gwynn Silvey. 1940. Limnological investigation on Texas reservoir lakes. Ecological Monographs 10:111-143.

Holzmann, R. 1993. Seasonal fluctuations in the diversity and compositional stability of phytoplankton communities in small lakes in upper Bavaria. Hydrobiologia 249:101-109.

Hutchinson, G. E. 1967. A treatise on limnology, volume 2 Introduction to lake biology and the limnoplankton. John Wiley and Sons, New York, New York.

Interland, S. J., and S. Kilham. 2001. Limiting resources and and regulation of diversity in phytoplankton communities. Ecology 82:1270-1282.

Joerns, J. O. 1961. Investigation of the sources of natural pollution: Wichita River basin above Lake Kemp, Texas, 1951-1957. U. S. Geological Survey, Water Resources Division, Open File Release No. 62. Austin, Texas.

Keller, A. A. 1989. Modeling the effects of temperature, light, and nutrients on primary productivity: an empirical and a mechanistic approach compared. Limnology and Oceanography 34:82-95.

Kimmel, B. L., O. T. Lind, and L. J. Paulson. 1990. Reservoir primary productivity. Pages 133-193, *in* Thornton, K. W., B. L. Kimmel, and F. E. Payne, editors. Reservoir limnology: ecological perspectives. John Wiley and Sons, New York, New York.

Makulla, A., and U. Sommer. 1993. Relationships between resource ratios and phytoplankton species composition during spring in five north German lakes. Limnology and Oceanography 38:846-856.

Moestrup, O. 1994. Economic aspects: 'blooms', nuisance species, and toxins. Pages 265-285 *in* Green, J. C., and B. S. C. Leadbeater, editors. The haptophyte algae. Clarendon Press, Oxford.

Moisan, J. R., T. A. Moisan, and M. R. Abbott. 2002. Modelling the effect of temperature on the maximum growth rates of phytoplankton populations. Ecological Modeling 153:197-215.

Nozaki, K. 2001. Abrupt change in primary productivity in a littoral zone of Lake Biwa with the development of a filamentous green-algal community. Freshwater Biology 46:587-602.

Padisak, J. 1993. The influence of different disturbance frequencies on the species richness, diversity, and equitability of phytoplankton in shallow lakes. Hydrobiologia 248:135-156.

Paxinos, R., and J. G. Mitchell. 2000. A rapid Utermöhl method for estimating algal numbers. Journal of Plankton Research 22:2255-2262.

Ramos, M. G. 1995. Texas almanac, 1996-1997. The Dallas Morning News, Dallas, Texas.

Reigman, R., and L.R. Mur. 1986. Phytoplankton growth and phosphate uptake (for P limitation) by natural phytoplankton populations from the Loosdrecht lakes (The Netherlands). Limnology and Oceanography 31:983-988.

Reynolds, C. S. 2000. Phytoplankton designer - or how to predict compositional responses to trophic-state change. Hydrobiologia 424:123-132.

Reynolds, C., M. Dokulil, and J. Padisak. 2000. Understanding the assembly of phytoplankton in relation to the trophic spectrum: where are we now? Hydrobiologia 424:147-152.

Rojo, C., and M. Alvarez-Cobelas. 2000. A plea for more ecology in phytoplankton ecology. Hydrobiologia 424:133-139.

Rojo, C., E. Ortega-Mayagoitia, and M. Alvarez-Cobelas. 2000. Lack of pattern among phytoplankton assemblages. Hydrobiologia 424:133-139.

Roxburgh, S. H., K. Shea, and J. B. Wilson. 2004 The intermediate disturbance hypothesis: patch dynamics and mechanisms of species coexistence. Ecology 85:359-371.

Sandusky, J. C., and A. J. Horne. 1978. A pattern analysis of Clear Lake phytoplankton. Limnology and Oceanography 23:636-648.

Sommer, U. 1988. Phytoplankton succession in microcosm experiments under simultaneous grazing pressure and resource limitation. Limnology and Oceanography 33:1037-1045.

Sommer, U. 1993. Disturbance-diversity relationships in two lakes of similar nutrient chemistry but contrasting disturbance regimes. Hydrobiologia 249:59-65.

Sommer, U. 1996. Plankton ecology: the past two decades of progress. Naturwissenschaften 83:293-301.

Sommer, U. Z. M. Gliwicz, W. Lampert, and A. Duncan. 1986. The PEG-model of seasonal succession of planktonic events in freshwaters. Archiv für Hydrobiologia 106:433-471.

Thornton, K.W., R.H. Kennedy, A.D. Magoun, and G.E. Saul. 1982. Reservoir water quality sampling design. Water Resources Bulletin 18:471-480.

U. S. Army Corps of Engineers (USACOE). 1994. Draft supplement I to the final environmental statement: Red River Chloride Control Project Texas and Oklahoma. Tulsa District, U. S. Army Corps of Engineers, Tulsa, Oklahoma.

Vanni, M. J. and C. D. Layne. 1997. Nutrient recycling and herbivory as mechanisms in the “top-down” effect of fish on algae in lakes. Ecology 78:21-40.

Wilde, G. R. 1997. Limnological survey of Lake Kemp, Texas: 1997. Final Report Submitted to the U.S. Army Corps of Engineers, Tulsa District.

Xu, Q. S., Y. Z. Liang, and H. L. Shen. 2001. Generalized PLS regression. Journal of Chemometrics 15:135-148.

Table 1.1. Statistical data from site to site comparison of total cell counts.

Group	Degrees of Freedom	F	Pr>F
Cyanophytes	4	0.31	0.86
Cryptophytes	4	1.69	0.16
Diatoms	4	0.46	0.76
Euglenophytes	4	3.4	0.1
Chlorophytes	4	0.31	0.87

Table 1.2. Akaike information criterion scores from regression models of phytoplankton community composition based on temperature, total nitrogen concentration, and total phosphorus concentration.

Variables	AIC
Temperature	-35.0
Total nitrogen	-35.37
Total phosphorus	-35.13
Temperature and nitrogen	-32.9
Temperature and phosphorus	-32.9

Phosphorus and nitrogen	-32.93
Temperature, phosphorus and nitrogen	-30.7

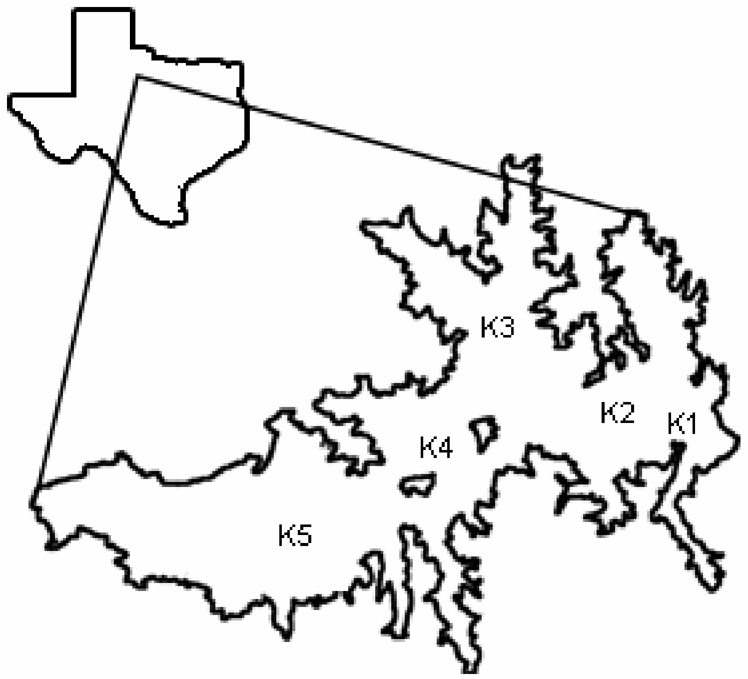


Figure 1. Map of Lake Kemp, Texas showing the five study sites K1 through K5.

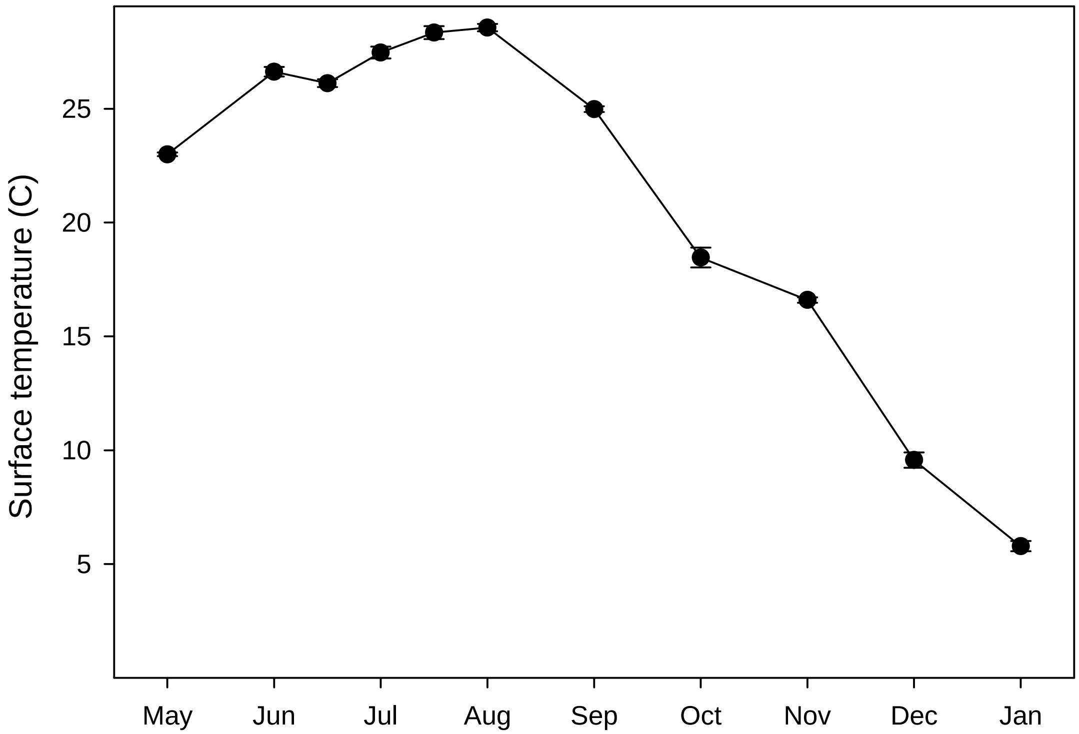


Figure 2. Mean surface temperatures from sites K1 through K5 (± SE) in Lake Kemp, Texas, 2001 through 2002.

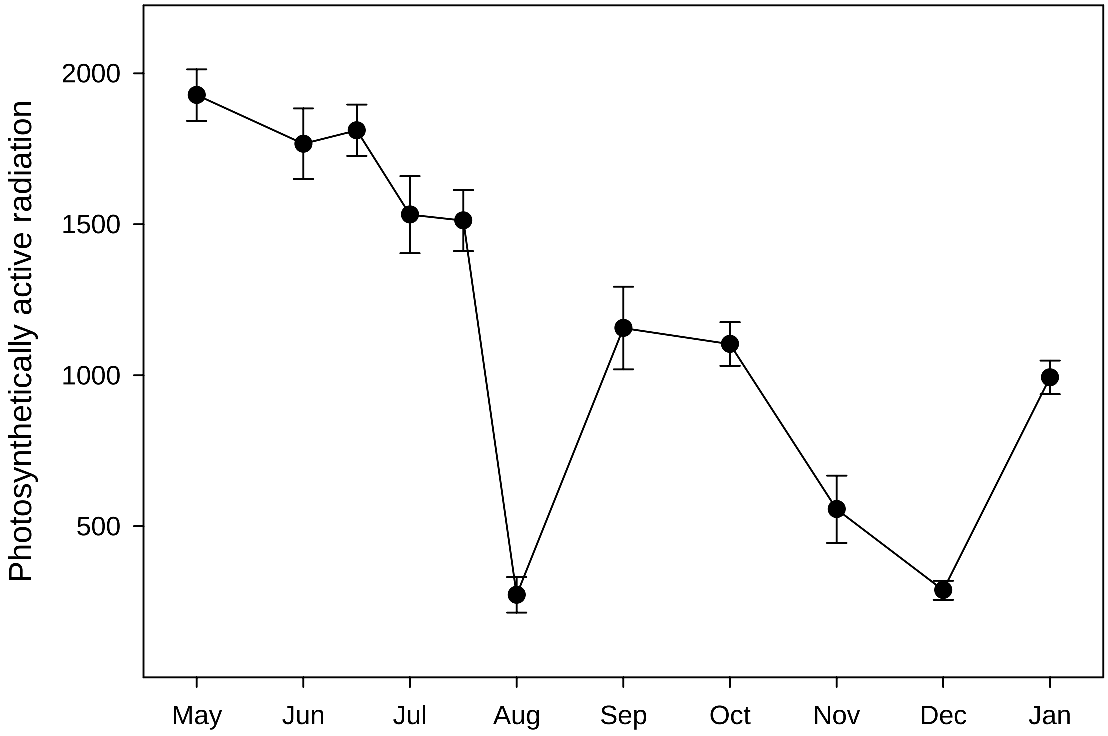


Figure 3. Mean surface photosynthetically active radiation from sites K1 through K5 (± SE) in Lake Kemp, Texas, 2001 through 2002.

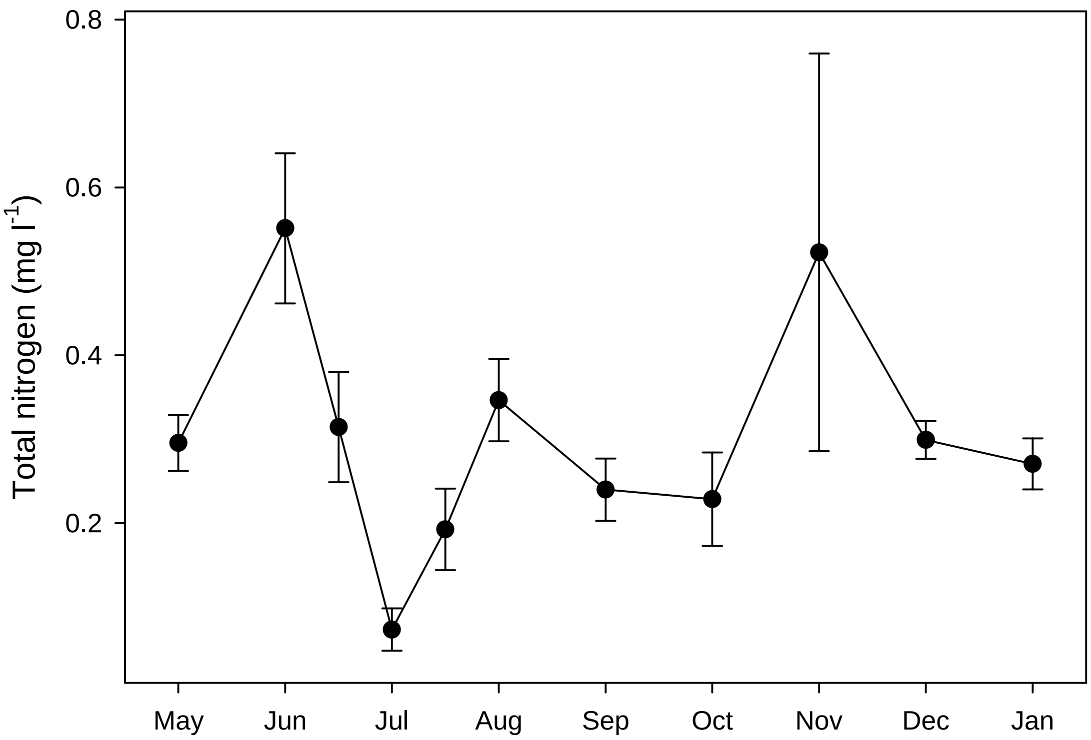


Figure 4. Mean surface total nitrogen concentration from sites K1 through K5 (± SE) in Lake Kemp, Texas, 2001 through 2002.

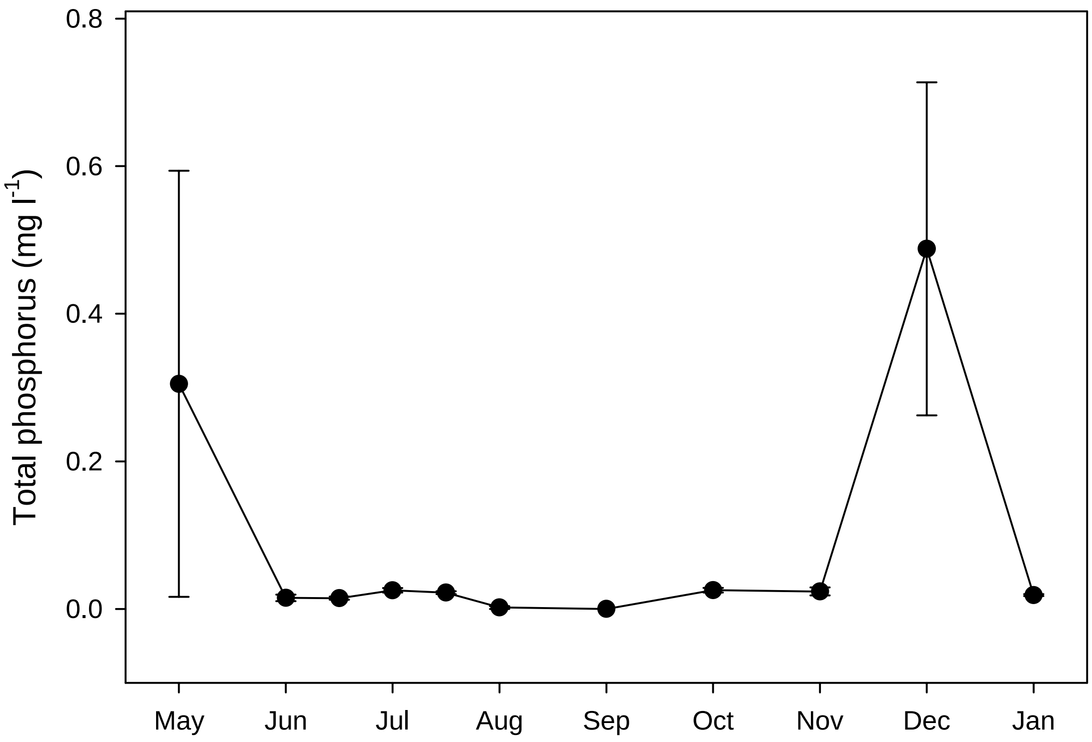


Figure 5. Mean surface total phosphorus concentration from sites K1 through K5 (± SE) in Lake Kemp, Texas, 2001 through 2002.

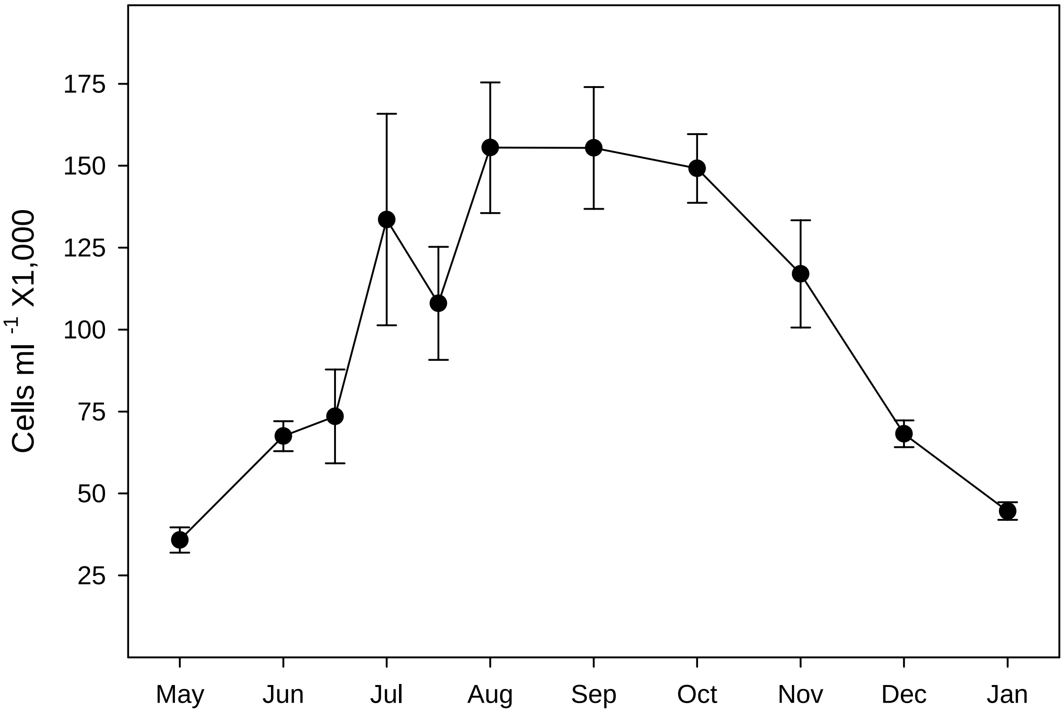


Figure 6. Total phytoplankton cell counts (± SE) in Lake Kemp, Texas, 2001 through 2002.

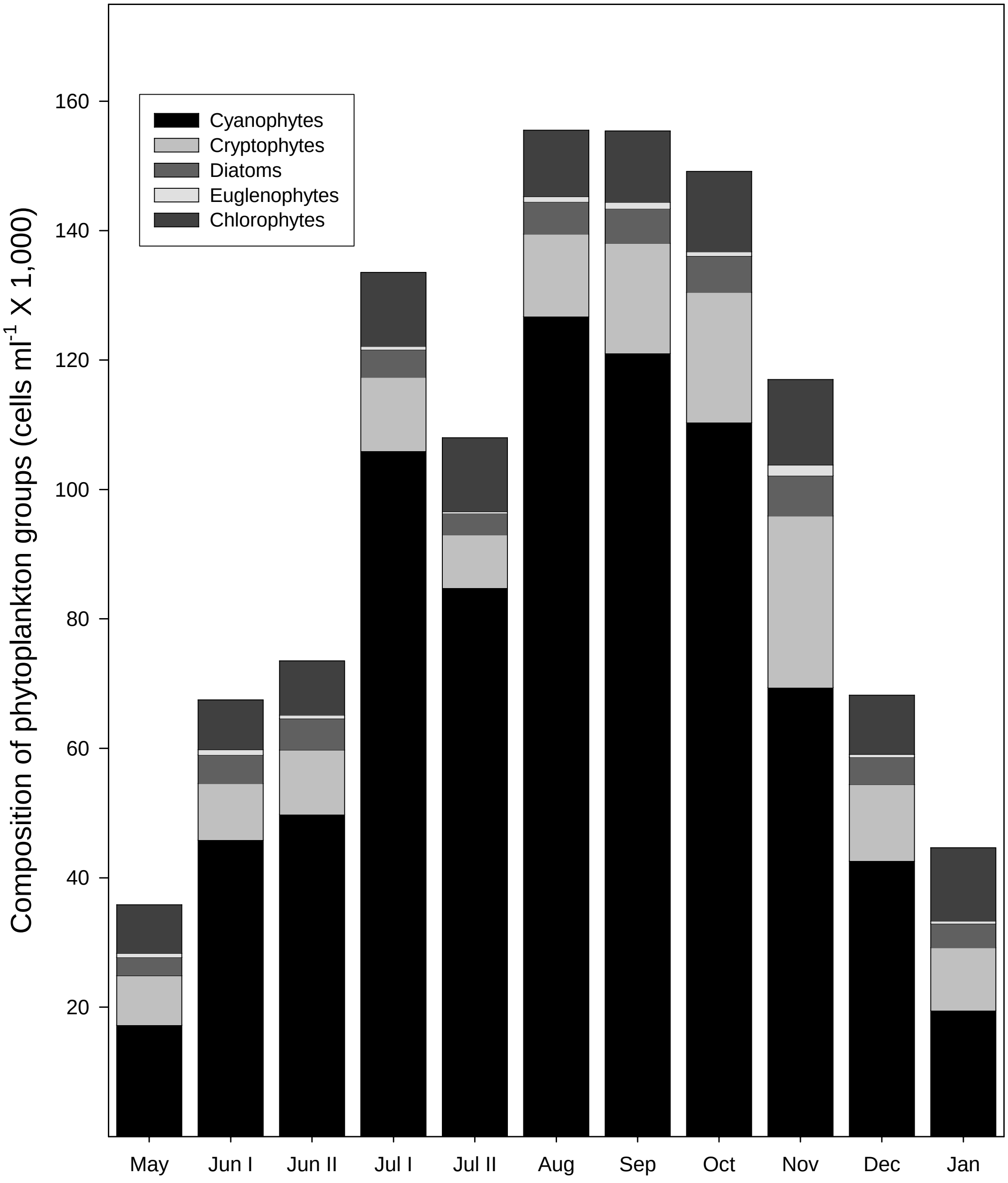


Figure 7. Relative abundance of phytoplankton groups in Lake Kemp, Texas, 2001 through 2002.

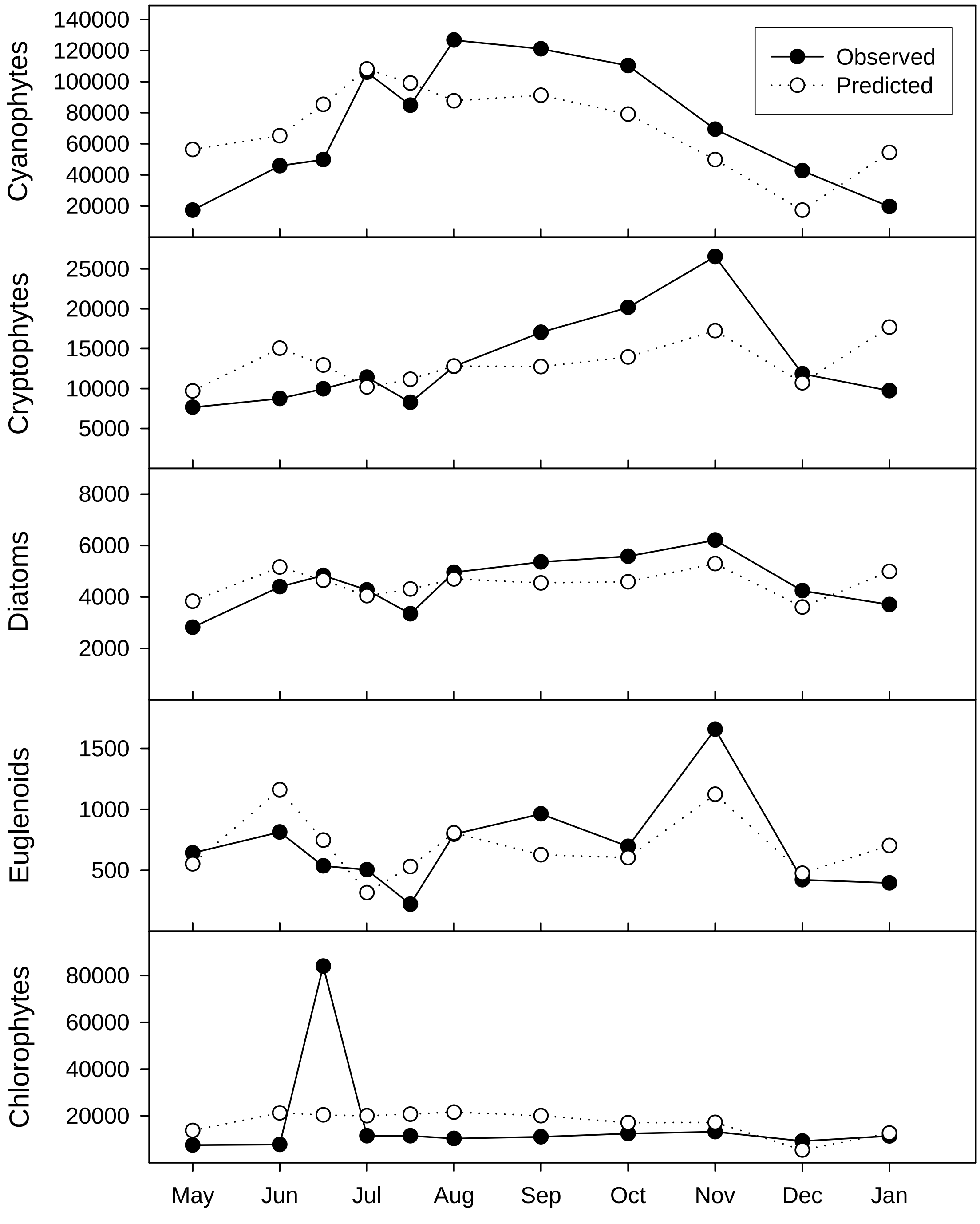


Figure 8. Predicted cell counts using partial least squares of the three variable model containing temperature, total phosphorus, and total nitrogen with the observed phytoplankton cell counts (cells ml^{-1}) in Lake Kemp, Texas, 2001 through 2002.

APPENDIX A

LIST OF PHYTOPLANKTON PRESENT

Table A.1. Phytoplankton families and genera found in Lake Kemp, Texas.

<u>Chlorophyta</u>
Carteria
Chlamydomonas
Chlorocapsa
Chloroccoccum
Coelastrum
Cosmarium
Crucigenia
Ankistrodesmus
Franceia
Golenkinia
Lagerheima (Chodatella)
Oocystis
Planktonema
Scenedesmus
Tetraedron
Tetrastrum

<u>Cryptophyta</u>
Cryptomonas
Rhodomonas
Trachelomonas

<u>Euglenophyta</u>
Lepocinclis
Phacus
Euglena

<u>Cyanophyceae</u>
Anabaena
Anabaenopsis
Anacystis
Chroococcus
Spirulina

<u>Cyanophyceae</u>
Dactylococcopsis
Gleocapsa
Gomphoshpearia

Table A.1. continued

Lyngbya
Oscillitoria
Merismopedia
Phormidium
Pseudanabaena
Raphidiopsis

<u>Bacillariophyceae</u>
Achnanthes
Chaetocerus
Cocconies
Cyclotella
Navicula
Nitzschia
Rhizoselenia
Synedra
Stenopterobia
Surirella

APPENDIX B

TOTAL PHYTOPLANKTON CELL COUNTS

Date

May 23 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	216.7	637.9	687.8	553.7	830.5	585.3	8.1
Chlamydomonas	240.7	108.3	292.3	0.0	252.8	178.8	2.5
Chlorocapsa	2046.1	1504.5	1986.0	2046.1	993.0	1715.1	23.6
Chloroccoccum	385.2	361.1	326.7	300.9	216.7	318.1	4.4
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium	625.9	710.1	154.8	962.9	625.9	615.9	8.5
Crucigenia	288.9	0.0	584.6	276.8	565.7	343.2	4.7
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Franceia	0.0	0.0	0.0	108.3	0.0	21.7	0.3
Golenkinia	0.0	0.0	25.8	0.0	397.2	84.6	1.2
Lagerheima	553.7	565.7	859.7	1685.1	1026.1	938.0	12.9
Oocystis	1324.0	1925.8	1874.2	2467.4	659.0	1650.1	22.7
Planktonema	132.4	0.0	0.0	0.0	0.0	26.5	0.4
Scenedesmus	0.0	0.0	0.0	433.3	481.4	182.9	2.5
Tetraedron	180.5	385.2	653.4	650.0	631.9	500.2	6.9
Tetrastrum	0.0	144.4	103.2	0.0	288.9	107.3	1.5
Cryptophyta							
Cryptomonas	493.5	1287.9	1530.3	2359.1	2978.9	1729.9	31.6
Rhodomonas	637.9	650.0	1874.2	914.7	1817.5	1178.9	21.5
Trachelomonas	252.8	204.6	111.8	397.2	96.3	212.5	3.9
Euglenophyta							
Lepocinclis	96.3	36.1	214.9	216.7	306.9	174.2	32.1
Phacus	216.7	276.8	283.7	60.2	671.0	301.7	55.5
Euglena	0.0	0.0	0.0	276.8	60.2	67.4	12.4
Cyanophyceae							
Anabaena	938.8	3827.5	1599.1	0.0	938.8	1460.8	8.5
Anabaenopsis	481.4	216.7	257.9	0.0	216.7	234.5	1.4
Anacystis	902.7	794.4	567.4	3550.7	3556.7	1874.4	11.0
Chroococcus	361.1	1961.9	4255.6	1925.8	1251.8	1951.2	11.4
Spirulina	0.0	60.2	0.0	758.3	0.0	163.7	1.0
Dactylococcopsis	168.5	120.4	214.9	337.0	541.6	276.5	1.6
Gleocapsa	1649.0	3309.9	1186.4	1324.0	2208.6	1935.6	11.3
Gomphoshpearia	2347.0	3213.6	7617.2	4405.2	3583.8	4233.4	24.8
Lyngbya	974.9	2527.6	541.6	0.0	2202.6	1249.4	7.3
Oscillatoria	0.0	361.1	2708.1	0.0	0.0	613.8	3.6
Merismopedia	1925.8	674.0	997.3	3213.6	6553.7	2672.9	15.6
Phormidium	1263.8	325.0	0.0	0.0	577.7	433.3	2.5
Pseudanabaena	6355.1	7703.1	11425.7	5729.2	3637.9	6970.2	40.8
Raphidiopsis	0.0	96.3	0.0	517.6	857.6	294.3	1.7
Bacillariophyceae							

Date

May 23 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Achnanthes	60.2	156.5	507.2	734.2	153.5	322.3	10.9
Chatoceros	0.0	36.1	0.0	0.0	261.8	59.6	2.0
Cocconies	674.0	589.8	636.2	2010.0	1808.4	1143.7	38.8
Cyclotella	637.9	349.0	103.2	2660.0	728.2	895.7	30.4
Navicula	72.2	180.5	283.7	373.1	460.4	274.0	9.3
Nitzschia	0.0	0.0	0.0	72.2	45.1	23.5	0.8
Rhizoselenia	0.0	0.0	0.0	505.5	0.0	101.1	3.4
Synedra	216.7	0.0	25.8	252.8	1053.2	309.7	10.5
Stenopterobia	0.0	0.0	0.0	0.0	36.1	7.2	0.2
Surirella	36.1	0.0	60.2	0.0	126.4	44.5	1.5

Date
June 11 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	1354.1	1233.7	1552.7	1287.9	1066.4	1298.9	17.0
Chlamydomonas	225.7	601.8	216.7	180.5	390.0	322.9	4.2
Chlorocapsa	1534.6	1745.2	1143.4	782.3	481.4	1137.4	14.9
Chloroccoccum	421.3	270.8	349.0	553.7	120.4	343.0	4.5
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium	451.4	662.0	1011.0	1311.9	1138.6	915.0	12.0
Crucigenia	902.7	240.7	240.7	240.7	481.4	421.3	5.5
Ankistrodesmus	120.4	0.0	0.0	1263.8	315.3	339.9	4.5
Franceia	0.0	0.0	0.0	0.0	14.4	2.9	0.0
Golenkinia	45.1	60.2	120.4	120.4	89.1	87.0	1.1
Lagerheima	270.8	541.6	0.0	397.2	1056.8	453.3	5.9
Oocystis	1113.3	902.7	3093.3	1504.5	1439.5	1610.7	21.1
Planktonema	0.0	0.0	0.0	0.0	60.2	12.0	0.2
Scenedesmus	90.3	481.4	240.7	120.4	14.4	189.4	2.5
Tetraedron	391.2	391.2	782.3	240.7	418.9	444.9	5.8
Tetrastrum	120.4	120.4	0.0	0.0	14.4	51.0	0.7
Cryptophyta							
Cryptomonas	1670.0	2557.7	1396.2	999.0	835.3	1491.6	25.3
Rhodomonas	1955.9	2076.2	2708.1	1504.5	912.3	1831.4	31.0
Trachelomonas	0.0	270.8	36.1	541.6	175.7	204.9	3.5
Euglenophyta							
Lepocinclis	376.1	270.8	373.1	180.5	240.7	288.3	45.4
Phacus	586.8	451.4	156.5	0.0	240.7	287.1	45.2
Euglena	0.0	90.3	0.0	0.0	207.0	59.5	9.4
Cyanophyceae							
Anabaena	481.4	120.4	0.0	3719.2	130.0	890.2	1.9
Anabaenopsis	0.0	0.0	0.0	0.0	231.1	46.2	0.1
Anacystis	4468.4	12216.7	6379.2	3129.4	1001.4	5439.0	11.8
Chroococcus	1173.5	3129.4	2611.8	2647.9	4754.3	2863.4	6.2
Spirulina	180.5	0.0	60.2	0.0	14.4	51.0	0.1
Dactylococcopsis	646.9	270.8	288.9	132.4	575.3	382.9	0.8
Gleocapsa	872.6	812.4	0.0	481.4	3105.3	1054.4	2.3
Gomphoshpearia	6048.2	12427.3	7161.5	7173.5	4176.5	7397.4	16.1
Lyngbya	8891.7	7402.2	9508.5	17837.5	10676.0	10863.2	23.6
Oscillatoria	7492.5	9087.3	14298.9	11374.1	6333.4	9717.3	21.1
Merismopedia	3971.9	7462.4	8148.5	7125.4	9628.9	7267.4	15.8
Phormidium	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudanabaena	511.5	2106.3	758.3	7618.9	3608.4	2920.7	6.4
Raphidiopsis	391.2	180.5	180.5	361.1	337.0	290.1	0.6
Bacillariophyceae							

Date June 11 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Achnanthes	240.7	300.9	421.3	276.8	459.8	339.9	7.8
Chatoceros	376.1	842.5	613.8	361.1	298.5	498.4	11.4
Cocconies	1354.1	2136.4	1432.3	1721.2	1865.6	1701.9	39.0
Cyclotella	421.3	662.0	866.6	276.8	532.0	551.7	12.6
Navicula	180.5	300.9	385.2	433.3	320.2	324.0	7.4
Nitzschia	0.0	120.4	60.2	0.0	72.2	50.6	1.2
Rhizoselenia	0.0	0.0	36.1	0.0	144.4	36.1	0.8
Synedra	1188.6	902.7	938.8	987.0	337.0	870.8	19.9
Stenopterobia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Date
June 25 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	854.6	1119.4	719.8	1003.8	1333.6	1006.2	12.9
Chlamydomonas	108.3	0.0	192.6	149.2	455.0	181.0	2.3
Chlorocapsa	662.0	842.5	662.0	361.1	120.4	529.6	6.8
Chloroccoccum	409.2	180.5	120.4	120.4	451.4	256.4	3.3
Coelastrum	0.0	0.0	0.0	28.9	0.0	5.8	0.1
Cosmarium	902.7	529.6	729.4	840.1	2075.0	1015.4	13.0
Crucigenia	529.6	240.7	1983.6	1107.3	1097.7	991.8	12.7
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Franceia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golenkinia	0.0	601.8	43.3	28.9	86.7	152.1	2.0
Lagerheima	349.0	252.8	618.7	144.4	216.7	316.3	4.1
Oocystis	1131.4	1769.3	1478.0	1875.2	2557.7	1762.3	22.6
Planktonema	60.2	60.2	505.5	433.3	491.1	310.1	4.0
Scenedesmus	481.4	288.9	240.7	958.1	57.8	405.4	5.2
Tetraedron	1011.0	974.9	669.2	510.3	849.8	803.1	10.3
Tetrastrum	0.0	288.9	0.0	0.0	0.0	57.8	0.7
Cryptophyta							
Cryptomonas	1107.3	1275.8	1670.6	1559.9	1569.5	1436.6	23.6
Rhodomonas	1324.0	1227.7	1080.8	1535.8	2975.3	1628.7	26.7
Trachelomonas	96.3	565.7	390.0	476.6	1516.6	609.0	10.0
Euglenophyta							
Lepocinclis	180.5	60.2	14.4	221.5	252.8	145.9	62.3
Phacus	156.5	120.4	0.0	60.2	0.0	67.4	28.8
Euglena	0.0	60.2	0.0	0.0	43.3	20.7	8.8
Cyanophyceae							
Anabaena	3129.4	1769.3	4463.0	3379.7	20239.6	6596.2	13.0
Anabaenopsis	288.9	0.0	996.6	1054.4	2885.1	1045.0	2.1
Anacystis	1998.0	2768.3	782.3	1083.3	1155.5	1557.5	3.1
Chroococcus	4008.0	3526.6	902.7	2135.2	1612.8	2437.1	4.8
Spirulina	0.0	0.0	0.0	0.0	144.4	28.9	0.1
Dactylococcopsis	613.8	252.8	86.7	60.2	402.0	283.1	0.6
Gleocapsa	2046.1	2106.3	3731.2	662.0	1943.8	2097.9	4.1
Gomphoshpearia	3550.7	5969.9	2063.0	2787.6	19058.1	6685.9	13.1
Lyngbya	6752.3	13540.6	8786.4	8750.3	17123.8	10990.7	21.6
Oscillatoria	16020.1	7318.0	6593.4	14361.5	22327.0	13324.0	26.2
Merismopedia	3947.9	5247.8	3639.7	4289.7	10765.1	5578.0	11.0
Phormidium	0.0	1516.6	0.0	0.0	1805.4	664.4	1.3
Pseudanabaena	7125.4	8437.3	25076.1	29890.5	35773.8	21260.6	41.7
Raphidiopsis	120.4	361.1	144.4	247.9	86.7	192.1	0.4
Bacillariophyceae							

Date June 25 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Achnanthes	794.4	433.3	1153.1	702.9	733.0	763.3	16.8
Chatoceros	264.8	325.0	293.7	536.8	1207.2	525.5	11.6
Cocconies	1793.4	1588.8	1011.0	1234.9	1783.8	1482.4	32.6
Cyclotella	1155.5	2010.0	402.0	808.8	548.8	985.0	21.7
Navicula	409.2	276.8	264.8	247.9	1245.7	488.9	10.8
Nitzschia	0.0	0.0	72.2	57.8	0.0	26.0	0.6
Rhizoselenia	0.0	0.0	14.4	0.0	43.3	11.6	0.3
Synedra	156.5	300.9	202.2	563.3	749.9	394.5	8.7
Stenopterobia	60.2	0.0	0.0	0.0	14.4	14.9	0.3
Surirella	96.3	120.4	161.3	0.0	132.4	102.1	2.2

Date
July 9 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	65.0	1278.2	1011.0	1299.9	2142.4	1159.3	11.8
Chlamydomonas	108.3	344.2	240.7	252.8	288.9	247.0	2.5
Chlorocapsa	0.0	421.3	902.7	686.1	782.3	558.5	5.7
Chloroccoccum	455.0	209.4	589.8	288.9	204.6	349.5	3.6
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium	1343.2	536.8	276.8	385.2	1155.5	739.5	7.5
Crucigenia	3206.4	1068.8	2166.5	1299.9	914.7	1731.3	17.6
Ankistrodesmus	0.0	86.7	445.3	0.0	0.0	106.4	1.1
Franceia	0.0	14.4	0.0	0.0	0.0	2.9	0.0
Golenkinia	65.0	149.2	276.8	36.1	240.7	153.6	1.6
Lagerheima	86.7	223.9	337.0	337.0	168.5	230.6	2.3
Oocystis	563.3	2790.0	2250.8	2780.3	3731.2	2423.1	24.7
Planktonema	2729.8	332.2	0.0	0.0	0.0	612.4	6.2
Scenedesmus	325.0	481.4	457.4	288.9	0.0	310.5	3.2
Tetraedron	801.6	1013.4	1588.8	1119.4	1384.2	1181.5	12.0
Tetrastrum	0.0	0.0	36.1	0.0	36.1	14.4	0.1
Cryptophyta							
Cryptomonas	1256.6	1237.3	1793.4	950.9	2142.4	1476.1	20.8
Rhodomonas	1126.6	1593.6	1480.4	746.2	3322.0	1653.8	23.3
Trachelomonas	1234.9	455.0	397.2	144.4	144.4	475.2	6.7
Euglenophyta							
Lepocinclis	43.3	120.4	108.3	228.7	337.0	167.5	45.0
Phacus	86.7	134.8	120.4	385.2	96.3	164.7	44.2
Euglena	21.7	60.2	60.2	0.0	60.2	40.4	10.9
Cyanophyceae							
Anabaena	27774.6	2556.5	7257.8	22808.5	28405.3	17760.5	16.3
Anabaenopsis	1494.9	57.8	180.5	0.0	902.7	527.2	0.5
Anacystis	8016.1	15582.0	30824.5	7667.0	12987.0	15015.3	13.8
Chroococcus	498.3	842.5	1937.8	2286.9	4934.8	2100.1	1.9
Spirulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dactylococcopsis	585.0	411.6	830.5	3971.9	2126.4	1585.1	1.5
Gleocapsa	1213.2	0.0	1540.6	842.5	806.4	880.6	0.8
Gomphoshpearia	1473.2	5794.2	4152.5	6788.4	6920.8	5025.8	4.6
Lyngbya	606.6	14843.0	17789.4	15785.4	27966.8	15398.2	14.1
Oscillatoria	14060.6	19301.1	28694.1	31606.0	137500.0	46232.5	42.5
Merismopedia	2946.4	3776.9	2985.0	6824.5	2455.4	3797.6	3.5
Phormidium	0.0	1107.3	216.7	782.3	782.3	577.7	0.5
Pseudanabaena	11742.5	28424.5	37516.6	46158.6	35157.5	31799.9	29.2
Raphidiopsis	21.7	284.1	361.1	156.5	361.1	236.9	0.2
Bacillariophyceae							

Date
July 9 2001

	Sites						
Species	K1	K2	K3	K4	K5	Mean	% Total
Achnanthes	281.6	252.8	409.2	457.4	1432.3	566.7	14.6
Chatoceros	541.6	1249.4	794.4	722.2	758.3	813.2	21.0
Cocconies	693.3	2339.8	758.3	577.7	794.4	1032.7	26.7
Cyclotella	108.3	481.4	180.5	421.3	517.6	341.8	8.8
Navicula	130.0	192.6	517.6	288.9	734.2	372.6	9.6
Nitzschia	108.3	28.9	216.7	240.7	300.9	179.1	4.6
Rhizoselenia	21.7	60.2	60.2	60.2	0.0	40.4	1.0
Synedra	238.3	209.4	541.6	830.5	517.6	467.5	12.1
Stenopterobia	0.0	0.0	0.0	60.2	0.0	12.0	0.3
Surirella	21.7	74.6	120.4	0.0	180.5	79.4	2.1

Date
July 23 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	1413.0	1203.6	1263.8	1685.1	1065.2	1326.1	13.8
Chlamydomonas	74.6	90.3	120.4	240.7	577.7	220.7	2.3
Chlorocapsa	1384.2	993.0	962.9	1865.6	541.6	1149.5	11.9
Chloroccoccum	134.8	601.8	298.5	932.8	433.3	480.2	5.0
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium	1064.0	722.2	929.2	1113.3	758.3	917.4	9.5
Crucigenia	885.9	962.9	471.8	361.1	361.1	608.5	6.3
Ankistrodesmus	0.0	0.0	57.8	120.4	0.0	35.6	0.4
Franceia	57.8	0.0	0.0	0.0	0.0	11.6	0.1
Golenkinia	255.2	0.0	0.0	120.4	90.3	93.2	1.0
Lagerheima	312.9	421.3	447.7	150.5	108.3	288.1	3.0
Oocystis	1367.3	2347.0	2067.8	2256.8	938.8	1795.6	18.6
Planktonema	0.0	0.0	14.4	0.0	90.3	20.9	0.2
Scenedesmus	0.0	240.7	8184.6	361.1	722.2	1901.7	19.7
Tetraedron	565.7	872.6	746.2	812.4	595.8	718.6	7.5
Tetrastrum	0.0	120.4	0.0	240.7	0.0	72.2	0.7
Cryptophyta							
Cryptomonas	982.1	1173.5	1372.1	962.9	1065.2	1111.2	21.5
Rhodomonas	1157.9	1173.5	1391.4	782.3	2022.1	1305.4	25.2
Trachelomonas	158.9	90.3	86.7	90.3	379.1	161.0	3.1
Euglenophyta							
Lepocinclis	60.2	60.2	0.0	180.5	108.3	81.8	61.8
Phacus	103.5	60.2	14.4	30.1	0.0	41.6	31.5
Euglena	14.4	0.0	0.0	30.1	0.0	8.9	6.7
Cyanophyceae							
Anabaena	7036.3	5055.2	3047.5	12317.0	16393.2	8769.8	10.0
Anabaenopsis	0.0	993.0	245.5	1324.0	1679.0	848.3	1.0
Anacystis	3456.8	15647.0	4337.8	12186.6	7835.5	8692.7	10.0
Chroococcus	1526.2	842.5	2130.4	1384.2	1480.4	1472.7	1.7
Spirulina	0.0	0.0	361.1	0.0	0.0	72.2	0.1
Dactylococcopsis	305.7	3610.8	120.4	1113.3	1354.1	1300.9	1.5
Gleocapsa	594.6	782.3	842.5	872.6	0.0	618.4	0.7
Gomphoshpearia	13865.6	10802.4	6444.1	10110.4	7366.1	9717.7	11.1
Lyngbya	9518.2	14383.2	8894.7	25847.6	34230.8	18574.9	21.3
Oscillatoria	21195.6	17482.5	8590.8	64583.9	39257.6	30222.1	34.6
Merismopedia	8873.0	4754.3	3589.2	5295.9	4928.8	5488.2	6.3
Phormidium	1685.1	1865.6	541.6	1685.1	1895.7	1534.6	1.8
Pseudanabaena	34659.2	31805.5	33997.3	33881.7	34628.0	33794.3	38.7
Raphidiopsis	524.8	1414.2	782.3	571.7	866.6	831.9	1.0
Bacillariophyceae							

Date

July 23 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Achnanthes	178.1	601.8	60.2	331.0	704.1	375.0	11.9
Chatoceros	361.1	662.0	929.2	662.0	469.4	616.7	19.6
Cocconies	717.4	571.7	507.9	962.9	1245.7	801.1	25.5
Cyclotella	743.8	451.4	539.2	150.5	90.3	395.0	12.6
Navicula	134.8	30.1	221.5	782.3	216.7	277.1	8.8
Nitzschia	72.2	90.3	195.0	150.5	451.4	191.9	6.1
Rhizoselenia	0.0	0.0	14.4	60.2	144.4	43.8	1.4
Synedra	60.2	451.4	361.1	391.2	650.0	382.7	12.2
Stenopterobia	0.0	120.4	0.0	0.0	54.2	34.9	1.1
Surirella	134.8	0.0	0.0	0.0	54.2	37.8	1.2

Date
August 14 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	1248.7	1203.6	1143.4	1324.0	3309.9	1645.9	16.1
Chlamydomonas	406.2	857.0	662.0	878.6	1564.7	873.7	8.6
Chlorocapsa	1278.8	390.0	481.4	385.2	1685.1	844.1	8.3
Chloroccoccum	1053.2	180.5	782.3	854.6	993.0	772.7	7.6
Coelastrum	0.0	120.4	0.0	120.4	0.0	48.1	0.5
Cosmarium	331.0	1177.1	662.0	1047.1	1203.6	884.2	8.7
Crucigenia	1083.3	57.8	481.4	1709.1	1444.3	955.2	9.4
Ankistrodesmus	902.7	479.0	300.9	240.7	0.0	384.7	3.8
Franceia	0.0	28.9	30.1	36.1	0.0	19.0	0.2
Golenkinia	165.5	209.4	90.3	0.0	90.3	111.1	1.1
Lagerheima	827.5	358.7	631.9	144.4	842.5	561.0	5.5
Oocystis	1218.7	765.5	1474.4	962.9	1955.9	1275.5	12.5
Planktonema	0.0	0.0	0.0	601.8	0.0	120.4	1.2
Scenedesmus	120.4	0.0	240.7	1011.0	0.0	274.4	2.7
Tetraedron	752.3	784.8	1023.1	1179.5	2738.2	1295.6	12.7
Tetrastrum	0.0	0.0	0.0	650.0	0.0	130.0	1.3
Cryptophyta							
Cryptomonas	1324.0	1160.3	1113.3	2250.8	5687.1	2307.1	21.2
Rhodomonas	586.8	1417.9	932.8	1745.2	6499.5	2236.4	20.5
Trachelomonas	0.0	276.8	210.6	0.0	331.0	163.7	1.5
Euglenophyta							
Lepocinclis	105.3	60.2	90.3	252.8	1775.3	456.8	58.4
Phacus	60.2	60.2	150.5	192.6	361.1	164.9	21.1
Euglena	105.3	0.0	30.1	36.1	631.9	160.7	20.5
Cyanophyceae							
Anabaena	5641.9	4359.5	6920.8	6836.5	12367.1	7225.2	5.7
Anabaenopsis	1444.3	1689.9	541.6	5079.2	3520.6	2455.1	1.9
Anacystis	6695.1	13225.3	6680.1	3466.4	12938.8	8601.1	6.8
Chroococcus	315.9	404.4	541.6	962.9	1504.5	745.9	0.6
Spirulina	0.0	0.0	0.0	300.9	0.0	60.2	0.0
Dactylococcopsis	1173.5	1764.5	1608.7	3719.2	1986.0	2050.4	1.6
Gleocapsa	2347.0	1805.4	0.0	16020.1	1203.6	4275.2	3.4
Gomphoshpearia	9102.3	13362.5	8786.4	9484.5	240.7	8195.3	6.5
Lyngbya	29661.5	32997.5	15978.0	8942.8	25155.5	22547.1	17.9
Oscillatoria	36595.6	44109.0	23590.8	53687.0	76081.3	46812.7	37.2
Merismopedia	2407.2	2729.8	2888.7	10555.7	3129.4	4342.2	3.4
Phormidium	16790.4	7809.0	11976.0	40453.4	16248.8	18655.5	14.8
Pseudanabaena	40667.1	30400.9	35386.2	35903.8	53169.6	39105.5	31.0
Raphidiopsis	827.5	1126.6	1504.5	1384.2	1233.7	1215.3	1.0

Date

August 14 2001

Species	Sites K1	K2	K3	K4	K5	Mean	% Total
Bacillariophyceae							
Achnanthes	421.3	885.9	270.8	397.2	1986.0	792.2	15.6
Chatoceros	2091.3	1263.8	1624.9	1420.3	2106.3	1701.3	33.4
Cocconies	496.5	592.2	391.2	746.2	1293.9	704.0	13.8
Cyclotella	0.0	74.6	60.2	72.2	902.7	221.9	4.4
Navicula	120.4	118.0	270.8	252.8	2407.2	633.8	12.5
Nitzschia	0.0	284.1	0.0	180.5	451.4	183.2	3.6
Rhizoselenia	0.0	60.2	0.0	0.0	0.0	12.0	0.2
Synedra	692.1	820.9	692.1	577.7	1203.6	797.3	15.7
Stenopterobia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surirella	0.0	57.8	0.0	0.0	150.5	41.6	0.8

Date

September 16 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	2527.6	2256.8	1925.8	2046.1	1143.4	1979.9	18.4
Chlamydomonas	917.8	361.1	601.8	436.3	722.2	607.8	5.7
Chlorocapsa	2467.4	2347.0	1700.1	1790.4	2226.7	2106.3	19.6
Chloroccoccum	782.3	391.2	451.4	872.6	782.3	656.0	6.1
Coelastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cosmarium	1083.3	1023.1	842.5	631.9	361.1	788.4	7.3
Crucigenia	1203.6	361.1	180.5	421.3	1324.0	698.1	6.5
Ankistrodesmus	421.3	0.0	300.9	511.5	0.0	246.7	2.3
Franceia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golenkinia	180.5	0.0	0.0	60.2	120.4	72.2	0.7
Lagerheima	1203.6	361.1	421.3	782.3	722.2	698.1	6.5
Oocystis	2106.3	872.6	1023.1	1354.1	1324.0	1336.0	12.4
Planktonema	0.0	45.1	0.0	0.0	120.4	33.1	0.3
Scenedesmus	0.0	481.4	361.1	0.0	0.0	168.5	1.6
Tetraedron	2136.4	1429.3	1023.1	1188.6	962.9	1348.0	12.5
Tetrastrum	0.0	0.0	60.2	0.0	0.0	12.0	0.1
Cryptophyta							
Cryptomonas	3776.3	2467.4	2076.2	2332.0	2226.7	2575.7	28.8
Rhodomonas	2091.3	1534.6	1369.1	1113.3	1324.0	1486.5	16.6
Trachelomonas	361.1	180.5	135.4	240.7	60.2	195.6	2.2
Euglenophyta							
Lepocinclis	631.9	466.4	255.8	165.5	300.9	364.1	46.4
Phacus	421.3	180.5	361.1	481.4	240.7	337.0	42.9
Euglena	60.2	0.0	90.3	90.3	180.5	84.3	10.7
Cyanophyceae							
Anabaena	12622.9	7868.6	2798.4	4498.5	9147.5	7387.2	6.1
Anabaenopsis	3159.5	2527.6	2708.1	4453.4	1324.0	2834.5	2.3
Anacystis	23094.3	13826.5	3294.9	9117.4	8666.0	11599.8	9.5
Chroococcus	601.8	812.4	1293.9	1685.1	1745.2	1227.7	1.0
Spirulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dactylococcopsis	2392.2	2542.6	1549.7	1745.2	1624.9	1970.9	1.6
Gleocapsa	3866.6	1835.5	511.5	1895.7	601.8	1742.2	1.4
Gomphoshpearia	10396.2	8485.5	9711.7	4408.2	4453.4	7491.0	6.2
Lyngbya	19152.5	24538.7	16700.1	9252.8	12698.1	16468.4	13.5
Oscillatoria	44684.1	76800.6	29990.0	53393.0	27743.3	46522.2	38.2
Merismopedia	13721.2	9388.2	8966.9	3851.6	3971.9	7980.0	6.6
Phormidium	16263.8	20476.5	13239.7	15782.4	18656.0	16883.7	13.9
Pseudanabaena	42818.5	35957.9	37086.3	42517.6	46459.5	40968.0	33.7
Raphidiopsis	4333.0	3610.8	1564.7	2151.5	2106.3	2753.3	2.3

Date September 16 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Bacillariophyceae							
Achnanthes	2422.3	1128.4	105.3	1128.4	421.3	1041.1	19.1
Chatoceros	767.3	1489.5	962.9	1399.2	541.6	1032.1	19.0
Cocconies	1038.1	872.6	285.9	977.9	541.6	743.2	13.7
Cyclotella	947.8	300.9	556.7	90.3	240.7	427.3	7.8
Navicula	2377.1	1098.3	646.9	1549.7	1444.3	1423.3	26.1
Nitzschia	1248.7	210.6	541.6	541.6	662.0	640.9	11.8
Rhizoselenia	120.4	0.0	0.0	60.2	60.2	48.1	0.9
Synedra	180.5	120.4	0.0	150.5	0.0	90.3	1.7
Stenopterobia	0.0	0.0	0.0	60.2	0.0	12.0	0.2
Surirella	180.5	0.0	0.0	0.0	0.0	36.1	0.7

Date
October 14 2001

	Sites						
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	3144.4	2723.2	3309.9	2888.7	2978.9	3009.0	24.6
Chlamydomonas	120.4	376.1	722.2	722.2	421.3	472.4	3.9
Chlorocapsa	1233.7	1308.9	1444.3	1624.9	1624.9	1447.3	11.8
Chloroccoccum	767.3	436.3	481.4	662.0	662.0	601.8	4.9
Coelastrum	0.0	120.4	240.7	782.3	0.0	228.7	1.9
Cosmarium	752.3	240.7	902.7	722.2	782.3	680.0	5.6
Crucigenia	722.2	1083.3	481.4	962.9	962.9	842.5	6.9
Ankistrodesmus	0.0	0.0	0.0	240.7	0.0	48.1	0.4
Franceia	60.2	0.0	0.0	0.0	0.0	12.0	0.1
Golenkinia	60.2	60.2	240.7	60.2	60.2	96.3	0.8
Lagerheima	406.2	45.1	481.4	300.9	240.7	294.9	2.4
Oocystis	1865.6	1068.2	1203.6	1925.8	1023.1	1417.3	11.6
Planktonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus	0.0	0.0	240.7	0.0	361.1	120.4	1.0
Tetraedron	2362.1	2753.3	2286.9	2647.9	2587.8	2527.6	20.7
Tetrastrum	0.0	0.0	722.2	1203.6	240.7	433.3	3.5
Cryptophyta							
Cryptomonas	2031.1	1624.9	3731.2	3069.2	2557.7	2602.8	33.3
Rhodomonas	616.9	677.0	722.2	902.7	1474.4	878.6	11.2
Trachelomonas	150.5	60.2	0.0	60.2	60.2	66.2	0.8
Euglenophyta							
Lepocinclis	150.5	225.7	541.6	361.1	601.8	376.1	55.6
Phacus	105.3	300.9	120.4	120.4	210.6	171.5	25.3
Euglena	90.3	135.4	180.5	120.4	120.4	129.4	19.1
Cyanophyceae							
Anabaena	3656.0	4694.1	9508.5	1986.0	2527.6	4474.4	4.0
Anabaenopsis	300.9	0.0	0.0	300.9	0.0	120.4	0.1
Anacystis	19333.0	45466.5	22989.0	16670.0	28059.2	26503.6	23.9
Chroococcus	1235.5	4122.4	2888.7	3249.8	2256.8	2750.6	2.5
Spirulina	0.0	0.0	361.1	0.0	0.0	72.2	0.1
Dactylococcopsis	1639.9	1293.9	1624.9	1444.3	1564.7	1513.5	1.4
Gleocapsa	2422.3	1910.7	2347.0	1624.9	1263.8	1913.7	1.7
Gomphoshpearia	6680.1	5010.0	5356.1	4874.6	2587.8	4901.7	4.4
Lyngbya	4530.3	6228.7	9147.5	11193.6	21183.6	10456.7	9.4
Oscillatoria	23861.6	34934.9	64212.8	46078.3	21394.2	38096.4	34.3
Merismopedia	5175.5	6604.8	2768.3	4573.7	3851.6	4594.8	4.1
Phormidium	10290.9	11073.2	18475.5	22327.0	15857.6	15604.8	14.1
Pseudanabaena	40727.3	40095.4	40682.1	32798.5	42577.8	39376.2	35.5
Raphidiopsis	2768.3	2467.4	2768.3	2046.1	1414.2	2292.9	2.1

Date

October 14 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Bacillariophyceae							
Achnanthes	1986.0	857.6	782.3	662.0	812.4	1020.1	18.7
Chatoceros	210.6	346.0	120.4	120.4	722.2	303.9	5.6
Cocconies	993.0	1173.5	1263.8	1083.3	812.4	1065.2	19.5
Cyclotella	1865.6	1369.1	2286.9	2347.0	1233.7	1820.5	33.4
Navicula	902.7	616.9	902.7	421.3	1745.2	917.8	16.8
Nitzschia	466.4	707.1	361.1	120.4	180.5	367.1	6.7
Rhizoselenia	60.2	60.2	60.2	0.0	0.0	36.1	0.7
Synedra	180.5	105.3	0.0	60.2	180.5	105.3	1.9
Stenopterobia	0.0	0.0	0.0	60.2	0.0	12.0	0.2
Surirella	105.3	90.3	60.2	0.0	60.2	63.2	1.2

Date
November 18 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	3896.7	4453.4	3671.0	2467.4	2004.0	3298.5	24.7
Chlamydomonas	541.6	361.1	240.7	285.9	325.0	350.9	2.6
Chlorocapsa	1308.9	2647.9	2166.5	1384.2	1931.8	1887.9	14.1
Chloroccoccum	586.8	962.9	1023.1	331.0	90.3	598.8	4.5
Coelastrum	255.8	0.0	0.0	0.0	0.0	51.2	0.4
Cosmarium	1113.3	1083.3	601.8	331.0	180.5	662.0	5.0
Crucigenia	421.3	1444.3	1083.3	1038.1	0.0	797.4	6.0
Ankistrodesmus	0.0	0.0	240.7	0.0	0.0	48.1	0.4
Franceia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golenkinia	60.2	180.5	0.0	0.0	90.3	66.2	0.5
Lagerheima	346.0	601.8	481.4	556.7	270.8	451.4	3.4
Oocystis	3701.1	2286.9	2828.5	1053.2	361.1	2046.1	15.3
Planktonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus	240.7	361.1	601.8	0.0	433.3	327.4	2.5
Tetraedron	3806.4	3430.3	3069.2	2001.0	1516.6	2764.7	20.7
Tetrastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cryptophyta							
Cryptomonas	2693.1	3009.0	4573.7	1730.2	4098.3	3220.9	27.3
Rhodomonas	962.9	722.2	902.7	1399.2	5109.3	1819.3	15.4
Trachelomonas	0.0	60.2	60.2	0.0	0.0	24.1	0.2
Euglenophyta							
Lepocinclis	105.3	240.7	421.3	270.8	1823.5	572.3	51.0
Phacus	90.3	180.5	180.5	406.2	1245.7	420.7	37.5
Euglena	0.0	60.2	120.4	105.3	361.1	129.4	11.5
Cyanophyceae							
Anabaena	361.1	782.3	1324.0	0.0	0.0	493.5	0.7
Anabaenopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anacystis	26019.5	20341.1	47964.0	13661.0	4423.3	22481.8	30.8
Chroococcus	4934.8	3791.4	2768.3	2061.2	1209.6	2953.1	4.0
Spirulina	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dactylococcopsis	1128.4	962.9	1865.6	782.3	90.3	965.9	1.3
Gleocapsa	3024.1	782.3	2226.7	1564.7	1516.6	1822.9	2.5
Gomphoshpearia	8229.7	6379.2	4513.5	1083.3	0.0	4041.1	5.5
Lyngbya	11855.6	13299.9	8184.6	5867.6	7041.1	9249.8	12.7
Oscillatoria	16158.5	42000.6	19498.5	15045.2	5975.9	19735.8	27.0
Merismopedia	8726.2	7582.8	9147.5	4212.6	1534.6	6240.7	8.5
Phormidium	6198.6	3129.4	9809.4	7913.8	2437.3	5897.7	8.1
Pseudanabaena	8365.1	29428.3	20762.3	11133.4	17837.5	17505.4	24.0
Raphidiopsis	2723.2	2888.7	3490.5	1624.9	830.5	2311.5	3.2

Date

November 18 2001			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Bacillariophyceae							
Achnanthes	1534.6	1324.0	962.9	571.7	668.0	1012.2	16.1
Chatoceros	60.2	120.4	60.2	1053.2	180.5	294.9	4.7
Cocconies	1038.1	722.2	782.3	331.0	361.1	646.9	10.3
Cyclotella	5356.1	6258.8	3370.1	1429.3	722.2	3427.3	54.4
Navicula	586.8	962.9	722.2	421.3	920.8	722.8	11.5
Nitzschia	120.4	180.5	120.4	0.0	0.0	84.3	1.3
Rhizoselenia	60.2	0.0	0.0	0.0	90.3	30.1	0.5
Synedra	60.2	120.4	0.0	45.1	0.0	45.1	0.7
Stenopterobia	0.0	0.0	0.0	0.0	90.3	18.1	0.3
Surirella	150.5	0.0	60.2	60.2	361.1	126.4	2.0

Date
December 1 2001

			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	2046.1	842.5	1444.3	1504.5	1188.6	1405.2	15.6
Chlamydomonas	240.7	541.6	240.7	0.0	270.8	258.8	2.9
Chlorocapsa	1203.6	1083.3	1203.6	1008.0	1218.7	1143.4	12.7
Chloroccoccum	421.3	300.9	300.9	270.8	361.1	331.0	3.7
Coelastrum	0.0	120.4	0.0	0.0	0.0	24.1	0.3
Cosmarium	601.8	361.1	120.4	662.0	300.9	409.2	4.5
Crucigenia	481.4	962.9	0.0	240.7	240.7	385.2	4.3
Ankistrodesmus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Franceia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golenkinia	120.4	300.9	300.9	692.1	105.3	303.9	3.4
Lagerheima	120.4	120.4	0.0	180.5	361.1	156.5	1.7
Oocystis	4092.3	1324.0	1925.8	3069.2	1700.1	2422.3	26.9
Planktonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scenedesmus	722.2	0.0	1203.6	1023.1	240.7	637.9	7.1
Tetraedron	2467.4	842.5	1263.8	1534.6	1128.4	1447.3	16.0
Tetrastrum	481.4	0.0	0.0	0.0	0.0	96.3	1.1
Cryptophyta							
Cryptomonas	1143.4	1444.3	1685.1	2708.1	2256.8	1847.5	36.5
Rhodomonas	662.0	601.8	662.0	1609.8	1143.4	935.8	18.5
Trachelomonas	0.0	240.7	0.0	60.2	0.0	60.2	1.2
Euglenophyta							
Lepocinclis	60.2	361.1	120.4	376.1	210.6	225.7	53.6
Phacus	120.4	180.5	180.5	165.5	90.3	147.4	35.0
Euglena	0.0	180.5	0.0	60.2	0.0	48.1	11.4
Cyanophyceae							
Anabaena	2046.1	0.0	0.0	0.0	361.1	481.4	1.1
Anabaenopsis	0.0	0.0	0.0	541.6	0.0	108.3	0.3
Anacystis	10290.9	23289.9	23410.3	20070.3	15932.8	18598.8	43.1
Chroococcus	3610.8	5295.9	3069.2	1715.1	1805.4	3099.3	7.2
Spirulina	0.0	0.0	0.0	0.0	60.2	12.0	0.0
Dactylococcopsis	180.5	180.5	60.2	60.2	90.3	114.3	0.3
Gleocapsa	2407.2	3309.9	1444.3	1609.8	2286.9	2211.6	5.1
Gomphoshpearia	4995.0	4333.0	2467.4	812.4	1564.7	2834.5	6.6
Lyngbya	4152.5	662.0	8244.8	2467.4	662.0	3237.7	7.5
Oscillatoria	9087.3	10411.3	8846.6	5747.3	3340.0	7486.5	17.4
Merismopedia	4814.5	7101.3	4333.0	2347.0	3249.8	4369.1	10.1
Phormidium	722.2	1023.1	421.3	541.6	631.9	668.0	1.5
Pseudanabaena	14684.1	10050.2	1263.8	20040.2	4664.0	10140.4	23.5
Raphidiopsis	1023.1	541.6	1023.1	1850.6	737.2	1035.1	2.4

Date

December 1 2001

Species			Sites				
	K1	K2	K3	K4	K5	Mean	% Total
Bacillariophyceae							
Achnanthes	1083.3	1203.6	1143.4	1023.1	331.0	956.9	22.4
Chatoceros	120.4	0.0	180.5	346.0	90.3	147.4	3.4
Cocconies	1083.3	361.1	902.7	616.9	511.5	695.1	16.3
Cyclotella	2647.9	1925.8	3129.4	1820.5	1083.3	2121.4	49.6
Navicula	722.2	240.7	300.9	556.7	406.2	445.3	10.4
Nitzschia	120.4	0.0	60.2	0.0	0.0	36.1	0.8
Rhizoselenia	120.4	180.5	0.0	45.1	240.7	117.4	2.7
Synedra	0.0	0.0	0.0	45.1	0.0	9.0	0.2
Stenopterobia	60.2	60.2	120.4	45.1	135.4	84.3	2.0
Surirella	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Date
January 8 2002

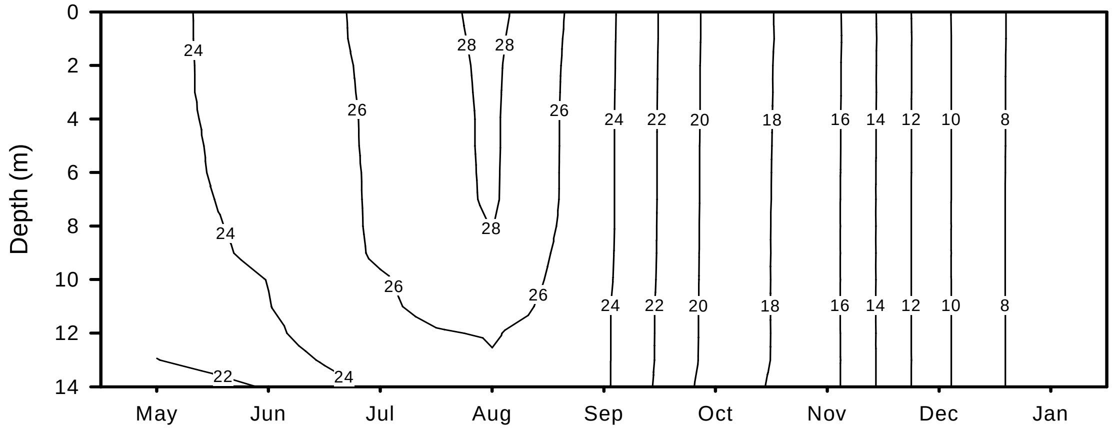
			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Chlorophyta							
Carteria	1504.5	1324.0	1805.4	1504.5	962.9	1420.3	12.6
Chlamydomonas	481.4	541.6	541.6	421.3	601.8	517.6	4.6
Chlorocapsa	722.2	1143.4	1143.4	1444.3	842.5	1059.2	9.4
Chloroccoccum	300.9	481.4	601.8	240.7	300.9	385.2	3.4
Coelastrum	120.4	0.0	0.0	0.0	0.0	24.1	0.2
Cosmarium	481.4	120.4	0.0	120.4	120.4	168.5	1.5
Crucigenia	0.0	0.0	0.0	0.0	481.4	96.3	0.9
Ankistrodesmus	0.0	421.3	0.0	842.5	0.0	252.8	2.2
Franceia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Golenkinia	300.9	60.2	120.4	0.0	0.0	96.3	0.9
Lagerheima	0.0	120.4	0.0	0.0	0.0	24.1	0.2
Oocystis	5295.9	7883.7	5115.4	2587.8	4333.0	5043.1	44.9
Planktonema	0.0	60.2	0.0	0.0	0.0	12.0	0.1
Scenedesmus	60.2	361.1	240.7	1143.4	240.7	409.2	3.6
Tetraedron	1805.4	2286.9	1865.6	1083.3	1384.2	1685.1	15.0
Tetrastrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cryptophyta							
Cryptomonas	1444.3	1685.1	1624.9	1986.0	2286.9	1805.4	33.5
Rhodomonas	1263.8	1324.0	722.2	601.8	481.4	878.6	16.3
Trachelomonas	240.7	0.0	0.0	0.0	0.0	48.1	0.9
Euglenophyta							
Lepocinclis	300.9	120.4	120.4	120.4	481.4	228.7	70.4
Phacus	0.0	60.2	180.5	0.0	120.4	72.2	22.2
Euglena	60.2	0.0	0.0	0.0	60.2	24.1	7.4
Cyanophyceae							
Anabaena	0.0	0.0	541.6	601.8	0.0	228.7	1.2
Anabaenopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anacystis	13239.7	1143.4	0.0	5416.3	9689.1	5897.7	29.9
Chroococcus	3309.9	3550.7	1865.6	5897.7	2166.5	3358.1	17.0
Spirulina	60.2	0.0	240.7	0.0	0.0	60.2	0.3
Dactylococcopsis	120.4	120.4	662.0	0.0	0.0	180.5	0.9
Gleocapsa	1685.1	4212.6	1143.4	842.5	2347.0	2046.1	10.4
Gomphoshpearia	902.7	1564.7	2587.8	962.9	3791.4	1961.9	9.9
Lyngbya	361.1	962.9	1023.1	0.0	0.0	469.4	2.4
Oscillatoria	4152.5	5476.4	0.0	0.0	421.3	2010.0	10.2
Merismopedia	2407.2	3189.6	1685.1	3971.9	722.2	2395.2	12.1
Phormidium	240.7	722.2	1263.8	3069.2	1384.2	1336.0	6.8
Pseudanabaena	2768.3	13781.4	2828.5	5175.5	0.0	4910.7	24.9
Raphidiopsis	662.0	541.6	60.2	180.5	240.7	337.0	1.7

Date

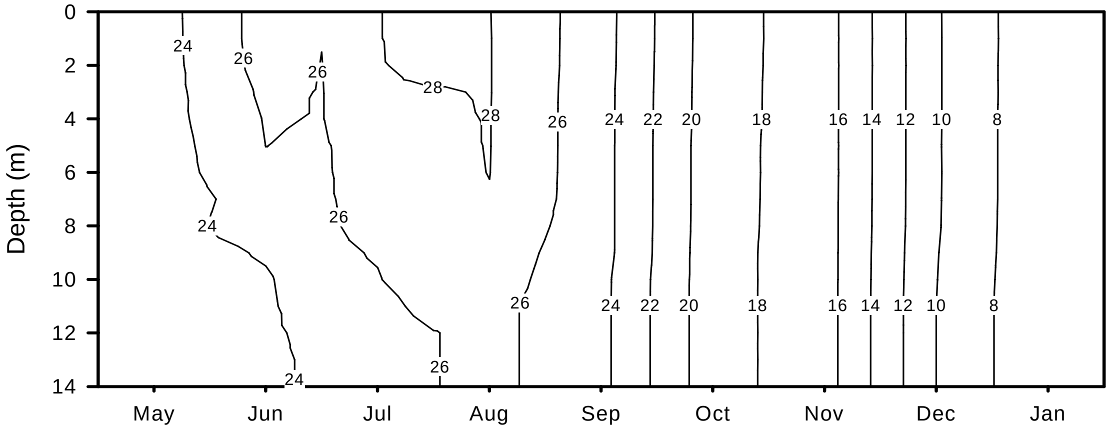
January 8 2002			Sites				
Species	K1	K2	K3	K4	K5	Mean	% Total
Bacillariophyceae							
Achnanthes	481.4	962.9	601.8	541.6	361.1	589.8	15.9
Chatoceros	180.5	421.3	0.0	60.2	120.4	156.5	4.2
Cocconies	1444.3	1203.6	1384.2	1203.6	782.3	1203.6	32.4
Cyclotella	1925.8	1986.0	1143.4	1143.4	662.0	1372.1	36.9
Navicula	180.5	782.3	240.7	240.7	60.2	300.9	8.1
Nitzschia	0.0	60.2	0.0	0.0	0.0	12.0	0.3
Rhizoselenia	300.9	120.4	240.7	120.4	300.9	216.7	5.8
Synedra	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stenopterobia	0.0	60.2	0.0	120.4	0.0	36.1	1.0
Surirella	60.2	0.0	60.2	0.0	0.0	24.1	0.6

APPENDIX C

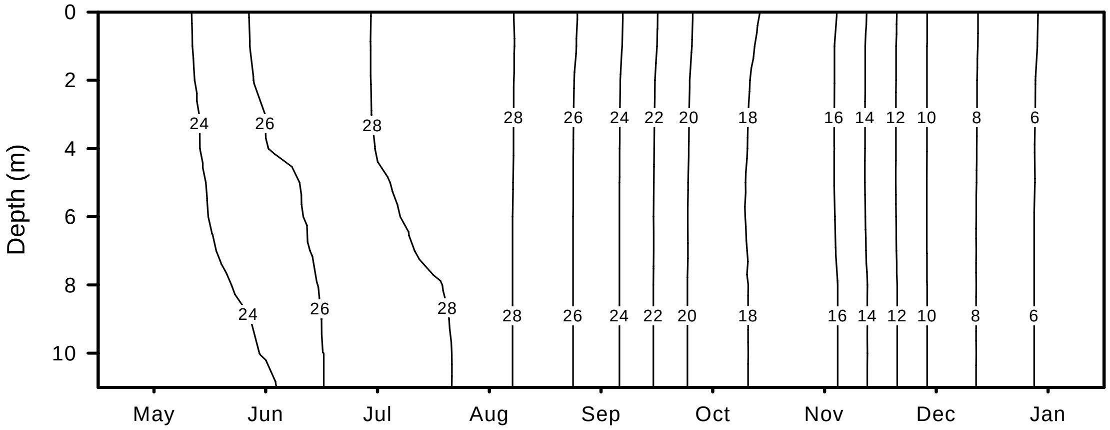
TEMPERATURE PROFILES



Kemp 1

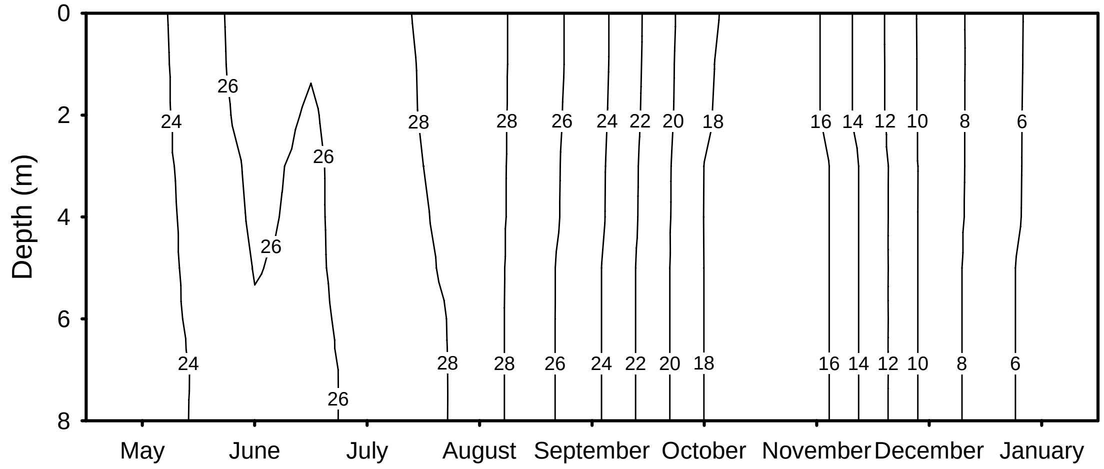


Kemp 2

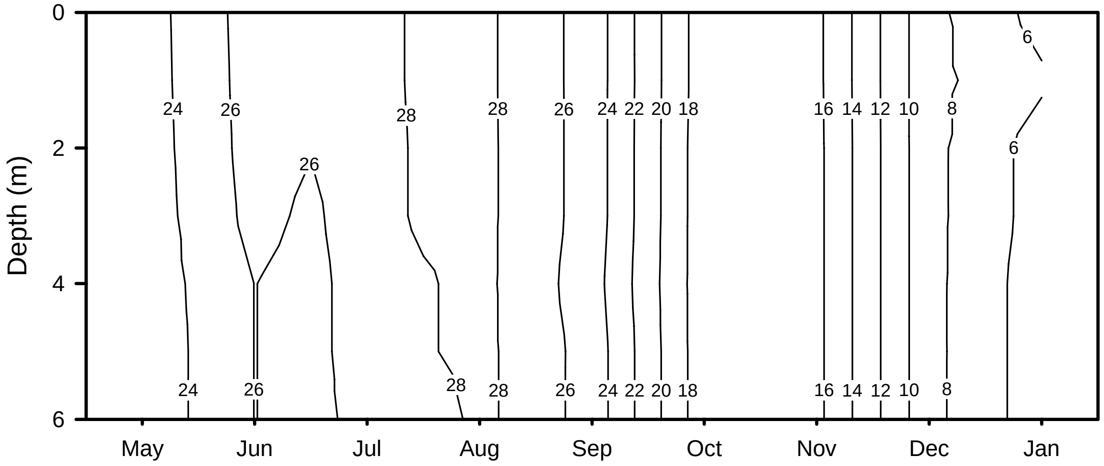


Kemp 3

Figure C.1. Temperature profiles for sites K1-K3 in Lake Kemp, Texas, 2001 through 2002.



Kemp 4



Kemp 5

Figure C.2. Temperature profiles for sites K4 and K5 in Lake Kemp, Texas, 2001 through 2002.

APPENDIX D

LIGHT EXTINCTION COEFFICIENTS

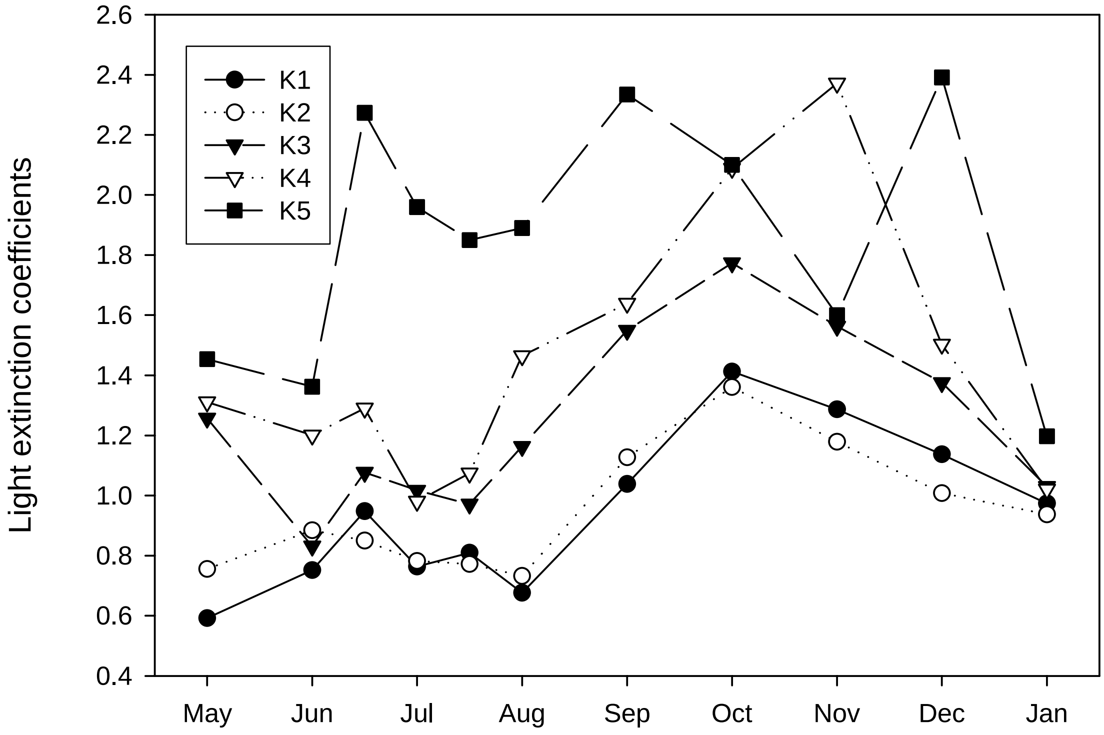


Figure D. Light extinction coefficients for all five sites in Lake Kemp, Texas, 2001 through 2002.

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