Assessment of Phytoplankton Productivity in Clear Lake (Riding Mountain National Park), Manitoba

by

Yvonne Nadia Hawryliuk

A thesis presented to the University of Manitoba in partial fulfilment of the requirements for a degree of Master of Science in the Faculty of Graduate Studies

Department of Botany
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

0-612-51751-9

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
*****
COPYRIGHT PERMISSION PAGE

Assessment of Phytoplankton Productivity in Clear Lake (Riding Mountain National Park), Manitoba

BY

Yvonne Nadia Hawryliuk

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University

of Manitoba in partial fulfillment of the requirements of the degree

of

Master of Science

Contents

ABSTRACT

The purpose of this study was to quantify phytoplankton primary production (one of the main primary sources of organic carbon) in Clear Lake (Riding Mountain National Park), Manitoba and to determine, where possible, sources of variability. This information will in part make it possible to assess and put forth ecologically based management decisions for the benefit of the Clear Lake Basin and its stakeholders.

Riding Mountain National Park (RMNP) comprises 2,976 km^2 of land in the south west portion of the province of Manitoba. The Clear Lake Basin, 125 km^2 (11,648 ha), is found in the south east portion of the park with the majority of the basin within the Park boundary. Extensive anthropogenic influences, including agricultural, residential, and commercial, impact the basin. Clear Lake is the largest (2947 ha) and deepest (34.2 m maximum depth) lake in RMNP. The townsite, Wasagaming, provides resort amenities and visitor services. High recreational demands are placed on the lake and basin.

Sampling of Clear Lake was conducted at two stations approximately every three to four days from ice out (May 24, 1996) to ice in (November 10, 1996). Winter sampling occurred once a month for the ice season (November 10, 1996 to May 9, 1997), then weekly sampling continued from ice out (May 9, 1997) to ice in (November 11, 1997). Phytoplankton productivity was related to physical (light and temperature) and chemical (nutrient debt assays and elemental ratios) parameters in the lake through a series of multivariate approaches that included stepwise multiple regression and principal component analysis.

The common phytoplankton species found were *Dinobryon sociale, Fragilaria crotonensis, Pediastrium duplex, Stephanodiscus niagarae, Cyclotella bodanica, Tabellaria*

fenestrata, and Peridinium sp. Chlorophyll-a and total particulate biovolume displayed similarities in trends but some seasonal differences. In 1996, chlorophyll-a increased with species richness following suit. A major peak in both was observed just before ice in. In 1997, chlorophyll-a decreased, while species richness increased, especially during May to June and mid August to October. July showed that as chlorophyll-a increased, species richness increased. *Peridinium* sp. dominated during the ice season and summer of 1997; *Fragilaria* sp. dominated during the spring and summer of 1996; *Tabellaria* sp. dominated during the spring of 1996; and *Synedra* sp. dominated during the spring of 1997.

Phosphorous deficiency was experienced when productivity was lowest, whereas when nitrogen deficiency increased, productivity increased. Severe nitrogen deficiency (according to nitrogen debt) was indicated on 51% of the sampling occasions whereas, severe phosphorous deficiency (according to phosphorous debt and alkaline phosphatase activity) was indicated 5% and 85% respectively. No trend for nutrient deficiency was observed throughout the study. Deficiency values obtained in 1997 were higher than 1996. Elemental particulate ratios displayed a variety of deficiencies: N/P indicated severe phosphorous deficiency 72% of the time; C/P indicated severe phosphorous deficiency 8% of the time; C/N indicated severe nitrogen deficiency was not experienced at all; and C/Chl-a indicated severe carbon deficiency 44% of the time. The mean Si / P atomic ratio was determined to be 1442.65 due to the dominance of diatoms.

A whole Lake Productivity Modelling exercise produced seasonal differences (6 distinctive stages) and differences between three models. Three increasingly simplistic models were developed. Productivity Model 1 was developed to provide the best estimates to model productivity in Clear Lake, Manitoba. This model accounted for hourly changes in light as opposed to Model 2, which used total daily light. Weather patterns, environmental conditions and cloud cover patterns undoubtedly resulted in varying light intensities throughout the day. Model 3 was developed using a single equation that would not allow for daily or seasonal changes, peaks/lows in productivity parameters, environmental conditions, and weather patterns that could affect *in vitro* experiments. All models were based on *in vitro* determinations of the numerical relationship between light and carbon fixation (using a 14-C tracer method)

It was determined (through stepwise multiple regression) that the control of primary productivity was different in each year. In 1996, light and temperature were the main controlling factors. This was not the case in 1997. Nutrient status had no apparent affect on productivity. Clear Lake temperature profiles varied between the two years by the thermal gradient being steeper and the thermocline deeper in 1997. Wind may have been the factor responsible for the thermal instability in 1997 because the winds were more variable and stronger. When wind speeds were higher than 8 - 9 km/hour, productivity decreased. It is speculated that wind in 1997 may have caused deeper mixing of phytoplankton during the summer months thus reducing productivity. The fact that total particulate biovolume was higher in 1997 does not support this speculation. Clear Lake experiences a unique hydrological cycle. Over the study the lake dropped 0.415m. With this decrease in lake levels, lake volume decreased lake levels causing an increase in nutrient concentration, which increased density of cells, as demonstrated by the total particulate biovolume. The result may have been an increase in phytoplankton production.

In Perspective.....

Side by side with modern Canada lies the last battleground in the long, drawn-out, bitter contest between civilization and the forces of nature. It is a land of shadows and hidden trails, lost rivers and unknown lakes, a region of soft-footed creatures going their noiseless ways over the carpet of moss and there is silence - intense, absolute and all-embracing.

Grey Owl, 1929

We have not inherited the Earth from out Fathers,
We are borrowing it from our Children.

Native American Saying

The future belongs to those who believe
in the beauty of their dreams.

Eleanor Roosevelt

Dedicated to

My Mom

[illegible]
[illegible]

ACKNOWLEDGEMENTS

I am extremely grateful to my supervisor and mentor, Dr. Gordon Robinson, who was extremely instrumental in developing my interest in algal ecology during my undergraduate degree. He has provided patience (lots of it), guidance, and support during the past few years. Thank you for taking all the long distance phones calls and providing advice 300 km away in the park. Your words, suggestions, and advise during my graduate experience and in compiling this thesis were greatly appreciated.

Pat Rousseau, the god of Riding Mountain National Park, was extremely instrumental in this project. It was through his determination and commitment to the project that a rigorous sampling schedule was maintained to develop a comprehensive dataset. I am extremely grateful for this. No bump in the road was too big to fix for this Park Warden. Thank you for your support and guidance through the years. I have learnt more from you than any course I will ever take.

A big thank you to Dr Gordon Goldsborough who provided me access to a spectrophotometer and light data from the University of Manitoba Field Station (Delta Marsh), without this data no modeling could have been done. Thank you for your advisory role in this project. I am grateful for the experience I gained working with you on the Urban Streams Project during my graduate career. It was beneficial in many ways.

Thank you Dr. Jim Teller, Department of Geological Sciences, for your advisory role and suggestions in this project.

I extend my appreciation to the Park Wardens who battled massive waves, fog, rain, calm water, ice, snow, and that boat motor to help me maintain a rigorous sampling schedule. I am grateful for your time, support, and help during the project. Thank you to Pat Rousseau, Laird Linklater, Sean Frey, Jacques Saquet, Brad Lloyd, Debbie Kilfoyle, Jonah Mitchell, Olaf Jensen, Andrew Promaine, Gord Pylypuik, and Marcy Nylen-Nemetchek.

I extend my gratitude and appreciation to Riding Mountain National Park (Parks Canada) for their financial commitment and support. Pat Rousseau, Ray Whaley, Paul Tarleton, and Greg Fenton were instrumental in acquiring this funding and a Park sampling permit. Thank you to Warden Services for providing boats, gas, transportation, logistics, the firehall for a laboratory, man power, time, and the weather station. My appreciation to other Parks Canada staff and Wasagaming town's people for all that they may have done.

I must also thank the below mentioned people for their time and expertise. It was greatly appreciated.

- Dr. Norm Kenkel for his statistical work and advise.
- Hedy Kling for her help in algal identification and electron micrographs.
- Len Hendzel for his help with the nutrient debt assays, loan of filters, and time during his holiday to work out some obstacles.
- University of Manitoba Field Station (Delta Marsh) for the use of light data.
- Manitoba Conservation (Dwight Williamson and Sharon Gurney) for the loan of a quantum sensor.
- Dr Badour and the Botany Department for the loan of a spectrophotometer.
- John Kozelko for the loan of a depth finder and help with chemistry related questions.

- Jim Hicks for his assistance at Norwest Laboratories

- Clear Lake Divers (Rod McGinn, Bruno Bruederlin, Heather Bruederlin, Ed Burridge, and Ed Riesmeyer) for their summer and winter dives to get a better understanding of the aquatic ecosystem within Clear Lake.

My appreciation is extended to the Botany Department Students and Staff for their part in my graduate experience. Thank you to the Botany Department (Dr. Punter and Rhonda McDougal) and Environmental Science Program (Dr. Robinson) for allowing me to interact with students as a teacher assistant and marker.

Finally, I would like to thank my mother, Phyllis Hawryliuk, for all her patience and support during this roller coaster ride. I really appreciated all your assistance whenever and wherever. Lastly, thank you to my dog, Cory, for guarding of the firehall and the late night walks to the laboratory to finish up experiments.

List of Figures

List of Tables

List of Appendices

Chapter 1 Introduction

1.1 Riding Mountain National Park

Riding Mountain National Park (RMNP) comprises 2,976 km^2 of land in the south west portion of the province of Manitoba (Bazillion, 1992) (Figure 1.1). The park is an island in the middle of a sea of agricultural lands. It is one of the last relics of woodlands that existed

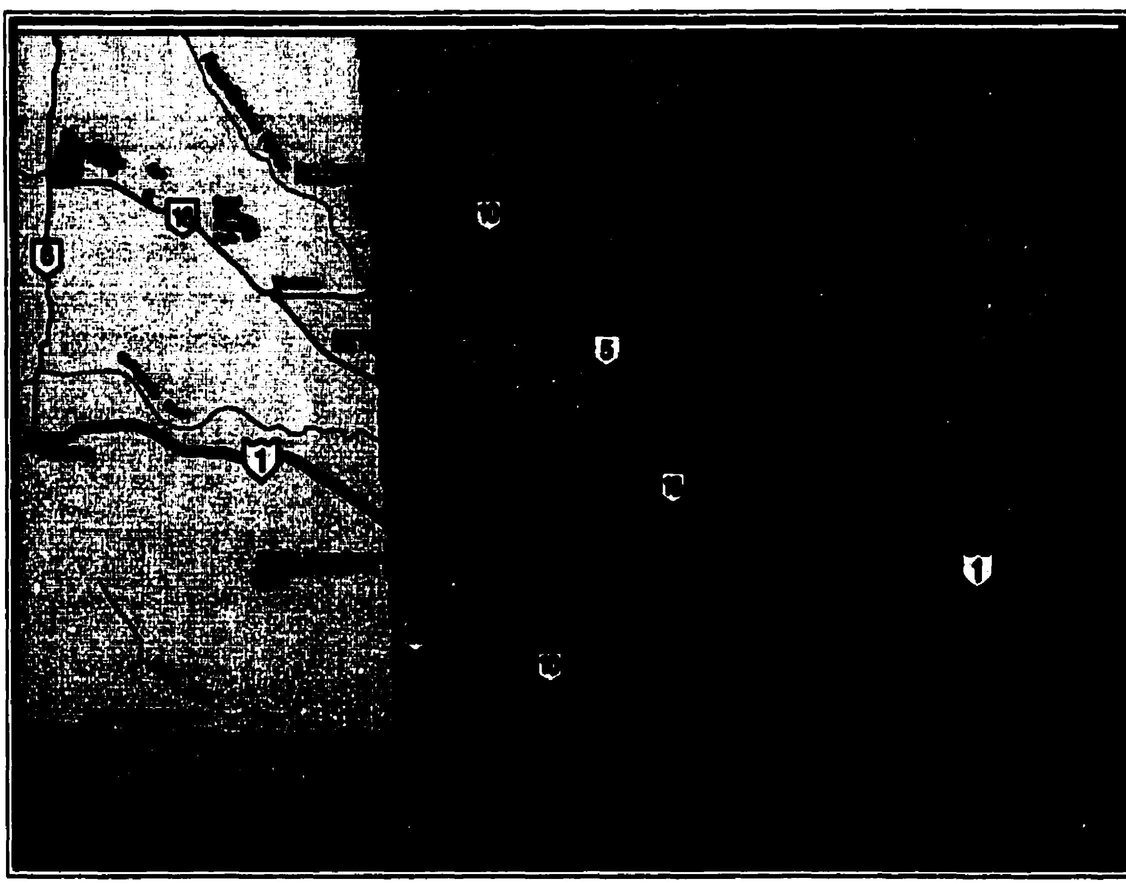


Figure 1.1 - Riding Mountain National Park Regional setting
Source :Ecosystem Conservation Plan Team, 1997

before the 1800s European settlement (Riding Mountain National Park Round Table, 1996). A mosaic of landscapes characterizes the park. Three life zones, grasslands, aspen-oak, and mixed wood ecosystems, are encompassed within the park (Riding Mountain National Park

Round Table, 1996). It is where Manitoba lowlands meet the second prairie level or Saskatchewan plain. The Manitoba Escarpment is a 475-metre rise between Manitoba Lowlands through the first to second prairie level. The Park stretches almost 100 km from the east to west boundaries, incorporating shallow lakes, rolling hills, wet meadowlands, and aspen forest. It is indicative of the southern boreal plains and plateaux natural regions of Canada (Riding Mountain National Park Round Table, 1996). Glacial action has contributed to the region being denoted as pothole country (Ecosystem Conservation Plan Team, 1997).

Glaciers, wind, and water have developed the landscape through the years (Bazillion, 1992). The Quaternary glaciers and fluvial processes of the past are portrayed in relict beach lines from ancient shorelines of glacial Lake Agassiz, hummocky knob and kettle topography, meltwater channels, rolling moraine ridges, outwash plains, and rounded depressions (Riding Mountain National Park Round Table, 1996). Geological history from fossils in shale bedrock dates to Permian and Cretaceous periods. Bentonite, a volcanic ash, was discovered. It is identified with the volcanic mountain building processes of the western cordillera (Riding Mountain National Park Round Table, 1996).

The Park inhabitants include human, elk, deer, bear, moose, wolf, lynx, fox, fish, birds, reptiles, ungulates, small mammals, scavengers, invertebrates, and bacteria (Riding Mountain National Park Round Table, 1996). Various types of vegetation are found in the park tracing back to three distinctive eras:

- Spruce Forest Invasion - 12,000 - 10,000 BP - spruce dominated forests that included trees (birch, poplar, ash, oak, elm), shrubs (juniper, willow, hazelnut), grasses (ragweed), and a variety of herbs.

- Grassland Expansion - 10,000 - 3,000 BP - fire from drier conditions transformed the area into countless deciduous tree and shrub islands among a sea of prairie.
- Aspen Parkland and Mixed Forest - 3,000 BP to present - cooler and wetter conditions spread aspen parkland upland and deciduous forest along rivers and streams, gradually returning mixed conifer-deciduous forest (Ecosystem Conservation Plan Team, 1997).

A trip through any portion of the park will allow observation of more diverse communities of plants and animals. The park is rich with aspen-white spruce correlated to the boreal mixed wood forest. Northern slopes consist of white birch, balsam poplar, aspen stands whereas, the southern slopes consist of white balsam fir and bur oak. Wet bogs are characterized by black spruce and tamarack whereas, in the drier drained areas jack pine dominates. Hazel scrubs are dominating within the park. Grassland areas still exist in the western area and eastern area (Ecosystem Conservation Plan Team, 1997). Archaeological evidence suggests Aboriginal people (Nakota (Assiniboine), Woodland Ojibway, Plains Cree, and Saulteaux) have inhabited the area for approximately 6000 years (Riding Mountain National Park Round Table, 1996). Even further back, the presence of Archaic Bison Hunters have been recognized archaeologically with the onset of the Altithermal Period and Woodland and Plains Groups (Ecosystem Conservation Plan Team, 1997).

The first arrival of European explorers and traders occurred in the mid 18th century to establish the first trading post, Fort Dauphin. Riding Mountain House I (south of the Park) and Riding Mountain House II (Elphinstone) were the closest fur trading posts to the Park (Ecosystem Conservation Plan Team, 1997). Several trails in the park today have their basis in this era. Two major trails existed:

- Strathclair Road - from Fort Ellice Trail north through the park toward Lake Dauphin
- Desjarlais Trail - from Eliphinstone east to Manitoba House post (Ecosystem Conservation Plan Team, 1997).

European settlers arrived in the area in the late 1800s on their westward journey and several trails in the park today are based on this period. The easiest mode of travel was by horse. Many settlers worked in the work camps developed in the 1930s before heading northward toward the Gilbert Plain / Duck Mountain areas. This work (relief camps) produced many of the visitor facilities still used today. Projects included Main Pier, road construction and upgrading, and land cleaning for cottages and campgrounds (Ecosystem Conservation Plan Team, 1997). Other projects included domestic timber harvest, hay, and livestock grazing. Today these activities no longer occur (Riding Mountain National Park Round Table, 1996).

Riding Mountain National Park Round Table (1996) has linked the Park to a larger framework. The park had been identified and contributes to fulfil:

- The Province of Manitoba's natural region 7, 'Western Uplands',
- the Province's commitment to the World Wildlife Fund Endangered Spaces Campaign, which protects representative areas to conserve Canada's biological diversity by 2000,
- Canada's global environmental commitments by means of the Conservation of Biodiversity and UNESCO Biosphere Reserves Program.

1.2 National Park Policy and Acts

Every national park across Canada must adhere to the requirements listed in the National Park Act (1989) and The Guiding Principles and Operational Policies (1994). The Riding Mountain National Park Management Plan (1996) and subsequent Ecosystem Conservation Plan (1997) are unique to the Park because of their management challenges of ecosystem conservation, protection, restoration, and monitoring of natural and cultural heritage (Riding Mountain National Park Round Table, 1996). This section will outline the important passages.

Parks Canada's objective or mandate is '*To fulfil national and international responsibilities in mandated area of heritage recognition and conservation; and to commemorate, protect and present, both directly and indirectly, places which are significant examples of Canada's cultural and natural heritage in ways that encourage public understanding, appreciation, and enjoyment, while ensuring long-term ecological and commemorative integrity*' (Canadian Heritage Parks Canada, 1994, page 13).

The National Parks Act states that '*Maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in a management plan*' (Canadian Heritage Parks Canada, 1989, page 3) Ecosystem protection must follow that the '*National park ecosystems will be given the highest degree of protection to ensure the perpetuation of natural environments essentially unaltered by human activity*'(Canadian Heritage Parks Canada, 1994, page 32). The ecosystem-based management of the '*National park ecosystem will be managed with minimal interference to natural processes. However, active management may be allowed when the* *structure or function of an ecosystem has been seriously altered and manipulation is the only possible alternative available to restore ecological integrity*' (Canadian Heritage Parks Canada, 1994, page 33). This ecosystem-based management must be '*In keeping with park management plans, Parks Canada will establish measurable goals and management strategies to ensure the protection of ecosystems in and around national parks*' (Canadian Heritage Parks Canada, 1994, page 33). Any '*Decision-making associated with the protection of park ecosystems will be scientifically based on internationally accepted principles and concepts of conservation biology*' (Canadian Heritage Parks Canada, 1994, page 33).

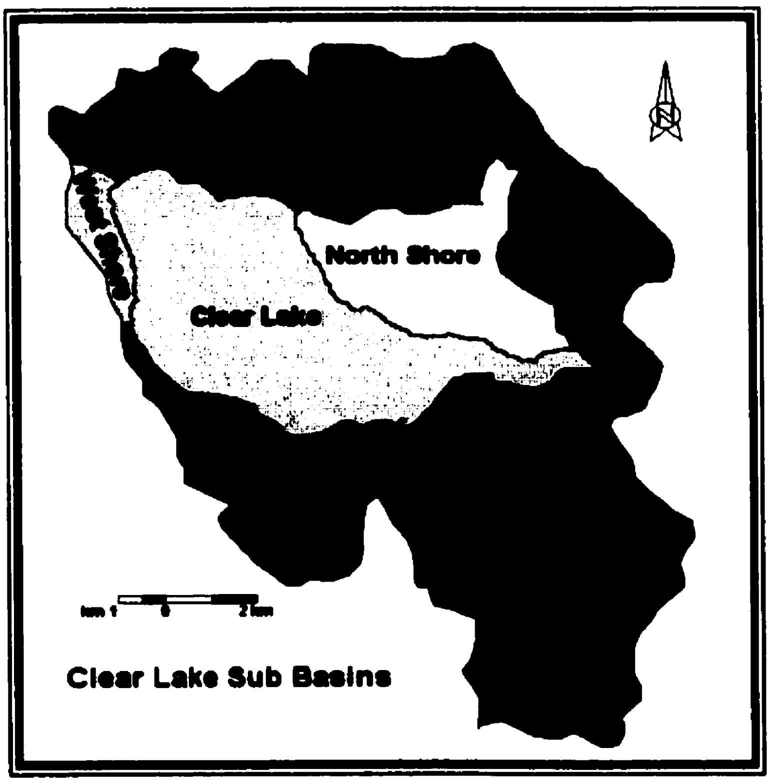


Figure 1.2 - Clear Lake Sub-Basins
Source Riding Mountain National Park Staff

1.3 Clear Lake Basin

The Clear Lake Basin, 125 km^2 (11,648 ha), is found in the south east portion of the park (DeLCan, 1982 and Bazillion, 1992). The majority of the basin is found within the Park boundary with approximately 33% lying outside the Park. Clear Lake Basin consists of 10 sub-basins The Octopus Creek sub-basin, 34.32. km^2, lies outside the Park (Moore, 1997)(Figure 1.2). Extensive anthropogenic influences, including agricultural, residential, and commercial, impact the basin.

Clear Lake is extremely accessible by vehicle because of its proximity to Highway #10, which is off the Trans-Canada Highway and Yellowhead Route. It is the largest (2947 ha) and deepest (34.2 m maximum depth) lake in Riding Mountain National Park (MacLaren, 1977 and DeLCan, 1982). The flushing time is approximated at 150 years due to the small drainage basin (Rousseau, 1990 and Terrestrial and Aquatic Environment Managers Manitoba Inc., 1993). Clear Lake, a relatively shallow oligotrophic lake, is known for its cool clear water. This typically dimictic lake does stratify thermally (holomictic) in the summer (Bazillion, 1992). A strong north west wind through the lake's biggest fetch can cause the lake to mix to homothermal conditions even at the deepest depths (Rousseau, 1986). The longest portion of the lake faces the prevailing wind causing the shoreline, which is comprised of 60% coarse gravel / stones, 30% sand, and 10% emergent vegetation, to become exposed and eroded. Vegetation along the shores includes water milfoil (*Myriophyllum sibiricum* Fern), common bladderwort (*Utricularia macrorhiza* LeConte), common coontail (*Ceratophyllum demersom L.* Linneaus), and star duck weed (*Lemna trisulca L* Linneaus)(DeLCan, 1982). Distribution of plants depends on water depth, wave action, sedimentation, and substrate type (DeLCan, 1982).

Wasagaming, townsite on the southern shore of Clear Lake, is the most frequently utilized recreational area in Riding Mountain National Park (Terrestrial and Aquatic Environmental Managers Manitoba Inc., 1993). (Figure 1.3) The townsite provides resort amenities and visitor services (Riding Mountain National Park Round Table, 1996). This area contains several camps, a campground, commercial accommodation, day use areas, golf course, landfill, sewage lagoons, trails, lawn bowling, tennis courts, shops, restaurants, cabins, cottages, and boat launches. High recreational demands are placed on the lake and basin. The population around the basin soars to more than 1,150,000 during peak seasons (Bazillion,

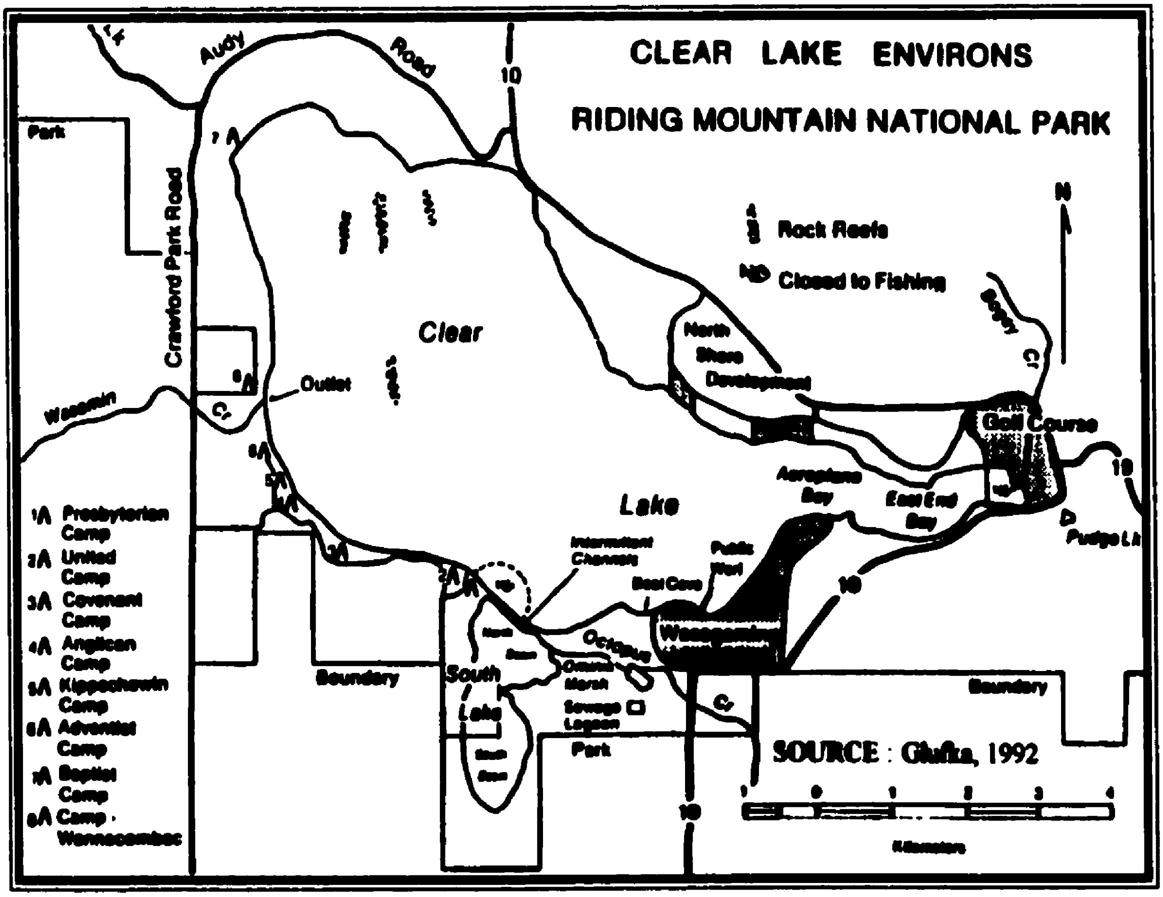


Figure 1.3 - The Clear Lake Area
Source Glufka, 1992

1992). In Wasagaming and surrounding area there are approximately 21 million dollars of investments. Apart from the recreational use, Clear Lake is a source of drinking water for the town of Wasagaming.

The streams that bring water into Clear Lake are Pudge Creek, Bogey Creek, Picnic Creek (Glen Beag), North Shore (creek that runs through Block 17 on the North Shore), Spruces (creek runs near Spruces picnic area), Aspen (creek runs near Aspen picnic area), and a series of culverts along Lake Audy Road. These creeks are along the northern part of the lake. One creek, Octopus Creek, originates outside the park and enters at the South Gate.

The only outlet, Clear Creek (or Wasamin Creek), was named after the lake from which it is derived. This creek flows out the western portion of the lake for approximately 12 km before it enters the Little Saskatchewan River (George, 1917). Through the years, the creek has been dammed for a variety of reasons. These reasons include providing water levels for the Minnedosa Power Company in times of low flow and to increase the water of the lake. On June 16, 1994, Mr. George McLaughlin identified a piece of wooden dam (approximately one foot long) that was found as one he used to fish off in the late 1930s and early 1940s. Today, no man-made dam is in existence. The Park allows the creek to flow in its natural state except that beaver activity in the creek influences its hydrology, and only minor removal of new beaver cuttings put into place to slow or stop the flow is conducted. Park Staff monitor Clear Creek from the mouth of the creek to PTH #354. In 1994, all dams breached naturally due to increased flows in the creek, which allowed suckers and pike to run up from the Little Saskatchewan River to Clear Lake for spawning. Minnows and fingerlings were found throughout the creek.

Bogey Creek flows past the landfill site and through the Clear Lake Golf Course. The creek enters Clear Lake from the Wishing Well on the eastern side of the lake. This creek originates from Ministic Lake and is mainly a groundwater stream with a sand / gravel bottom. The groundwater is believed to come from the area around the golf course (Kooyman, 1980b). The Clear Lake Golf Course is now using only environmentally friendly management practices.

Farming activity does not occur in the park but areas beside the park are heavily farmed. The Octopus Creek system that drains into the lake via the Ominik Marsh has major farming activity occurring outside the park. Pesticides and nutrient pollution are found in the creek. Although these chemicals are used on the land, they do end up in the creek from land runoff during rain events and soil leaching.

In the late 50s / early 60s, a one celled sewage system (cell 3) was built with two clay lined cells (cells 1 and 2) added in the early 70s (Pratt, 1991). Boat Cove Road exists because of the ditch built from Ominik Marsh to South Lake to carry waste overflows from the sewage lagoons (Bazillion, 1992). Once the effluent goes through South Lake, it enters Clear Lake. When Octopus Creek water levels are high, the water can be seen draining through the marsh and directly to Clear Lake at the Boat Cove. Sewage enters cell 1 from the force main, then into cell 2, and finally into cell 3 before it is discharged into Ominik Marsh where further biological 'treatment' occurs by way of macrophyte (and algal) nutrient removal (MacLaren, 1977). In the 1970s, water quality tests were done to detect impacts of the sewage system on South Lake. These tests showed that this indirect discharge of sewage into South Lake via Ominik Marsh was having no significant impact (MacLaren, 1977). South Lake was originally examined in 1955 as the possible site of the sewage lagoon but the lake was already heavily polluted (MacLaren, 1977). Cell 3 was built from in-situ soils that have poor water retention capacity, therefore this cell leaks. In the early 70s two more cells were built east of the existing cell. These cells were constructed of coarse material (Pratt, 1991). Studies in the 70s were done to find groundwater pollution from exfilteration of the sewage lagoon. A low yield aquifer was degraded and this was found to flow toward South Lake (MacLaren, 1977). According to a 1970s report, approximately 200,000 to 250,000 gallons of sewage are produced per day from April to October (MacLaren, 1977 and Pratt, 1991). It is estimated that the sewage lagoons receive 60 million gallons of sewage annually from the townsite area (MacLaren, 1977). Increased amounts of sewage increases the nitrogen and phosphorous loading in Clear Lake. If the sewage lagoon system is working properly, fecal contamination is unlikely to occur. This discharge results in warmer temperatures and nitrification, which in turn threatens fish spawning grounds and induces winter kills, common occurrences in South Lake (Bazillion, 1992). There is concern that lagoon cell leaks, may be causing the release of improperly treated sewage.

Clear Lake supports Blacknose Dace (*Rhinichthys atratulus* (Mitchill) Evermann and Goldsborough), Blacknose Shiner (*Notropis heterolepis* Eigenmann and Eigenmann), Cisco (Lake Herring - *Coregonus artedi* LeSueur), Fathead Minnow (*Pimephales promelas* Rafineque), Johnny Darter (*Etheostoma nigra* Rafineque), Lake Trout (*Salverlinus namaycush* Jordan and Gilbert), Lake Whitefish (*Coregonus clupeaformis* Agassiz), Blacksided Darter (*Percina maculata* Girard), Brook Stickleback (*Culaea inconstans* Bailey and Allum), River Shiner (*Notropis reticulatus* Eigenmann and Eigenmann), Northern Pike (Jackfish - *Esox lucius* Jordan), Slimy Sculpin (*Cottus cognatus* Richardson), Spottail Shinner (*Notropis hudsonius* (Clinton) Scott), Trout Perch (*Percopsis omiscomaycus* (Walbaum) Kendall), Walleye (Pickerel - *Stizostedion vitreum* (Mitchill) Jordan and Evermann), White Sucker (*Catostomus commersoni* Bean), and Yellow Perch (*Perca fluviatilis* Linnaeus) (DeLCan, 1982). The Brook Trout (*Salverlinus fontinalis* Jordan and Copeland) and

Rainbow Trout (*Salmo gairdneri* Suckley) were stocked in the Lake and believed to die out because of starvation (Kooyman, 1980a). Angling occurs from boats more so than the shoreline with Northern Pike (Jackfish - *Esox lucius* Jordan), Pickerel (Walleye - *Stizostedion vitreum* (Mitchill) Jordan and Evermann), Lake Trout (*Salverlinus namaycush* Jordan and Gilbert), and Lake Whitefish (*Coregonus clupeaformis* Agassiz) as the most commonly sought fish (DeLCan, 1982). Through the early 1980s, Park Wardens and the Canadian Wildlife Services have looked at the fisheries aspect cf Clear Lake. The Park is examining the possibility of enhancement. Clear Lake shows mercury contamination, over the 0.5ppm limit recommended for human consumption in the larger fish populations (Lockhart, 1986 and Rousseau, 1986). Kooyman (1979) suggests the mercury contamination could occur from Pudge Creek and/or South Lake because high mercury levels are found in those waters. Other sources of mercury contamination may include natural or bedrock sources, golf course, landfill site, and sewage lagoon (Kooyman, 1979 and Rousseau, 1986).

The pier was built in 1925 and the beach was developed in the 1930s by hauling sand over from the North Shore. Wasagaming beach deterioration was noticed since the pier was built. This was due to decreased water circulation leading to deposition of silts and muds, swimmers itch, submerged vegetation growth, and interception of sand being transported through the littoral region (DeLCan, 1982). In the late 40s, bluestone was added to the lake to control the swimmer's itch and a month later a large fish kill was observed (Rounds, 1992). Swimmer's Itch is a problem caused when algal growth attracts snail parasites. Bluestone or Copper Sulfate has been use to treat the water (Bazillion, 1992). However, this chemical likely has a negative impact, copper sulfate resistant strains have been produced and copper is toxic to the aquatic life that supports the lake, as seen on Killarney Lake, Manitoba (Hysop, 1994). In 1975, an attempt was made to improve this condition, a nine-metre gap was made in the pier. This proved unsuccessful. It is believed that the pier was built to provide a protected swimming area (Baird, 1994). Two studies have been done on the pier: DeLCan (1982) and Baird (1994). The second study expands on the first. Baird (1994) proposed five alternatives:

1. maintain existing situations,
2. leaving an existing beach without maintenance - the aesthetic value would decrease and leave the area undesirable,
3. develop beaches on west side of the pier and no maintenance to existing area,
4. remove the breakwall and develop a beach beside the park,
5. remove breakwall partially

All five alternatives will be looked at in the future to decide the fate of the pier. Both positive and negative impacts will be examined with the intention that the pier suit the needs of visitors while not negatively impacting the environment. Consideration of these five alternatives was not part of this thesis.

1.4 Clear Lake Basin Project

The Clear Lake Basin Project began after a workshop was held in Brandon, Manitoba in March of 1993. For three days, people with an interest or stake in the basin, gathered to decide a common vision for the basin. Participants were considered stakeholders because they had a direct concern for the future of the basin. The group together had a chance to develop the basis for long term monitoring and management of the basin. At the end of the workshop, a common vision was reached on the water quality of the Clear Lake Basin. The vision states: *We the stakeholders as stewards of the Clear Lake Basin, will work in partnership to sustain and enhance water quality to ensure social needs, economic viability, and ecological integrity* (Terrestrial and Aquatic Environment Managers Manitoba Inc., 1993). A Steering Committee was established to focus research efforts, assist in protocols, data collection, and data interpretation. Until 1992, no extensive water quality monitoring program had existed. Current water quality data were showing little change from historic levels. A list of recommendations was developed, which was used to develop a water quality monitoring program for the Clear Lake Basin. These data will help determine any anthropogenic impacts on the basin. The monitoring program will answer the following five questions:

1. How much water goes in and out of the lake?
2. What kinds of chemicals are in the water and where do they come from?
3. What kinds of bacteria are in the water and where do they come from?
4. How many boats are on the lake in the summer?
5. How many people live in the Clear Lake Basin?

These five questions together will aid in the development of a Park management plan to maintain the watershed in its natural state. The ultimate goal is to strive for sustainable development of the lake basin. This combines health of the society, the environment and the economy together to unite and balance without endangering the ability of future generations to meet their needs.

Once all this Clear Lake Basin information and data are collected, a better understanding of the impact we, as users, have on the basin's health should be available. Limits for acceptable change will be established for the Clear Lake Basin and especially the lake. This is the most important step of the process because it is a public process. The stakeholders can potentially work together to reach the vision and maintain the quality of the basin for future generations.

1.5 Past Work Done on Clear Lake

Until recently, an extensive water quality monitoring program has not occurred. However, this is not to say that no water quality monitoring has occurred at all. Chemical and physical monitoring has been conducted in the past for other projects. To keep within the Parks Canada mandate for resource protection, baseline data and yearly data are ideally to be used to assess current pollution levels and controls of pollution (Rousseau, 1992). Past work includes:

- 1970s - A. H. Kooyman and R. C. Hutchison produced a multi volume report of aquatic aspects of RMNP (mainly an historical record).
- 1980s - Patalas and Salki (DFO, WPG) complied water chemistry and zooplankton community data (mainly historical and baseline data).
- 1993 - a workshop to gather stakeholders together to develop the basis for a long term monitoring and management program of the basin.
- 1993 - Dr. Goldsborough (Brandon University, now U of M) analysed sediment cores for levels of Chlorophyll-a and phosphorous.

- 1994 - a two-year hydrological study was started to examine incoming / outcoming stream flow, water holding capacities, evaporation, precipitation, snowfall etc. to develop a water budget.

1.6 History of the Clear Lake Basin

Human activity has been traced through Archaeological excavation, which revealed tools, pottery, axes, and other artifacts of Cree culture dated back 1,750 years. Aboriginal people have inhabited and used the land for hunting and gathering. The first highways through the park were a series of foot and horse trails created by these early inhabitants. Non-aboriginal people started coming to the area once the Canadian Pacific Railway stretched to Brandon (Bazillion, 1992).

The following historical outline is chronological and outlines the course of major events (Tabulenas, 1983 and Riding Mountain National Park Round Table, 1996):

- 1895 - Land was withdrawn from European settlement to establish the Riding Mountain Forest Reserve.
- 1886 - Keeseekoowenin Band of Elphinstone had a Fishing Reserve established on Clear Lake shores.
- 1912 - Minnedosa Power Company built an earthen dam on the outlet of Clear Lake (mouth of Wasamin Creek) to maintain water levels high in the lake for winter time.
- 1918 - Clark's Beach was established and beach lots became available for the public through a lottery conducted by the Department of the Interior, Forest

Service.

- 1921 - Fish stocking in Clear Lake began. Pickerel fry were released, making fishing one of the main attractions to Clear Lake.
- 1926 - Wasagaming opened its first inn. Business development and facilities began to develop because of increased tourism to the area.
- 1927 - Forestry Service built bath houses, pier, and outdoor fireplaces at Clark's Beach and promoted Clear Lake as a resort to make the public aware of the value of national forests and gain support for adoption of conservation and preservation polices. Lobbying began to have Riding Mountain designated as a National Park.
- 1929 - Clear Lake Golf Course construction began on the first nine of eighteen holes, watering system, and clubhouse.
- 1930 - February 8th, Riding Mountain was established as a National Park. A wooden dam replaced the earthen dam on the outlet of Clear Lake (mouth of Wasamin Creek). The Keeseekoowenin Band Indian Reserve was 'wrongfully' removed by the Department of the Interior.
- 1935 - Clear Lake Campground, 5,000 person capacity, was established complete with tables, kitchen shelters, and camp stoves. On the north shore of Clear Lake, a fish hatchery was built to raise Kamloops trout.
- 1936 - A sewage holding pond was constructed by constructing a dike across Ominik Marsh. This sewage originated from low volume sewer systems and holding tanks. To hold water pumped from Clear Lake and distribute it through

a shallow main series, a 20,000 gallon steel tank was built. (system did not include the cottage area).

- 1961 - A one cell sewage lagoon system, which discharged into Ominik Marsh, was constructed.
- 1970 - Between Ominik Marsh and South Lake, a ditch was dug to allow the flow of water from the marsh to South Lake.
- 1971 - The sewage system had two additional cells added.
- 1976 - An Engineering Study was done of the sewage treatment and disposal requirements to identify pollution sources.
- 1982 - A water quality study was conducted. Basic water quality data were collected to establish if point source problems existed, where point source problems may occur, and make recommendations.
- 1991 - Wasagaming Townsite Utilities Capacity Study was conducted to review municipal utilities and assess capability of these utilities to meet existing demands and projected increases of 15% in demands. The Keeseekoowenin Band First Nations received land back after a land claim.
- 1993 - Clear Lake Basin 'A Vision for Water Quality Workshop' was held in Brandon, Manitoba.

1.7 Introduction to Thesis

Fish production and yield depend primarily on food availability and environmental parameters. Prediction and management therefore require specific information in these areas.

The objective of this Master's Thesis has been to quantify phytoplankton primary production (one of the main primary sources of food) and to determine control mechanisms. This represents a first, and an essential stage in the development of a quantitative understanding of Clear Lake Basin Aquatic Ecosystem and ultimately management strategies for stewardship for the benefit of all stakeholders. Further stages that should be examined include quantification of productivity of the benthic algal assemblages, macrophytes and allochthonous additions, and ultimately a quantitative model of the entire community.

The Canadian Park Service mandate is to ensure that Clear Lake evolves naturally and is sustained for present and future generations. This requires all aspects of the lake to be examined and assessed for any impact on the basin. Past work on the lake has shown Clear Lake to be a unique lake to study for the following reasons:

1. both northern and southern aquatic organisms are present making it an excellent lake to monitor change with respect to global climate change,
2. it is a forerunner in scientific research conducted on a small drainage basins,
3. it has extensive recreational demands due to the Wasagaming townsite,
4. it is a lake found within the National Park system.

The basis of the food chain / web is dependent on autochthonous and allochthonous primary production. Primary producers are dependent on abiotic factors like light, temperature, and nutrient availability, but also biotic factors. Information on the nature of the food web is crucial to the establishment of ecologically based management and decisions regarding water quality, recreational use, aesthetics, ecosystem relationships, and ultimately a sustainable aquatic ecosystem. The major issues identified as facing the Clear Lake Basin Ecosystem are:

1. Poor fishing success, which has anglers upset - should fishing limits change?
2. Reserve 61A has regained settlement rights - netting could occur, it is not known to what extent such fishing activity can be sustained.
3. Management strategies, stewardship, and research must comply with National Park Policies, Acts, Regulation, and EARP's (No more fish stocking).
4. Identification of the interconnections and components of the Clear Lake Basin Ecosystem.
5. What has to occur (via management and stewardship) to maintain and possibly improve current conditions of the Clear Lake Basin ecosystem for future generations.

1.8 Research Design

1. To estimate phytoplankton primary productivity in Clear Lake, Manitoba
    - to assess any relationship between primary productivity and light
    - to calculate the parameters of the relationship between productivity and light
    - to model productivity

2. To determine the control mechanisms of productivity by way of
    a. Nutrient availability as assessed from the following
        - water chemistry and elemental ratios
        - nitrogen (TKN, particulate, and NO_4/NO_3)

- phosphorous (total, particulate, and dissolved)
- carbon (total, particulate, and dissolved)
- nutrient status measures (nitrogen and phosphorous debt, and alkaline phosphatase activity)
- Si values

b. Light Regulation of productivity by way of

- light history (PAR for the day of measurement and preceding 6 days)
- daily / hourly light (PAR) readings (total light)
- extinction of light in the water column
- integrated light above the 1% level
- degree of light limitation, which is the production occurring at PAR below saturation levels (I_K)

c. Others

- phytoplankton biomass
- pH
- alkalinity
- surface water temperature
- gradient slope of the thermocline
- depth of thermocline relationships
- algal species composition

Although it is recognized that other factors (e.g. herbivory) may influence productivity, they have not been included in this study.

1.9 Phytoplankton Photosynthesis and Nutrient Status Relationships

As outlined in the objective, the project has two major components: assessment of phytoplankton production and the nature of its controlling factors. The first of these was achieved through a simple modelling exercise based upon the relationship between incoming radiation and phytoplankton photosynthesis (Chapter 2). The second was to assess nutrient status of phytoplankton and analyze of the impact of nutrient status along with other environmental parameters on the estimated production (Chapter 3). The following two chapters are intended to introduce the reader to photosynthesis / irradiance relationship and algal nutrient status.

Chapter 2 Sources of variability in Photosynthesis - Irradiance Curves

2.1 Introduction

Information on the nature of the food web of any ecosystem is crucial in order to establish ecologically based management decisions, recreational use, aesthetics, and ultimately a healthy ecosystem. Baseline information on all components of a lake's ecosystem is required. Phytoplankton is very often considered an important component of the base of a lake's food web. The efficiency of these microorganisms can be evaluated in response to varying environmental conditions and community structure changes.

Phytoplankton photosynthesis can be described by the simple empirical equation as

$$6CO_2 + 6H_2O \Rightarrow C_6H_{12}O_6 + 6O_2$$

assuming light is available to drive the reaction forward (Forti, 1966). For natural assemblages or single species photosynthesis - irradiance relationships (P-I curve) can model, measure and possibly predict photosynthesis in aquatic environments. These describe the relationship between carbon utilization or oxygen evolution and available irradiance. Response of such relationships to changing environmental conditions can assess the roles of controlling or limiting factors. This portion of the thesis will outline the components of the photosynthesis - irradiance relationship (P-I curve) and assess the role of controlling or limiting factors as sources of variability. Finally, an introduction to the photosynthesis modelling based on the above relationship will be discussed.

2.2 Components of the Photosynthesis - Irradiance Curve (P-I Curve)

The P-I curve is a line that can be divided into three separate stages as photosynthesis relates to increasing irradiance (Figure 2.1). Stage one, or initial slope, shows a linear straight line relationship (alpha). As irradiance increases so does the photosynthetic rate as a result

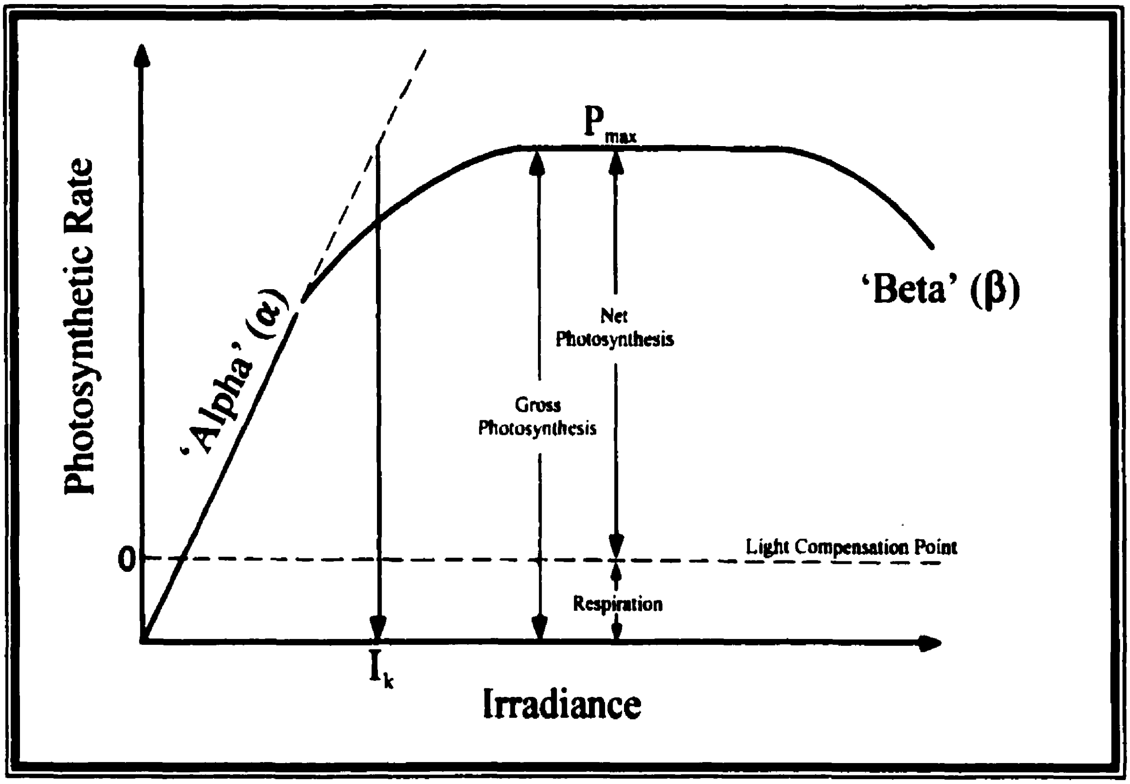


Figure 2.1 - Photosynthesis - Irradiance Curve
x axis - Irradiance y axis -measure of photosynthetic rate
Source South and Whittick, 1987

of light limitation (Geider and Osborne, 1992). Once 'alpha' (α) begins to decrease, the line begins to curve and eventually straighten or plateau forming Stage Two or maximum photosynthesis (P_{max}). This plateau occurs as photosynthesis because independent of irradiation (Geider and Osborne, 1992). When light-limited photosynthesis (slopes described by alpha (α)) and P_{max} intersect, light intensity or I_k can be determined. Stage three begins as irradiance further increases causing photoinhibition or decrease in photosynthesis forming a negative slope ('beta' (β)) (Geider and Osborne, 1992). The parameters of the curve are as follows:

1. **'Alpha' (α) (light-limited component)** - This is a phase of linear increase with light availability. Light limitation occurs in phytoplankton in the lower portion of the euphotic zone. α is the slope of the line, and is often described as 'photosynthetic efficiency'. Light harvesting and maximum carboxylation rates determine this initial slope (Geider and Osborne, 1992). The light reactions of photosynthesis are considered the controlling factor making light availability and the nature of the light absorption apparatus (Cote and Platt, 1983) of primary importance. Cell metabolism and temperature are extremely influential (Darley, 1982). Sources of variability in values for α can come from cell size, pigment composition, adaptation to sun and shade conditions, light quality, and nutrient availability (Cote and Platt, 1983).

2. **P_{max} (light saturation)** - This plateau or upper limit describes the maximum photosynthetic capacity achieved. This upper limit depends on the limitation by which light energy can be absorbed and then used in the dark reactions to fix inorganic carbon. The dark reaction of photosynthesis and carboxylation enzymatic reactions are considered the controlling factors of P_{max}. Factors like temperature, nutrient regime, light history, time of day, cell size, biochemical composition, and species composition cause variability (Cote and Platt, 1983). Harris (1978) stated that structural changes with respect to the light absorbing apparatus that is associated with

the light reaction may also to be influential.

3. **I_k (irradiance at which P_{max} intercepts with alpha)** - This is the light intensity when light saturation or P_{max} is achieved. Cote and Platt (1983) denotes I_k as an indicator of light limitation and varies with α, P_{max}, and a combination of both. Actual values for I_k are most often calculated from α and P_{max}.

4. **'Beta' (β) (photoinhibition)** - This component is not fully understood because of the difficulties in replicating full sunlight in laboratory situations. Photoinhibition is not always present in P-I curves, although surface waters exposed to full sunny conditions can be susceptible to this condition (Kirk, 1983). It is believed to occur due to photo-oxidation of enzymatic and photochemical reactions and inactivation of photosystem II (Geider and Osborne, 1992). High temperature and nutrient deficient conditions in combination with high light intensity can cause inhibition (Darley, 1982). Recovery from inhibition can take place by moving to lower light intensity but the ability to recover is dependent on the exposure time (Kirk, 1983). Sun adapted phytoplankton cells develop some resistance to photoinhibition by way of prolonged exposure to high light intensities. This is important because cells that are experiencing mixing conditions and come to the surface can adapt to the higher light intensities (Darley, 1982, and Gallegos *et al.*, 1983).

5. **Light Compensation Point** - As irradiance increases from zero a light

compensation point is reached when photosynthetic oxygen liberation equals respiration oxygen consumption (Kirk, 1983). Net photosynthesis occurs beyond this point. The light compensation point denotes the lower limit euphotic zone. A general field study rule is that the light compensation point occurs at 1% of the surface light or 2-3 times the Secchi disc depth (Darley, 1982).

6. **Respiration (R)** - Dark respiration can be determined by taking the initial (α) slope to darkness (Geider and Osborne, 1992). Oxygen is consumed while carbon dioxide is given off. As the irradiance increases from dark (zero), some oxygen liberation and carbon dioxide consumption can occur (Kirk, 1983). At very low light intensities (the compensation point) net photosynthesis is zero, cell growth cannot occur until the respiration rate equals the gross photosynthetic rate (Darley, 1982 and Kirk, 1983).

7. **Gross Photosynthesis (G_P)** - Total organic production including losses to respiration and other metabolic processes (net productivity plus respiration).

8. **Net Photosynthesis (G_N)** - Total organic production excluding losses to respiration and other metabolic processes (gross productivity minus respiration).

2.3 Sources of Variability

In this discussion of sources of variability, only α and P_{max} will be discussed in detail. Sources of variability will be divided into biological and physical parameters, although many physical parameters may influence biological parameters. Physical parameters will include nutrients, density gradients, atmospheric conditions, temperature, short term light history, and light intensity and quality of light. On the other hand, the biological parameters will include cell size, species composition within an assemblage, pigment composition, diel oscillation, and grazing pressure.

2.4 Physical Parameters

2.4.1 Nutrients

For algal growth and reproduction to occur a variety of nutrients are needed in varying concentrations. Most of these are found in sufficient quantities so as not to affect growth but phosphorous, nitrogen, and sometimes silicon may be limiting. Phosphorous is often cited as the limiting nutrient in freshwater. Silicon can limit diatom growth in both freshwater and marine systems (Darley, 1982). Death can occur if limitation is extreme. Deficiency or limitation may cause stress that can result in inefficient photosynthesis. Cote and Platt (1983) pointed out that phytoplankton nutrient assimilation and recycling (between zooplankton and phytoplankton) make it difficult to quantify the importance of available nutrients.

Darley (1982) states that the algal response to nutrient deficiency is to decrease chlorophyll to carbon ratios by chlorosis. Low temperatures but high irradiance further favour chlorosis. Other responses can include decreasing the size of the photosynthetic apparatus in times of depressed nitrogen, or use of stores of phosphorous (accumulated via luxury consumption).

Williams' (1978) study on Lake Tahoe showed that α varied directly with nitrate concentrations in the euphotic zone. Concentrations of nitrate vary with seasons due to vertical mixing and phytoplankton consumption. Once stratification occurs, nitrate supply may not be readily replenished from deeper waters. Platt (1982) found that in open oceans higher nitrate concentrations correlated with both higher values of α and P_{max}. Not much information is available on the initial slope and nutrient stress but it is proposed that both photosynthetic unit numbers and size decrease under nutrient stress (Cote and Platt, 1983).

2.4.2 Density gradients

Circulation of the water body is dependent on temperature and wind stress. When water temperature is lowered to maximum density 4°C (freshwater systems), whole system mixing (turnover) can take place and replenish nutrients. Once thermal stratification is established, nutrient replenishment from deep waters is severely limited resulting in possible nutrient limitation in the epilimnion, which can influence the P-I curve. Diffusion through the thermocline may occur but it is a very slow process. Williams (1978) showed that after stratification concentration of nitrate decreased to be limiting and reduced α. Harris *et al.* (1980) found that in Hamilton Harbour, P_{max} and I_k increased with an index of water column stability. The lag time was about one week. Nanoplankton in the Bedford Basin showed an opposite relationship between stratification and biological activity (Cote and Platt, 1983).

2.4.3 Temperature

Because of the connection between metabolism and light saturation, photosynthesis and cell growth are dependent on both light and temperature. Generally when temperature increases by 10°C, enzymatic activity rates increase by a factor of 2-3 (Neilson and Hansen 1959, and Darley, 1982). *Skeletonema* adapts to low temperature by increasing its cell size (via protein synthesis). The cells can be twice as big at 2°C than at 20°C. Enzyme concentrations increase resulting in the photosynthetic rate being the same at the same light intensity at both high and low temperatures (Jorgensen, 1968). In a single species experiment, P_{max} has been shown to be significantly affected by temperature, whereas α was not affected (Fee *et al.*, 1987). In P-I curves, α responds to increasing light because of the physiological photochemical reactions of pigments in the light reactions of photosynthesis. On the other hand, P_{max} is the enzymatic portion and dependent on active enzyme concentrations and temperature. Enzymatic activity can influence carbon dioxide fixation and the electron transport chain. More specifically, the RUBISCO enzyme is affected by changing temperature that ultimately affects both carboxylase and oxygenase activity (Geider and Osborne, 1992). Neilson and Hansen's (1959) studies showed in high latitude (arctic areas) locations as compared with low latitude locations (tropical areas), enzyme concentrations were higher although P_{max} was lower, energy being used for enzyme activity and not photosynthetic activity directly. Rhee and Gotham (1980) showed that diatoms and green algae require more nutrients as decreases in temperature below optimal ranges occurred. Protein synthesis was favoured and increased respiration rates (per unit of Chlorophyll) occurred at low temperatures.

2.4.4 Short term light history

The light intensity that the cells have experienced in their recent history is a time dependent factor that influences P_{max}. Within a short amount of time, a high P_{max} will decrease in high light intensity when cells have recently been exposed to low light intensity and even darkness. If light intensity is low, P_{max} takes longer to decrease. Full advantage of this brief period of high light intensity is taken by cells. To balance growth rate and carbon uptake, photosynthesis rates decline if exposure to high light intensity is continued (Darley, 1982). Photosynthesis is regulated by both the electron carrier's cyclic and non-cyclic electron transport between photosystem I and photosystem II (Marra and Heinemann, 1982 and Geider and Osborne, 1992). Marra (1980) further suggested that caution should be taken when developing any P-I curve relationship because the light saturation rate can vary considerably. Longer incubations were recommended. The overall photosynthetic rate as affected by previous light history can seriously influence species survival in the mixed layer (Harris *et al.*, 1980)

2.4.5 Atmospheric conditions

Irradiance levels and other atmosphere conditions cause varying photosynthetic rates of phytoplankton. Light exposure varies during cloud cover, Langmuir circulation, and vertical migration (Darley, 1982). A linear relationship between irradiance and photosynthesis is usually seen on cloudy days. Whereas under sunny day conditions, a nonlinear relationship may be more likely. On variable days there is a rapid reaction of photosynthesis to changes in irradiance (Marra and Heinemann, 1982). Phytoplankton are sensitive to turbulence because resulting rapid light fluctuations make previous light history important to species survival (Harris *et al.*, 1980). Deep water mixing elevate algae that are photosynthetically efficient and have low light intensity saturation. When incubated *in situ*, these algae may show photoinhibition whereas vertically mixed algae are subjected to shallow epilimnion mixing. Algae, not vertically mixed, generate a consistent vertical distribution and adapt to light intensities throughout the water column (Harris *et al.*, 1980). Transient physical phenomena (storms and upwellings) will influence any 'normal' seasonal progression of phytoplankton community structure and growth (Cote and Platt, 1983).

2.4.6 Light intensity

Darley (1982) states that algal cells maximize their growth with varying light intensities by modifying dark (P_{max}) and/or light reactions (α). Cells take full advantage of their environment and assemble light capturing systems that are proficient. Shade adapted cells show higher photosynthetic efficiency (α) because pigment levels increase allowing the photosystem to take advantage of higher proportions of available irradiance. Falkowski and Owens (1980) studied light-shade adaptation (transfer and harvest of light energy to the reaction centres) by examining the number and size of the photosynthetic units. Adaptation appears to result from changes in pigment content, photosynthetic response, chemical composition and cell volume. The study showed P_{max} decreased as the cells adapted to low irradiance but no significant difference was shown in α as cells adapted to various light intensities. The decrease in P_{max} was attributed to the fact that cells increased production of chlorophyll instead of producing dark reaction enzymes (Darley, 1982). I_k would be lower as a result of this adaptation.

'Sun' cells are cells in the upper part of the water column that are not limited by light. Lower amounts of chlorophyll are characteristic of sun cells. In this case, photosynthesis is not limited by light but by the dark reactions of photosynthesis. Carbon fixation rates are dependent on cell metabolism. It is more beneficial for sun adapted cells to devote more energy into RUBISCO synthesis and other dark reaction enzymes than chlorophyll formation. Sun adapted cells show lower α, higher I_k, higher P_{max}, and at high light intensity are less susceptible to photoinhibition (Darley, 1982).

Sun-shade adaptions also change ratios of chlorophyll-a to accessory pigments. The result is the light capturing efficiency per unit of chlorophyll is adjusted and the slope of light limitation changes (Darley, 1982). To account for this, Geider and Osborne (1992) suggest the use of chlorophyll-a normalized data so comparisons can be made between organisms from different size classes and light regimes.

2.4.7 Light quality

Kirk (1983) states the total incident irradiance quality that is available for absorption by the photosynthetic pigments is affected by cell size, cell shape, chloroplast arrangement, pigment content, and thylakoid packaging. Algal chemical composition changes with depth in the photic zone because of the differential attenuation of composite wavelengths of PAR. This is provided that algae remain in place long enough to express this. Longer wavelengths are absorbed first while the shorter wavelengths penetrate to the deepest depths. Blue (oceanic waters) and green (coastal waters) travel the furthest (Wallen and Geen, 1971).

Wallen and Geen (1971) have demonstrated that I_k and P_{max} were higher in blue light compared to green or white light of equal intensities due to high enzyme levels. When the P-I curves were compared between white, blue, and green light, the blue light curve was shifted to the right of the other curves. In green and white light, the dark reactions were more affected than light reactions. They concluded that chemical composition of phytoplankton varies with depth in the water column. Carbohydrate synthesis is favoured in white light but protein synthesis is favoured under blue and green light environments. Wavelengths that are available to the algae may ultimately affect what species can grow. Light profiles may, in fact, be used to predict characteristics of the algal community. Algal size and pigment composition determine an organism's ability to use different wavelengths at low light intensities (Glover *et al.*, 1987). Therefore, variations in the P-I curve can be attributed, to some extent, to the variations in light quality and/or resulting pigments present in any one species.

2.5 Biological Parameters

2.5.1 Cell Size

Studies in the Bedford Basin showed a bimodal seasonal cycle of phytoplankton biomass and mean cell volume (Harrison and Platt, 1980). These peaks were taxonomically distinct with diatoms occurring the spring time and dinoflagellates in the fall. Harrison and Platt (1980) found that high assimilation numbers correlated with lower mean cell volumes. Further studies (Platt *et al.*,1993) performed in the Celtic Sea showed that P_{max} values varied with algal fractions of different sizes. Small organisms have shorter generation times than larger organisms. Size dependency is affected by immediate deteriorating surrounding growth conditions but not changes in larger scale overall environmental conditions. This size dependency can ultimately influence the photosynthetic rate (Banse, 1976). Smaller cells' photosynthetic rates are faster than in larger cells (Taguchi, 1976 and Glover *et al.*, 1987). Other studies have shown that algae of different size but similar accessory pigments grown at lower light intensities display similar trends (Glover *et al.*, 1987). Taguchi (1976) suggests that light use efficiency in larger cells decreases due to 'self' shading of the chloroplasts in larger cells. Specific Photosynthesis (photosynthetic rate normalized per unit of chlorophyll) shows an inverse relationship with size. This suggests that the surface area of the cell controls photosynthesis, as well as respiration and nutrient uptake (Glover *et al.*, 1987).

2.5.2 Species Composition

Phytoplankton assemblage composition is a result of the surrounding environment. Temperature, nutrient availability, life history strategies (eg circadian rhythm), grazing pressure, adaptation to irradiance, seasonality changes related to meteorological events, pigment composition, water composition (pH, alkalinity, salinity, and density) play differing roles. Dunstan (1973) has compared five diverse marine organisms' P-I curves and found no statistically significant differences between them, although he did add that other studies comparing dinoflagellates with coccolithphores exhibited these organisms to be inefficient photosynthetically. Green algal light harvesting units preadapt to high light intensities better than do those of diatoms, dinoflagellates, and coccolithphorids. Whereas, Cote and Platt's (1983) studies in the Bedford Basin showed that the species composition of phytoplankton was transformed during short term physical events like storms, hurricanes, and winds. These changes were related to resulting alterations in density gradients, temperatures, nutrients, and possibly increased grazing pressure. Cote and Platt (1983) found smaller species (like *Dinobryon balticum*) had higher photosynthetic efficiency because they have a low tolerance for high light intensities and use light intensities below saturation more efficiently than many other algal species. Changes in an environmental condition may cause conditions that favour one species. Increased abundances of that species will occur. Phytoplankton communities' composition may demonstrate long term changes resulting from seasonal variation in conditions (Harris *et al.*, 1980).

2.5.3 Pigment Composition

As discussed in relation to the influence of light quality, algal size and pigment composition determine an organism's ability to use different wavelengths at low light intensities (Glover *et al.*, 1987). Wallen and Geen (1971) concluded that chemical composition of phytoplankton varied with depth in the water column. Carbohydrate synthesis is favoured in white lights but protein synthesis via algal metabolism is favoured by blue and green light. Halldal (1970) stated that the photosynthetic apparatus is flexible. Differences in light quality and efficiency of transferred energy to chlorophyll-a can be influenced by a wide spectrum of algal species by way of pigment content and composition.

2.5.4 Diel Oscillation

The P-I response may be influenced by diel oscillations of phytoplankton. The photosynthetic apparatus response varies with the irradiance changes. This type of event occurs in both light saturated and limited photosynthesis with proportional changes to P_{max} and α. Maximum values occur during light periods (between midmorning and midafternoon) and minimum values occur with dark periods. *Ulva lactuca* (a benthic green alga) has been seen to be an exception with α remaining constant. When experiments were done under laboratory condition, the greatest effect was seen when cells were in early exponential growth. Late stationary phase cultures were the least affected (Geider and Osborne, 1992) some degree of synchrony during exponential growth may have influenced this. Diatoms (large and centric) displayed pronounced oscillation. It was suggested that photosynthesis diel periodicity may be independent of chlorophyll content changes (pigment concentrations) and may be controlled by an endogenous biological rhythm. Since diel oscillations occur through the day, to obtain true representative productivity values rigorous sampling is suggested (Harding *et al.*, 1982).

2.5.5 Grazing Pressure

Zooplankton grazing is an important contributor to nutrient cycling. Diel oscillation of nutrient concentrations may be due to zooplankton excretion. Grazing pressure depends on vertical migration and feeding rhythm of the grazers. Most often zooplankton display nightly upward migration to feed with breeding occurring during the day. On the other hand, migratory phytoplankton migrate up during the morning to assimilate in the light and in the dark they divide (Sournia, 1974). P_{max} may then be correlated to grazing pressure. Cote and Platt (1983) using the phaeopigment to chlorophyll-a ratio as an estimator of zooplankton grazing found that increases in P_{max} coincided with the intensity of zooplankton grazing.

2.6 Photosynthesis Modelling

Photosynthesis - Irradiance relationships maybe described empirically and numerical descriptions used for modelling of long term productivity. Geider and Osborne (1992) outline several curve fitting techniques to model photosynthesis - irradiance relationship. If a minimal number of parameters are used to describe the Photosynthesis - Irradiance relationship, the resulting model will not account for all influencing parameters (Geider and Osborne, 1992). The curve fitting technique described by Platt *et al.* (1980) was used to model photosynthesis in Clear Lake, Manitoba (Riding Mountain National Park). Chlorophyll-a specific photosynthesis (P_s) is estimated as follows:

$$P_s = P_{max} \times (1 - e^{(-\alpha \times I)/Pmax}) \times e^{(-\beta \times I)/Pmax}$$

where P_{max} - maximum observed rate of P_s

α - slope of light limited photosynthesis (photosynthetic efficiency)

I - incident PAR

β - photoinhibition slope

This type of model was used (knowing that photoinhibition can underestimate P_{max} (Geider and Osborne, 1992)), because of its inclusion of photoinhibition.

2.7 Conclusion

A quantitative model for phytoplankton production estimation can be based on the photosynthesis - irradiance (P-I) relationship. In theoretical studies of phytoplankton productivity, this light saturation curve is the principal component because it relates photosynthesis (per chlorophyll-a unit) to irradiance. A variety of mathematical descriptions of the P-I curve are outlined in Kirk (1983). The two most important parameters are α, the initial slope or light limiting portion, and P_{max}, the plateau or light saturation portion. Variations of these parameters are likely not dependent on one variable but on combinations of sources variables. These parameters will likely vary with season, depth within the photic zone, species composition, and other environmental factors.

Chapter 3 Nutrient Status

3.1 Introduction

Aquatic scientists and lake managers are increasingly aware of the algal response to nutrient additions. One example is the Laurentian Great Lakes where anthropogenic effluents (cultural eutrophication) induce nuisance algal blooms. An Eutrophication Control Policy was adopted by the International Joint Commission, which stated that phosphorous removal from the influents should take place because phosphorous is most often the limiting nutrient and its removal is less expensive and less difficult than nitrogen removal (Fleet *et al.*, 1980). Nitrogen removal would be pointless because essentially uncontrollable atmospheric nitrogen fixation could supply a considerable amount of that nutrient into any lake under appropriate conditions (Fleet *et al.*, 1980). On the other hand, nutrient supply (both phosphorous and nitrogen) often controls algal biomass in oligotrophic lakes (Dodds and Priscu, 1990). The result is that in both eutrophic and oligotrophic systems nutrient deficiency and algal growth response to nutrient additions need to be examined.

In order for algal cells to reproduce, they require conservative proportions of elements (both macro and micro nutrients). In other words, stoichiometric requirements are needed to meet algal growth demands, although this may vary some with interspecies variation (Hecky and Kilham, 1988). The phosphorous limiting theory was assumed to be correct for many years and evidence supporting the theory has come from several sources. This has been displayed in systems ranging from algal culture to whole lakes (Hecky and Kilham, 1988). Schindler (1971) outlines a variety of studies that pose challenge to the theory and critiques Lange's (1970) (in Schindler, 1971) work on carbon limitation. In most natural freshwaters the underlying limiting nutrient is phosphorous (Schindler, 1971).

Apart from nutrient limitation, other factors may influence algal growth and in the end may be limiting: species specific growth requirements, community requirements, zooplankton communities, trophic structure, temperature, light, rain events, replacements rates, rivers and streams, wind events, and lake size to name a few (Wetzel,1983) . These factors must be kept in mind before conclusions are drawn as to the exact nature of any limiting factor. Such models like the Droop model (Droop, 1974) or Monod model (1942 in Droop, 1974) have been developed to examine phytoplankton growth response to nutrient limitation.

Examining nutrient metabolism in natural environments is complex due to uptake, storage, oxidation, and reduction processes involved (Pettersson, 1980). The ability to evaluate the nutrient status (deficiency and sufficiency) in phytoplankton communities has involved several simple approaches. Certainly, some measurements of nutrient concentration in a water sample are not sufficient. Besides the use of specific algal species successions, as being indicative of nutrient conditions, the following approaches have been used :

1. Enrichment of a sample (plankton or filtered lake water) with an inoculum of algae with some nutrient (or combination of) and measurement of growth response:

a. An assemblage is enriched with a single nutrient. Increased growth is interpreted as indicative of that nutrient being limiting,

b. The use of an algal (usually *Selenastrum*) culture that is grown in natural waters and in which comparison of growth values is used to indicate nutrient availability in the water,

2. Comparison of algal composition (chemical) that is limited by a particular nutrient to that of an unknown,

3. Determination of some metabolic change believed to be specific to a certain nutrient limitation,

4. Determination of the nutrient ratios in phytoplankton and surrounding water (Pettersson, 1980 and Healey, 1973).

Two types of problems can arise from these approaches. The first is the application of laboratory conditions to natural samples although there is increasing evidence that manifests a uniformity among diverse algal associations in their response to nutrient conditions. Healey (1975) and Healey and Hendzel (1979) have provided a quantitative approach based on controlled laboratory procedures, which may then be used in natural situations. The second problem is the comparison of short and long term bioassays in determining nutrient deficiency in natural phytoplankton assemblages. The short term bioassays examine uptake rates of NH_4^+, or PO_4^{3-}, or based on NH_4^+ enhancement of dark carbon fixation. These protocols are convenient and cost effective. On the other hand, long term bioassays are based on net increases of phytoplankton community biomass (Dodds and Priscu, 1990). This portion of the thesis will outline the concept of limitation, importance and sources of nitrogen and phosphorous to the system, laboratory methods, and application to the natural environment.

3.2 Concept of Limitation

In natural settings, phytoplankton assemblages are composed of a variety of species that fluctuate based on existing surrounding conditions. This fluctuation depends on a phytoplankton's cellular growth rate through time or Reynolds equation (population growth rates), which states that growth rate must exceed or equal losses to dilution, sedimentation, physiological death, and grazing over a certain time period. One must include abundance of the phytoplankton species and phytoplankton biomass at the start and finish of any assessment of growth (Reynolds, 1984). A phytoplankton species can be limited by its growth coefficient and/or loss terms. Hecky and Kilham (1988) state that low abundance does not necessarily suggest low cellular growth rates.

Population growth rates are affected by nutrients through the cellular growth rate because it varies with light, temperature, and nutrient supply. Therefore, growth due to nutrient limitation can be modeled through one of two equations: the Droop model or the Monod model (Hecky and Kilham, 1988). The Monod model relates growth rates to external dissolved nutrient concentrations (Hecky and Kilham, 1988). The Monod equation for nutrient limited growth is based on the generally correct assumption that the kinetics of limiting nutrient assimilation also describes nutrient limited growth (Droop, 1973):

$$K' = K'_{max} * s / (K_s + s)$$

where K' - specific growth rate (increase in biomass per unit biomass per unit time)

K'_{max} - maximum growth rate at infinite external substrate concentration

s - external substrate (limiting nutrient) concentration (mass per volume)

K_s - half saturation constants (external concentrations giving half maximal rates or half saturation component)

Droop (1974) argued that growth rate is a result of internal substrate concentrations rather than external. The Droop model examines phytoplankton growth response to the internal nutrient concentrations (Hecky and Kilham, 1988) but he further adds the implications of Liebig's law and luxury consumption (Droop, 1973). Droop equation for nutrient limited growth (Droop, 1973):

$$K' = K'_{max} * (q - q^{o}) / K_{s} + (q - q^{o})$$

where K' - specific growth rate (increase in biomass per unit biomass per unit time)

K'_{max} - maximum growth rate at infinite external substrate concentration

s - external substrate (limiting nutrient) concentration

K_s - half saturation constants (external concentrations giving half maximal rates of growth)

q - cell quota (total nutrient available to cell)

q^{o} - nutrient level when K' is zero (absolute minimum amount of nutrients)

This is also known as the Cell-Quota model, which considers how several nutrients and light can potentially limit growth. Growth is limited via a threshold (non-interactive) model not a multiplicative (interactive) model (Tett *et al.*,1985). Threshold models present a single nutrient, the one in shortest supply with respect to cellular needs, as that which controls growth. Droop (1974) states that the multiplicative model demonstrates that at all times some control is exerted by all nutrients. When algal growth is controlled by nitrogen or phosphorous, high N:C or P:C ratios would depict near maximal growth rates and the Redfield ratio (C:N:P of 106:16:1) (Tett *et al.*, 1985). However, if light controls growth, algal growth could occur slowly with C:N:P close to the Redfield ratio (106 C :16 N :1 P) . This would follow the Cell-Quota model of Droop (Tett *et al.*, 1985). Tett *et al.* (1985) applied a (threshold) model (based on the Cell-Quota) to a natural situation, euphotic zone, in which light limitation may be possible. They found phytoplankton in the lower portion of the euphotic zone was growing slowly although uptake of high nutrient was high. Yet Droop (1974) found that under severe nutrient limitations (vitamin B_{12}), other nutrient (eg. - phosphorous) uptake was prevented, although present in large amounts. Ahlgren (1980) outlines a variety of experiments done to support Droop's Cell-Quota / Threshold model for nutrient limitation: example Rhee (1978) with *Scenedesmus* and Feuillade & Feuillade (1975) with *Oscillatoria*.

Hecky and Kilham (1988) state that cellular composition and physiology change under nutrient limitation, Healey's (1975) studies showed under P or N limitation, chlorophytes, cyanophytes, diatoms, chrysophytes, and dinoflagellates grown at similar growth rates displayed similarities in internal nutrient concentration and physiological responses. Natural phytoplankton communities can be selectively influenced by nutrient loading ratios by influencing the nutrient limiting most species (biomass yields of individual species will change). These natural assemblages are composed of complex mixtures of species that have very individual needs. Despite this, results of nutrient limitation or enrichment experiments are most often expressed in terms of total phytoplankton biomass and not individual species (Hecky and Kilham, 1988).

3.3 Nutrient Requirements

Within freshwater systems, nutrient cycles are controlled by redox potential and nutrient element transformation by microbes in oxygen deprived conditions (Schlesinger, 1991). Algal cells require a fixed proportion of elements (both macro and micro nutrients) for growth. In other words, stoichiometric requirements are needed to meet algal growth requirements (Hecky and Kilham, 1988).

Past research has shown that marine and freshwater algae have similar growth requirements with respect to light and major nutrients (nitrogen, phosphorous, and carbon). Although the environments differ, the physiological processes are the same. The Redfield ratio of C:N:P (106:16:1) tends to be consistent with phytoplankton chemical composition (Tett *et al.*, 1985). This ratio was established for marine phytoplankton under conditions of near optimum growth rates and sufficient supply of nutrients (Hecky *et al.*, 1993). Goldman (1980) further states "change in cellular chemical composition as a function of varying growth rates is a biochemical response to different degrees of nutrient limitation". When algal growth is controlled by nitrogen or phosphorous, high N:C or P:C ratios would depict near maximal growth rates and / or the Redfield ratio. However, if amount of light controls growth, algal growth could occur slowly with C:N:P close to the Redfield ratio (Tett *et al.* ,1985).

An ideal N:P ratio is 15:1 (Round, 1981). When nitrogen levels are high and phosphorous are low, there is not enough phosphorous in the system to use up all of the nitrogen that is available for phytoplankton growth therefore the system is phosphorous limited. On the other hand, when phosphorous levels are high and nitrogen is low, there is not enough nitrogen in the system to use up all of the phosphorous that is available for phytoplankton growth and therefore the system is nitrogen limited. Nitrogen and phosphorous availability may affect phytoplankton that is available for grazing. A bottom-up dynamic occurs and the upper part of the food chain may be greatly affected because the food available is decreased.

3.3.1 Nitrogen

Nitrogen is an important component of the aquatic cycle. Most of the activity is by plants (both microphytes and macrophytes). Animals do influence nitrogen availability by grazing on algae and microbes and nitrogen recycling. Nitrogen is involved in three processes that are nitrogen fixation ($N_2 \rightarrow NH_3$), nitrification ($NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$) and denitrification (biochemical reduction of oxidized forms of N (NO_2^- and NO_3^-) to N_2 or NH_3). The rates of the reactions are dependent on oxygen and temperature. Two general patterns occur with nitrogen. In the winter, input of nitrogen exceeds that used by algae. Hypolimnetic mixing allows for the regeneration of nitrates (or ammonia under anoxic conditions) from the sediments. In the summer, algal uptake of nitrogen is greater than the input. Because stratification occurs, the hypolimnion is essentially sealed so extremely little nutrient availability is possible from sediments. Nitrogen can, however, also be available from nutrients in sewage, and pesticide leaching. If the nitrogen levels are too high, some algae may bloom provided sufficient phosphorous is available (Cole, 1983).

3.3.2 Phosphorous

Phosphorous is often the limiting element in freshwater ecosystems because phosphorous is sparsely contained in minerals; it is tightly bound to minerals in the soil; and phosphorous has no gaseous phase. It is essential because it allows the cell to store and transfer energy and genetic material (Cole, 1983). Phosphorous is often the least abundant macro nutrient used by plankton for growth and is often known to be the growth limiting nutrient. It can be found in natural waters as orthophosphate (HPO_4^{-2}) or dihydrogen phosphate ($H_2PO_4^{-1}$), in apatite (a natural mineral from which phosphorous is weathered), particulate phosphorous, and dissolved organic phosphorous (DOP). Inputs include external loading (geochemical input), sediments, and recycling within the water.

3.4 Laboratory Methods

The following approaches were outlined in the introduction as ways to evaluate the nutrient status (deficiency and sufficiency) of phytoplankton assemblages:

1. Enrichment of phytoplankton with a nutrient supplement of a lake water sample with a unialgal assay, both being accompanied by measured phytoplankton algal response.

2. Comparison of algal elemental composition (chemical) with that of algae growing under optimal conditions. (Surplus phosphorous or the luxury consumption of phosphorous (polyphosphate) may be accounted for (Pettersson, 1980)).

3. Quantification of metabolic changes believed to be specific to a specific condition of nutrient limitation. This most often involves the determination of uptake kinetics of possibly limiting nutrients (nitrogen and phosphorous debt experiments), and enzymatic responses such as alkaline phosphatase and nitrogenase activity (Flett *et al.*, 1980, Healey and Hendzel, 1980, Healey, 1973, Pettersson, 1980).

4. Comparison of the nutrient ratios in phytoplankton with that of surrounding water to determine which nutrient is likely to become limited (evaluate elemental compositional ratios). This would most often involve the determination of particulate or seston carbon, nitrogen, and phosphorous. Then comparisons could be done on atom : atom or atom : weight basis with the weight being dry weight, it is not uncommon to express nutrients as per unit of chlorophyll-a basis (Healey, 1975).

For this thesis, the second, third, and fourth approaches will be discussed in further detail since these were the approaches utilized in this study. The first approach is mainly a laboratory method that examines a single species response to nutrient limitation, whereas the later three approaches examine the whole phytoplankton community response to nutrient limitations.

The second approach describes the concept of luxury consumption, which is the internal accumulation of a nutrient beyond immediate requirements (mainly phosphorous - condensed polyphosphate). Droop (1973) demonstrates an example of this concept. Uptake of phosphorous is quickened (uptake >specific growth rates) when a phosphorous limited alga is place into fresh culture medium. Phosphorous surplus allows continued optimal growth for several generations when external concentrations of phosphorous become exhausted. This can account for some species responses to nutrient limitation (for nutrients for which luxury consumption occurs).

The third approach is the quantification of the metabolic changes believed to be specific to specific nutrient limitation. Healey (1973) demonstrated *Anabaena* sp. assimilates phosphates according to Michaelis Menton kinetics. For saturation of uptake, high phosphate levels were required. In other words, the higher degree of deficiency was indicated by a higher initial saturation rate of uptake. Nutrient (nitrogen and phosphorous) debt assays measure the total amount of nutrient taken up during a period of time. Samples are usually placed in the dark for 24 hours, so a non-growth period is achieved (net uptake is approximately zero). Healey (1975) describes this method to involve both the quantity of nutrient needed to surmount limitation and luxury consumption (especially with phosphorous). The assay of alkaline phosphatase activity is an enzymatic approach to measure phosphorus deficiency because alkaline phosphatase activity, occurring on the cell surface, increases with phosphorous deficiency. Pick (1987) states this should exhibit rapid fluctuations in cell nutrient status from sudden nutrient input. The assay of alkaline phosphatase activity simply involves the hydrolysis of *o*-methyl-fluorescein phosphate to *o*-methyl-fluorescein, which is followed either colorimetrically or fluorometrically (the latter being the more sensitive method and less subject to detrital interference) (Healey and Hendzel, 1979b). Nitrogenase (an oxygen sensitive, iron, sulphur, and molybdenum containing enzyme complex) activity is an enzymatic approach to measuring nitrogen deficiency in certain phytoplankton because it is the trigger mechanism for nitrogen fixation. Many nitrogen fixing organisms (cyanobacteria) contain heterocysts that form in nitrogen limiting conditions (South and Whittick, 1987). Acetylene reduction to ethylene is one assay to measure nitrogen fixation (and nitrogenase activity). Gas Chromatography separates the substrate from the product. Flett *et al.* (1980) revealed considerable rates of acetylene reduction only in the presence of nitrogen fixing blue green algae. Nitrogen fixation (and nitrogenase activity) may also, however, be assessed directly by following the kinetics ofN-15 uptake by mass spectrometry.

The fourth approach involves the determination of particulate or seston carbon, nitrogen, and phosphorous. Then comparisons may be conducted on an atom : atom or atom : weight basis (dry weigh or chlorophyll-a) (Healey and Hendzel, 1980). Once ratios are determined, they can be compared with the Redfield ratio (106C : 16N : 1P), which is consistent for nutrient sufficient phytoplankton chemical composition (Tett *et al.*, 1985). In Hecky *et al.* (1993), Goldman described nutrient sufficiency by C : P ranging from 75 : 1 to 150 : 1 and N : P ranging from 10 : 1 to 20 : 1. Deviations from such ratios are then indicators of altered sufficiency / deficiency conditions. Concern is raised when examining the seston rates for two reasons. The first reason is the influence of allochthonous detritus on ratios. The second reason is the effects on secondary production because of the fixed stoichiometry of zooplankton (Hecky *et al.*, 1993).

Healey (1975) and Healey and Hendzel (1979) have provided a quantitative approach 'calculated' on laboratory cultures, which is generally applicable to natural situations. In summary, extreme deficiency shows increased metabolic indicators and decreased compositional elemental ratios. Metabolic indicators are extremely sensitive to the beginning of deficiency and therefore high values tend to be seen with from slight and extreme deficiency (as indicated in the Table 3.1 with *). Healey (1975) first studied various nutrient deficiencies' affect on algal composition and metabolism and categorized the results into four divisions.

Table 3.1 - Indicators of phytoplankton nutrient deficiency / sufficiency (Healey, 1975).

variable		Extreme Deficiency	Moderate Deficiency	Slight Deficiency	No Deficiency - Sufficiency
growth rate		< 20% of max	≈50% of max	≈80% of max	exponential growth
Nitrogen	μg/mg dry weight	< 40	40 - 70		> 70 - 120
Phosphorous	μg/mg dry weight	< 5	5 - 10		> 10
Chlorophyll	μg/mg dry weight	< 5	5 - 10		> 10
protein	μg/mg dry weight	< 300			> 400
carbohydrate	μg/mg dry weight	<400			< 300
protein : carbohydrate		< 0.8			> 1.2
protein : carbohydrate : lipid		< 0.5			> 0.7
dark ammonium uptake	μmole/mg dry weight/hr	> 0.3	0.2 - 0.3	'*'	< 0.2
light ammonium uptake	μmole/mg dry weight/hr	> 0.8	0.6 - 0.8	'*'	<0.6
phosphate uptake	μmole/mg dry weight/hr	> 0.2	0.1 - 0.2	'*'	< 0.1
Alkaline phosphatase	μmole/mg dry weight/hr	> 2	1 - 2	'*'	< 1

Note - * - Metabolic indicators are extremely sensitive to the beginning of deficiency and therefore high values tend to be seen with from slight and extreme deficiency.

Healey (1975) concludes that expressing metabolic indicators of deficiency on a per unit of chlorophyll basis increases the sensitivity since such measurements are less subject to interference from detritus.

Table 3.2 - Pooled data from a variety of sources developed to provide division points between nutrient sufficiency and deficiency. Conversions were done to change values from μg:μg to μmole:μmole for particulate values (Healey and Hendzel 1979b, and 1980).

	Measure	units	No Deficiency	Moderate Deficiency	Severe Deficiency
P deficiency	C:P	μmole:μmole	<129	129 - 258	>258
	N:P	μmole:μmole	<22		>22
	Alk phos	μmole P/μg Chla/ hr	<0.003	0.003 - 0.005	>0.005
	P debt	μmole P/μg Chla/24 hr			>0.75
N deficiency	C:N	μmole:μmole	<8.3	8.3 -14.6	>14.6
	N debt	μmole N/μg Chla/24 hr			>0.15
General	C:Chl	μmole:μg	<4.2	4.2-8.3	>8.3

3.5 Application to the Natural Environment

Many questions arise when laboratory procedures are applied to natural settings. Healey (1975) and Healey and Hendzel (1979) have provided a quantitative approach based on laboratory procedures. The following will outline some results and conclusions from the application of these procedures to field studies.

At the Experimental Lakes Area (ELA) in Ontario, the researchers from Freshwater Institute (DFO, Winnipeg, Canada) have performed a variety of whole lake studies to examine the role of nutrients on phytoplankton and how morphometric parameters modify nutrient status, both within the lake and the algae. Hecky *et al.* (1993) extended this research from the arctic to tropical climates to examine a total of 51 lakes and lake basins. They found stratification and residence times influenced nutrient processing and ultimately algal elemental ratios. Seasonality differences were seen in chlorophyll and compositional ratios. Spring time chlorophyll levels were at maximum levels while seston ratios (C:N and C:P) were near minima. Nitrogen and phosphorous were high in the spring and decreased through the season. Opposite results were seen later in the season. In a nutrient (phosphorous) addition lake (Lake 227 - ELA) increased chlorophyll showed an increase in C:P but a decrease in C:N. Yet, *Anabaena*, a nitrogen fixing alga, prevailed in an increasingly phosphorous limited system. They concluded that under phosphorous limitation, phytoplankton must grow more slowly and adjust by species selection that can support growth at low cell quotas.

Another study at ELA (Lake 226) examined the role of algal growth limited by phosphorous in a dual basin study, in which one basin received nitrogen, phosphorous, and carbon and the other received nitrogen and carbon (Hecky and Kilham, 1988). The phosphorous induced lake responded by increased chlorophyll and primary production. Lake 226 was dominated by nitrogen fixing blue greens, whereas Lake 227 (above) was dominated by chlorophytes. Hecky and Kilham (1988) concluded that phytoplankton community composition is influenced by N:P supply ratios and continued research in bloom forming cyanobacterial response to N:P supply ratios. Heterocystous blue greens dominate when the N:P supply ratio falls below 11:1. Pettersson's (1980) study of phosphorous deficiency in Lake Erken in Sweden concluded that phytoplankton growth limitation in Lake Erken switched from phosphorous in the spring (severe lack of phosphorous) to nitrogen in the summer / fall (good supply of phosphorous). Heterocystous blue greens developed there also. These results show that a moderately eutrophic lake (Lake Erken) behaves similarly to recovering polluted lakes (Lake 226 and 227) (Pettersson, 1980). Healey and Hendzel (1980) and Dodds and Priscu (1990) conclude that oligotrophic lakes can exhibit simultaneous nitrogen and phosphorous deficiencies contradictory to the phosphorous limitation theory.

Researchers at the Freshwater Institute (DFO, Winnipeg, Canada) examined lake size on phytoplankton productivity as part of the Northwest Ontario Lake Size Series (NOLSS) (Fee *et al.*, 1992). Their hypothesis was that algae grown in low light tend to be less nutrient deficient. Therefore, small lakes are more nutrient deficient than large because low turbulence levels in small lakes intensifies this by reducing in nutrient availability. This has been proven true in small ELA lakes. Fee *et al.* (1992) states, therefore, that phosphorous loading will influence phytoplankton biomass and productivity more in small lakes than in larger lakes.

Rhee and Gotham (1980) suggest that population dynamics can be enhanced by the varying optimum ratios of different species and diel changes in cellular N:P ratios within a species. The probabilities of species coexisting will, therefore, increase. Diel cycles could result in temporal variation in the limiting nutrient. Now, if these temporal changes are dissimilar between species, these species cannot coexist with each other. The degree of limitation can be altered over a 24 hour period due to such diel cycles modifying limitation (more than 24 hours). This degree of limitation can be quantified as the difference between cellular and optimum N:P ratios.

Lean (1987) proposes that phosphorous availability is dependent on the length of time of spring mixing. The longer this period, the less phosphorous is available for later in the summer. Some phosphorous may, however, be recycled in the euphotic zone due to alkaline phosphatase activity, in which orthophosphates are made available for uptake by the hydrolysis of phosphate ester bonds in the dissolved organic phosphorous pool (Pick, 1987).

The role of nitrogen fixation on nutrition of phytoplankton and aquatic weeds is important. Fitzgerald (1969) examined an algal bloom containing *Microcystis* sp. and *Aphanizomenon* sp. from Lake Monona in 1967. *Microcystis* sp. was nitrogen limited and contained a surplus of phosphorous. *Aphanizomen*on sp. was not nitrogen limited but was probably phosphorous limited. A 1966 sample of *Microcystis* sp. and *Anabaena* sp. mimicked 1967 with *Anabaena* sp. being phosphorous limited while *Microcystis* sp. had a phosphorus surplus. Fitzgerald (1969) concluded that in *Aphanizomenon* sp. and *Anabaena* sp. nitrogen levels were surplus or sufficient but unavailable to *Microcystis* sp. On the other hand, in *Microcystis* sp. phosphorous levels were surplus or sufficient and unavailable to *Aphanizomenon* sp. and *Anabaena* sp.

3.6 Conclusions

Phytoplankton has several requirements for growth and reproduction. If these requirements are limiting or deficient, phytoplankton growth and reproduction can be restricted or suppressed. Evaluating the phytoplankton assemblage nutrient status to detect the effects of nutrient deficiency or possible sufficiency with respect to the algal metabolism and composition, is therefore important. Healey (1975) and Healey and Hendzel (1979) have provided a quantitative approach of laboratory procedures to calculate nutrient status based upon a consistency in reaction to nutrient conditions among diverse algal associations.

Chapter 4 Materials and Methods

4.1 Introduction

This chapter outlines establishment of sampling stations and sampling times in Clear Lake and the methods utilized in the determination of the physical / chemical environment, and phytoplankton parameters. The chapter will close with a brief introduction to the calculation and statistical techniques used in subsequent chapters.

4.2 Establishment of sampling stations

Sampling stations were established during the 1996 field season (June 1, 1996). Three transects were selected to establish appropriate sampling stations that might accurately represent the entire lake. The three transect locations were (Figures 4.1 and 4.2):

1. North shore (Ma-ee-gun) (N 50°41.62' W 99°59.78') to the west of South Lake (N 50°41.38' W 99°59.96'). A total of four samples were taken along this transect.
2. Wasagaming (west of main pier) (N 50°39.65' W 99°58.39') to the North Shore (N 50°40.19' W 99°58.42'). A total of four samples were taken along this transect.
3. Deep Bay (swim area) (N 50°40.18' W 99°56.56') to the deep hole off the tip at Deep Bay (N 50°40.34' W 99°56.39'). A total of three samples were taken along this transect.

Water samples were taken at equal distances from shore to the middle of lake. At each point along the transect the following were recorded: GPS location, temperature profile, and water depth. Water samples (3 L) were from 2 m depth for triplicate biomass determination

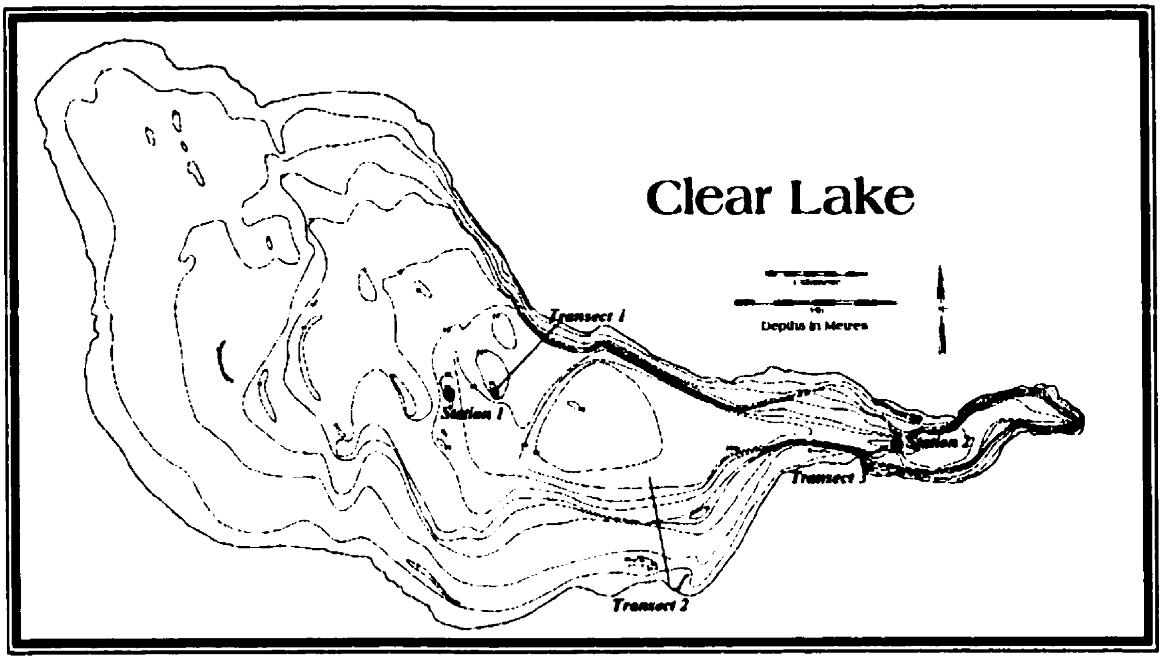


Figure 4.1 - Bathymetric map of Clear Lake, Manitoba with Station and Transect locations
(Source: Riding Mountain National Park Staff)

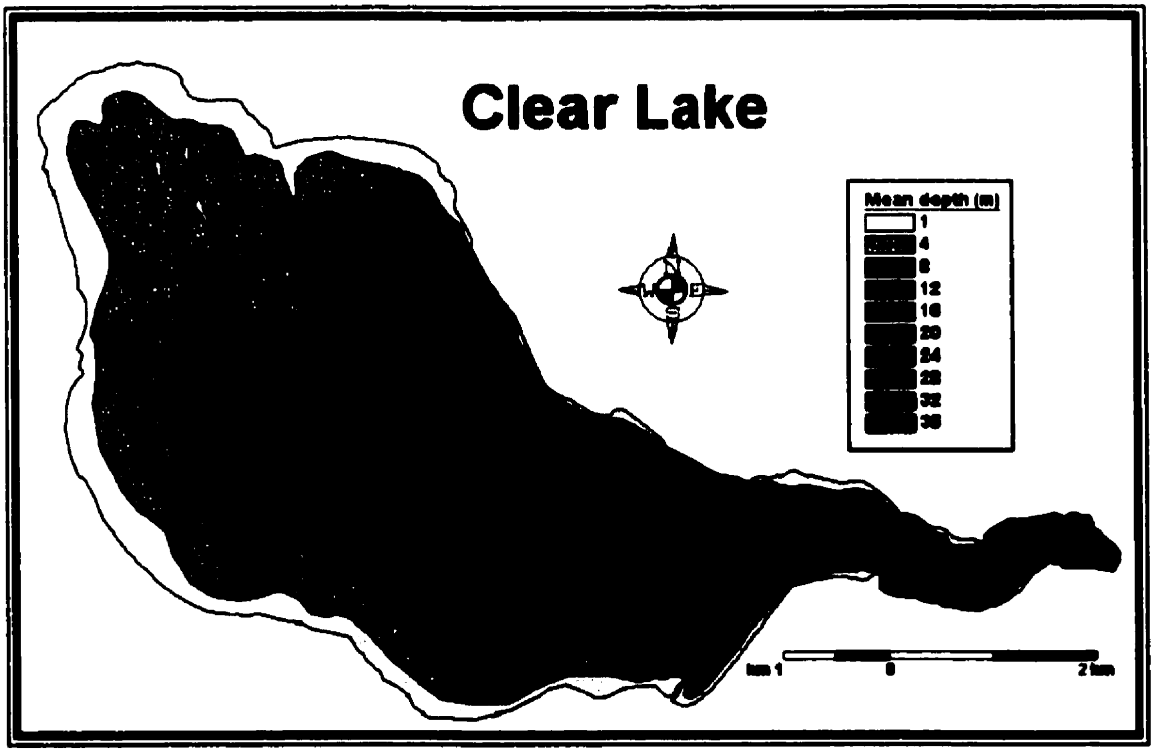


Figure 4.2 - Bathymetric map of Clear Lake, Manitoba
(Source: Riding Mountain National Park Staff)

(chlorophyll-a). At the end of transect (middle of lake), an extra sample (1 L) was taken at the 2m depth for phytoplankton analysis to determine species composition. The purpose of the exercise was to compare the variability within the sites with that between sites and produce a small number (and possibly even one) of sites that accurately represented the entire lake. Chlorophyll-a results displayed (Table 4.1 and Figure 4.3) little differences between the means of the samples along each transect, one sampling could likely have been utilized

Table 4.1 - Phytoplankton Biomass (Chlorophyll - a (μg/L)), sample depth (m), and total depth (m) collected at each transect to determine where sampling stations will be located. Samples collected from the discrete depth of 2m on June 1, 1996.

Transect	Location	Total Depth (m)	Chlorophyll -a (μg/L)
1	Shore	1.5	3.64
1	to	7	3.37
1	Mid	13	3.34
1	Lake	19	2.83
2	Shore	1.75	1.90
2	to	6.5	1.47
2	Mid	23	1.61
2	Lake	31	1.95
3	Shore	10	2.26
3	to Mid	20	2.00
3	Lake	28	1.96

The field data collected on this day can be found in the Appendix (Table A.4.1).

An one-way ANOVA (analysis of variance) confirmed that the three transects did not have the same mean Chlorophyll-a value. The F-ratio (14.528) was sufficiently large to reject the

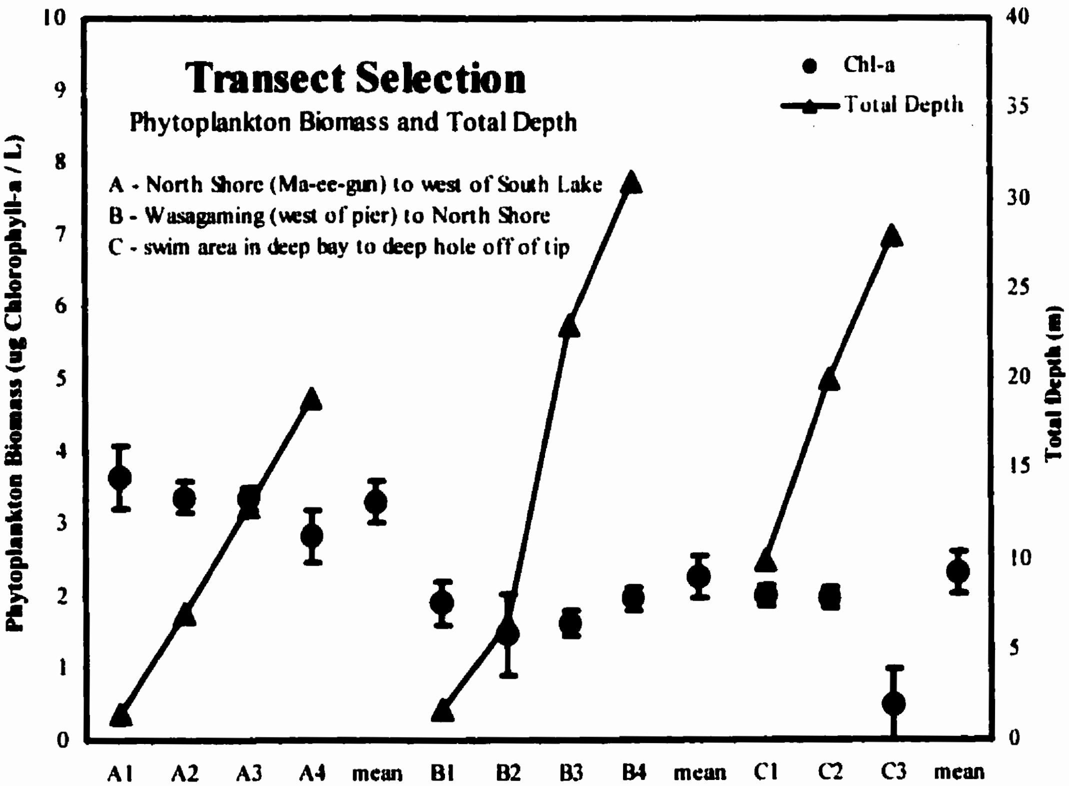


Figure 4.3 - Total depths and Phytoplankton biomass (chlorophyll-a)(n=3) at each sampling station along each of three transects in Clear Lake, Manitoba. Mean chlorophyll-a values with standard deviations for each transect are included (data are presented in Table 4.1). Samples collected from the discrete depth of 2m on June 1, 1996.

null hypothesis of equal Chlorophyll-a means at all three transects with any of the standard α-levels. A dot plot of Chlorophyll-a against transect location indicates that much of the difference among the transects may be attributed to Transect 1 (Station 1), which had a higher mean and was more variable than the other transects. Transect 1 mean chlorophyll-a was higher than Transect 2 and Transect 3. Based however on the obvious differences in morphometry, that was 2 distinct basins (Figure 4.2), two sampling stations were selected to represent the lake (Figure 4.1).

4.3 Sampling Stations

Station 1 (N 50°4 1.27' W 100°0 0.15') was approximately in the middle of the bigger basin where water depth was approximately 19 m. Station 2 (N 50°4 0.30' W 99°5 6.40') was approximately in the middle of the smaller basin and was about 32 m deep. Sampling occurred approximately every three to four days from ice out (May 24, 1996) to ice in (November 10, 1996). Winter sampling occurred once a month for the ice season (November 10, 1996 to May 9, 1997), then weekly (for logistic reasons) sampling continued from ice out (May 9, 1997) to ice in (November 11, 1997). At each station the following were recorded: GPS location, temperature profile, light profile (the penetration of photosynthetically active radiation - PAR), total water depth, and general environmental conditions (cloud cover, wind, waves, sun, rain, etc.) on each sampling occasion. Integrated water samples (6 L) were taken through the epilimnion with an integrating sampler (Shearer *et al.* 1985) for triplicated biomass determinations (chlorophyll-a)(3 L), phytoplankton species composition determination (1 L), a primary productivity experiment (1 L), and additional measures (pH, alkalinity, dissolved inorganic carbon (DIC), alkaline phosphatase activity and nitrogen & phosphorous debt) (1 L). At Station 2, a nanoplankton net (10 μm) was dragged through the water for purpose of phytoplankton species identification. Subsequent analyses were done at the Clear Lake Field Laboratory in the Wasagaming Firehall. Water samples (2m depth) was taken at both stations approximately at two week intervals for chemical analysis by Norwest Lab (Winnipeg) in 1996. The chemical analyses included total nitrogen, total phosphorous, dissolved silica, particulate carbon, particulate nitrogen and particulate phosphorous. To calculate *in situ* productivity, it was intended to record photosynthetically active radiation (PAR) as close to Clear Lake as possible by logging hourly integrations with a LI-COR quantum sensor with a data logger set at the Warden Store complex (Wasagaming) for the duration of the project. Regrettably the data logger malfunctioned part of the way through the first year, so no complete set of data was available for the Clear Lake area. The University of Manitoba Field Station (Delta Marsh, Manitoba), however, did have a complete set of hourly incident radiation data set. A regression analysis of the existing incomplete data from Clear Lake and the equivalent Delta Marsh data revealed little variation ($r^2 = 0.893$) between Clear Lake and Delta Field Station hourly light readings (Figure 4.4). Accordingly, Delta Marsh hourly light readings (PAR) were employed for phytoplankton productivity calculations throughout the study. To account for scatter and reflection of light before penetrating the water, Hutchinson (1975) recommends reducing the values by 10%. In the case of this study, it was estimated from direct comparison of light above the water surface and immediately below the surface that 75.01% of the incident light penetrated the water. Integrated hourly PAR values were therefore reduced by 24.99%. To determine daily

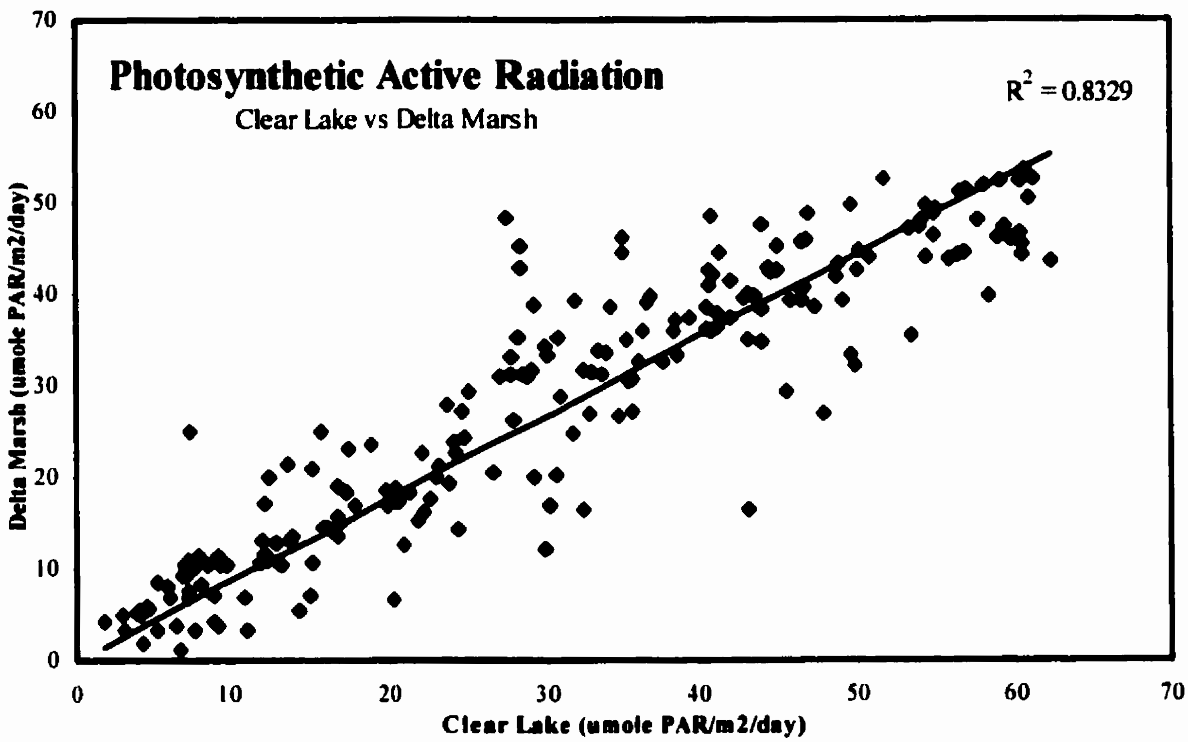


Figure 4.4 - A comparison of integrated hourly photosynthetically active radiation at the University of Manitoba Field Station (Delta Marsh) and Clear Lake, Manitoba (data from Delta Marsh provided by L.G. Goldsborough). Absolute lack of difference was not accounted for.

integrated PAR (when needed), hourly values were totalled over a 24-hour period.

4.4 Daily Cycle and Horizontal Distribution

On September 3, 1996, sampling occurred at two hour intervals from sunrise to sun set to determine whether any diurnal rhythm in photosynthesis occurred. This was a means of assessing what sampling time best represented what occurred during the day. Station 2 was selected for this due to ease of accessibility. The first sample was taken at 7:00 CST and last sample was taken at 16:45 CST for a total of five sampling times. At each sampling, the data collection and sampling procedure were as above. The maximum productivity (P_{max}), chlorophyll-a, and maximum chlorophyll-a normalized productivity (SP_{max}) were determined (as will be described in section 4.5). Detailed data are available in Table A.4.2

Total Alkalinity (mean = 193.2 mg /L), pH (mean = 8.35), and Dissolved Inorganic Carbon (mean = 46.368 mg / L) showed little to no variation throughout the day. Phytoplankton biomass was low at the first sampling in the morning (1.72 μg Chlorophyll-a / L) and increased as the day progressed. A peak level (2.28 μg Chlorophyll-a / L) was seen when the sun was highest (Figure 4.5).

The highest P_{max} (10.246 μg C L^{-1} $hour^{-1}$) and SP_{max} (5.957μg C L^{-1} $hour^{-1}$ μg Chl-a^{-1}) values were seen at the 7:00 CST sampling, while lowest values were seen at the last sampling of the day (16:45 CST), P_{max} was 10.246 μg C L^{-1} $hour^{-1}$ and SP_{max} was 5.957μg C L^{-1} $hour^{-1}$ μg Chl-a^{-1}. The 11:45 CST sampling showed the greatest amount of variability with values ranging from 3.250 μg C L^{-1} $hour^{-1}$ to 11.750 μg C L^{-1} $hour^{-1}$ for P_{max} and 2.125 μg C L^{-1} $hour^{-1}$ μg Chl-a^{-1} to 4.454 μg C L^{-1} $hour^{-1}$ μg Chl-a^{-1} for SP_{max}. Figures 4.5

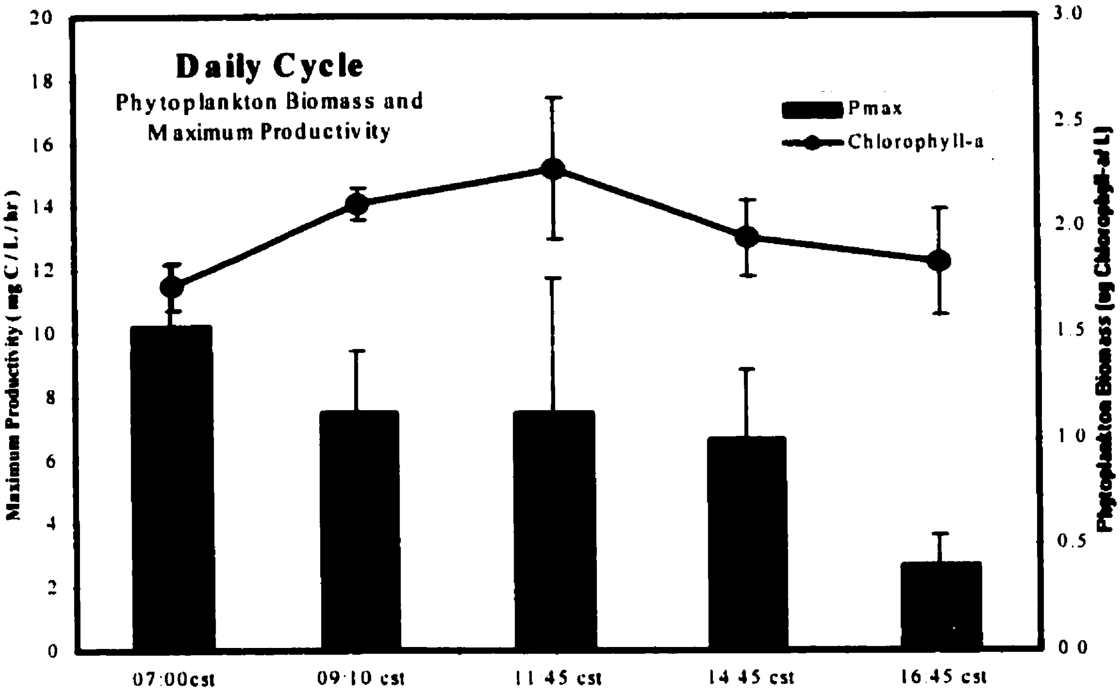


Figure 4.5 - A time series plot comparison of Pmax (productivity at light saturation) error bars indicate the lower and upper 95% confidence intervals and Chlorophyll-a with standard error bars for Clear Lake, Manitoba (Station 2) September 3, 1996 throughout a daily cycle.

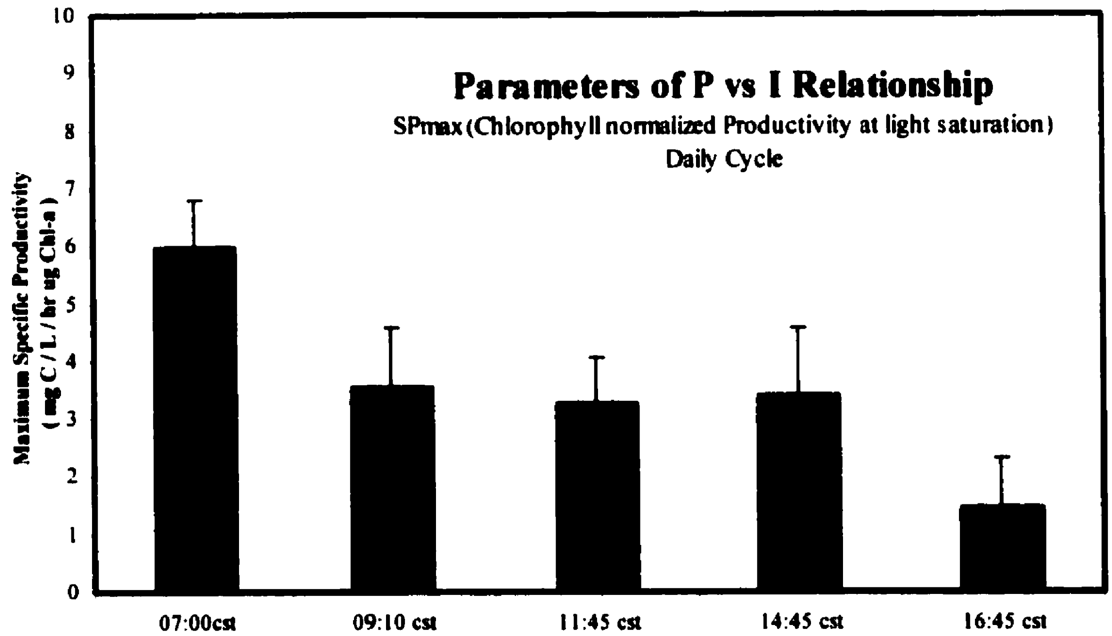


Figure 4.6 - A time series plot comparison of SPmax (Chlorophyll normalized Productivity at light saturation) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 2) September 3, 1996 throughout a daily cycle.

and 4.6 illustrate these trends.

The highest 'alpha' (0.074 µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1}) and chlorophyll-a normalized 'alpha' (0.043µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1} µg Chl-a^{-1}) values were seen at 7:00 CST sampling, while lowest values were seen at the last sampling of the day (11:15 CST), 'alpha' was 0.034 µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1} and chlorophyll-a normalized 'alpha' was 0.015 µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1} µg Chl-a^{-1}. The higher the 'alpha' value, the more efficient usage of irradiance was achieved. The 9:10 CST showed the greatest amount of variability with values ranging from 0.036 µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1} to 0.099 µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1} for 'alpha' and 0.017 µg C L^{-1} µmole PAR m^{-2} sec^{-1} $hour^{-1}$ µg Chl-a^{-1} to 0.047 µg C L^{-1} $hour^{-1}$ µmole PAR m^{-2} sec^{-1} µg Chl-a^{-1} for chlorophyll-a normalized 'alpha. Figure 4.7 illustrates these trends.

'I_k' is the light intensity when light saturation or P_{max} is achieved and can be an indication of light limitation. The highest 'I_k' (220.588 µmole PAR m^{-2} sec^{-1}) was seen at 11:15 CST, while lowest value (74.500 µmole PAR m^{-2} sec^{-1}) was seen at the last sampling of the day (16:45 CST).

The point of this exercise was to determine whether any significant difference occurred between different times of the days. As demonstrated by the standard error bars (Figure 4.5) for Chlorophyll-a (p=0.012) there was little difference between time of sampling. Peak Pmax (productivity at light saturation) values were seen first thing in the morning. Time of sampling was thus assumed to be insignificant (Chlorophyll-a) as an error source and sampling during the two field seasons occurred between 7:00 CST and 9:00 CST when Pmax was highest.

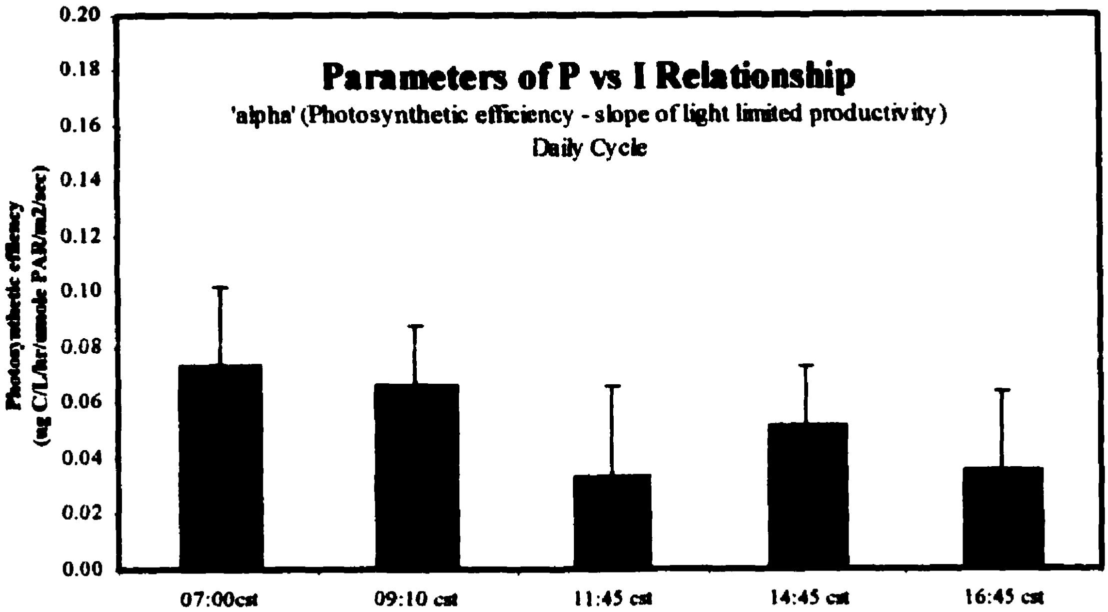


Figure 4.7 - A time series plot of 'alpha' (Photosynthetic efficiency - slope of light limited productivity) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 2) September 3, 1996 throughout a daily cycle.

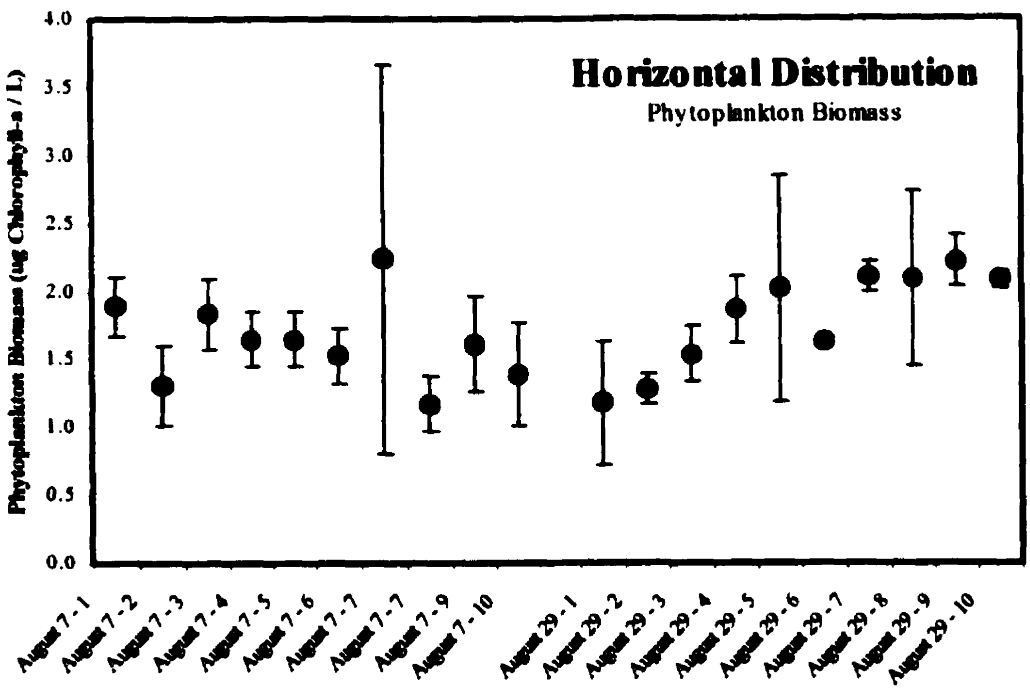


Figure 4.8 - Phytoplankton Biomass (μg Chlorophyll-a/L) with standard deviation) (n=3) at equal distance points along a west-east transect of Clear Lake, Manitoba on August 7 and August 29, 1996 to determine any occurrence of horizontal biomass patchiness due to wind patterns.

As already indicated, the length of Clear Lake lies in the path of northwesterly winds. Therefore on August 7 and 29, 1996, ten sampling points were selected at equal distance, from the west shore to east shore, to examine if any horizontal biomass patchiness due to wind patterns. This was to assure that the distribution of algal biomass was uniform within the accuracy of the method available. Both dates experienced different wind events before sampling. For each sampling point replicated chlorophyll-a estimates were conducted. Field data are presented in the Appendix (A.4.3). On August 7, mean chlorophyll-a was 1.55 μg / L (standard error 3.66%) with a minimum value of 1.18 μg / L and maximum value of 2.14 μg / L. On August 29, mean chlorophyll-a was 1.80 μg / L (standard error 4.88%) with a minimum value of 1.18 μg / L and maximum value of 2.22 μg / L. It would appear (Figure 4.8) that there were slight differences horizontal biomass patchiness due to wind patterns (p=2.8E-09 August 7, 1996, p=5.3E-06 August 29). A decision was made to assume uniform distribution, although this may have contributed to some lack of precision in the whole lake data.

4.5 Laboratory Procedures

4.5.1 Chlorophyll-a

Chlorophyll-a content of phytoplankton was utilized as a convenient indicator of biomass that is widely practised in the phycological literature. It should be noted that chlorophyll-a content of algal cells varies with light and nutritional conditions. The method followed is outlined in Marker *et al.* (1980). Three x 1.0 L of stirred lake water were filtered through a Whatman GF-C filters. Each filter paper was placed in a vial and frozen for later analysis. For determination, 10 mL of 90% methanol was added to each filter and left at 4°C in the dark overnight. The next day, a syringe with a 0.45 μm membrane filter in a filter holder was used to transfer 4 mL of each shaken sample to a spectrophotometer cuvet. Absorbencies of the extracts were measured at 665 and 750 nm wavelengths in a spectrophotometer (LKB Biochrom Ultraspec II). In order to correct calculated values for phaeophytin, samples were then acidified with 100 uL of 4×10^{-2} M HCL and allowed to sit for one hour. Absorbency of the acidified extracts was again measured at 665 and 750 nm. Calculations (Marker *et al.*, 1980) were then completed on a customized Microsoft excel spreadsheet designed by Dr. L.G. Goldsborough (University of Manitoba).

4.5.2 Phytoplankton Assemblage Composition

The biovolume and taxonomic composition of the phytoplankton assemblage was determined. For this quantitative phytoplankton analysis, 1.0 L of lake water had Lugol's solution added to it. Then the sample was allowed to settle for 48 hours. The top 900 mL was siphoned off the top and the remaining volume transferred to a smaller bottle to settle for a further 48 hours. Nanoplankton net samples was preserved in Lugol's iodine solution. Both quantitative phytoplankton and net samples were eventually siphoned down to 20 mL and transferred to vials. A couple drops of formalin were added to each for additional fixation of each sample. Net samples were used in the development of algal species lists (Table 4.2). Algal identification assistance was provided by Ms. Hedy Kling of the Freshwater Institute (DFO, Winnipeg) and G.G.C. Robinson (University of Manitoba).

Assemblage composition and identification were conducted on an inverted microscope

Table 4.2 - Phytoplankton Species List from Clear Lake (Riding Mountain National Park) Manitoba with authorities

Common Name	Class	Order	Genus	Species	Authority
Diatoms	Bacillariophyceae	Centrales	*Aulacoseira*	*ambigua*	(Grun) O.M.
Diatoms	Bacillariophyceae	Centrales	*Chaetoceros*	*sp.*	Ehrenberg
Diatoms	Bacillariophyceae	Centrales	*Cyclotella*	*bodanica*	Eulenst.
Diatoms	Bacillariophyceae	Centrales	*Cyclotella*	*cf distinguenda*	Hustedt
Diatoms	Bacillariophyceae	Centrales	*Cyclotella*	*cf ocellata*	Pantocsele
Diatoms	Bacillariophyceae	Centrales	*Cyclotella*	*meneghiniana*	Kuetzing
Diatoms	Bacillariophyceae	Centrales	*Cyclotella*	*stelligera*	Cleve and Grunow
Diatoms	Bacillariophyceae	Centrales	*Stephanodiscus*	*agassiziensis*	Hakansson and Kling
Diatoms	Bacillariophyceae	Centrales	*Stephanodiscus*	*alpinus*	Hustedt
Diatoms	Bacillariophyceae	Centrales	*Stephanodiscus*	*cf alpinus*	Hustedt
Diatoms	Bacillariophyceae	Centrales	*Stephanodiscus*	*niagarae*	Ehrenberg
Diatoms	Bacillariophyceae	Pennales	*Asterionella*	*formosa*	Huss
Diatoms	Bacillariophyceae	Pennales	*Cymatopleura*	*sp.*	W. Smith
Diatoms	Bacillariophyceae	Pennales	*Fragilaria*	*crotonensis*	Kitton
Diatoms	Bacillariophyceae	Pennales	*Nitzschia*	*palea*	(Kuetzing) W. Smith
Diatoms	Bacillariophyceae	Pennales	*Nitzschia*	*sp.*	A. H. Hassall
Diatoms	Bacillariophyceae	Pennales	*Surirella*	*sp.*	Furpin
Diatoms	Bacillariophyceae	Pennales	*Synedra*	*acus*	Kuetzing
Diatoms	Bacillariophyceae	Pennales	*Synedra*	*cf acus*	Kuetzing
Diatoms	Bacillariophyceae	Pennales	*Synedra*	*sp.*	Ehrenberg
Diatoms	Bacillariophyceae	Pennales	*Tabellaria*	*fenestrata*	(Lyngbya) Kuetzing
Diatoms	Bacillariophyceae	Pennales	*Tabellaria*	*flocculosa*	(Rothest) Kuetzing
Greens	Chlorophyceae	Chlorococcales	*Ankistrodesmus*	*spiralis*	(Turner) Lemmermann
Greens	Chlorophyceae	Chlorococcales	*Botryococcus*	*sp.*	Kuetzing
Greens	Chlorophyceae	Chlorococcales	*Coelastum*	*microporum*	Naegeli
Greens	Chlorophyceae	Chlorococcales	*Crucigenia*	*tetrapedia*	(Kirchner) W. & G. S. West
Greens	Chlorophyceae	Chlorococcales	*Crucigenia*	*sp.*	Kirchner
Greens	Chlorophyceae	Chlorococcales	*Lagerheimia*	*sp.*	Lagerheim
Greens	Chlorophyceae	Chlorococcales	*Monoraphidium*	*arcuatum*	(Kors)Hind.
Greens	Chlorophyceae	Chlorococcales	*Monoraphidium*	*sp.*	Komarkova-Legnerova
Greens	Chlorophyceae	Chlorococcales	*Monoraphidium*	*contortium*	(Turer) Komarkova
Greens	Chlorophyceae	Chlorococcales	*Monoraphidium*	*minutum*	(Naegeli) Komarkova
Greens	Chlorophyceae	Chlorococcales	*Oocystis*	*sp.*	Nageli
Greens	Chlorophyceae	Chlorococcales	*Pediastrum*	*boryanum*	(Turer) Meneghini
Greens	Chlorophyceae	Chlorococcales	*Pediastrum*	*duplex*	Meyen
Greens	Chlorophyceae	Chlorococcales	*Scenedesmus*	*sp.*	Meyen
Greens	Chlorophyceae	Chlorococcales	*Selenastrum*	*sp.*	Reinsch
Greens	Chlorophyceae	Chlorococcales	*Tetraedron*	*minimum*	Kuetzing
Greens	Chlorophyceae	Chlorococcales	*Thorakochloris*	*cf nygaardii*	Komarek
Greens	Chlorophyceae	Chlorococcales	*Thorakochloris*	*sp.*	Pascher
Greens	Chlorophyceae	Tetrasporales	*Botryococcus*	*braunii*	Kuetzing
Greens	Chlorophyceae	Tetrasporales	*Chodafella*	*sp.*	Lemmermann
Greens	Chlorophyceae	Tetrasporales	*Elaktothrix*	*gelantinosa*	Wills
Greens	Chlorophyceae	Tetrasporales	*Elaktothrix*	*sp.*	
Greens	Chlorophyceae	Volvocales	*Carteria*	*sp.*	Diesing
Greens	Chlorophyceae	Zygnematales	*Closterium*	*sp.*	Nitzsch
Greens	Chlorophyceae	Zygnematales	*Staurastrum*	*tetracerum*	(Kuetzing) Ralfs
Greens	Chlorophyceae	Zygnematales	*Staurastrum*	*sp.*	Meyen
Brown	Chrysophyceae	Chrysocapsales	*Chrysocapsa*	*sp.*	Pasch.
Brown	Chrysophyceae	Ochromonadales	*Dinobryon*	*divergens*	Imhot
Brown	Chrysophyceae	Ochromonadales	*Dinobryon*	*sociale*	Ehrenberg
Brown	Chrysophyceae	Ochromonadales	*Dinobryon*	*stipitatum*	Stein
Brown	Chrysophyceae	Ochromonadales	*Mallomonas*	*sp.*	Perty
Brown	Chrysophyceae	Ochromonadales	*Uroglena*	*sp.*	Ehrenberg

Table 4.2 - Phytoplankton Species List from Clear Lake (Riding Mountain National Park) Manitoba with authorities

Common Name	Class	Order	Genus	Species	Authority
Cryptomonads	Cryptophyceae		*Cryptomonas*	*cf erosa*	Ehrenberg
Cryptomonads	Cryptophyceae		*Cryptomonas*	*reflexa*	(Marsson) Skuja
Cryptomonads	Cryptophyceae		*Cryptomonas*	*sp.*	Ehrenberg
Cryptomonads	Cryptophyceae		*Rhodomonas*	*minuta*	Skuja
Blue Green	Cyanobacteria		*Anabaena*	*sp.*	Bory
Blue Green	Cyanobacteria		*Chroococcus*	*sp.*	Naegeli
Blue Green	Cyanobacteria		*Coelosphaerium*	*sp.*	Naegeli
Blue Green	Cyanobacteria		*Microcystis*	*sp.*	Kuetzing
Blue Green	Cyanobacteria		*Oscillatoria*	*sp.*	Vaucher
Blue Green	Cyanobacteria		*Pseudanabaena*	*cf articulata*	Skuja
Blue Green	Cyanobacteria		*Pseudomonas*	*metalus*	
Blue Green	Cyanobacteria		*Radiocystis*	*geminata*	Skuja
Blue Green	Cyanobacteria	Chroococcales	*Radiocystis*	*sp.*	Skuja
Blue Green	Cyanobacteria	Chroococcales	*Snowella*	*sp.*	Elenkin
Blue Green	Cyanobacteria	Oscillatoriales	*Planktothrix*	*sp.*	Anagnostidis &Komarek
Blue Green	Cyanobacteria	Chroococcales	*Woronichinia*	*sp.*	Elenkin
Pyrrophyta	Dinophyceae	Gonyaulacales	*Ceratium*	*sp.*	Schrank
Pyrrophyta	Dinophyceae	Gymnodiniales	*Gymnodinum*	*sp.*	Stein
Pyrrophyta	Dinophyceae	Peridiniales	*Glenodinium*	*sp.*	(Ehrenberg) Stein
Pyrrophyta	Dinophyceae	Peridiniales	*Peridinium*	*cf cinctum*	Ehrenberg
Pyrrophyta	Dinophyceae	Peridiniales	*Peridinium*	*goslaviense*	Woloszynska
Pyrrophyta	Dinophyceae	Peridiniales	*Peridinium*	*inconspicuum*	Lemmermann
Pyrrophyta	Dinophyceae	Peridiniales	*Peridinium*	*sp.*	Ehrenberg
Pyrrophyta	Dinophyceae	Peridiniales	*Peridinium*	*willei*	Huitfeedt-Kass

Footnotes

1 Coelosphaerium, Radiocystis, and Snowella were counted as Coelosphaerium

2 Synedra and Nitizschia were counted as Synedra

3 Mononraphidium was counted as Selenastrum

4 Glenodinium, Gymnodinium, and Peridinium were counted as Peridinium

using 2 mL sub sample in a settling chamber (10mm high with a 18 mm diameter). Counts were conducted at magnifications of x100 and x400. At x100 power, half of each the chamber bottom was used (approximately 65 fields), while at x400, a sweep across the center of the chamber was done (approximately 44 fields). The size and volume (μm^3) of each algal species was compiled through a variety of measurements as outlined in Lund *et al.* (1958). Manipulation of phytoplankton data is outlined:

1. Determination of cells / L at x100 and x400 powers

x100 power

(total cells of each species / 1 mL) x multiplication factor = cell / L

where	species total	- total number species counted at the time period
	1 mL	- volume of ½ of the chamber
	Multiplication factor	- 1000 mL sample was siphoned down to approximately 20 mL (1000 / 20 = 50)

X400 power

(chamber area / (field area x number of fields)) / 2 mL = volume counted

where	chamber area	- 254340000 μm^2	(r = 9000 μm^2)
	field area	- 107466.5 μm^2	(r = 185 m^2)
	number of fields	- 44	

(species total x volume counted) x a multiplication factor = cell / L

where	species total	- total number species counted at the time period
	volume counted	- see above
	Multiplication factor	- 1000 mL sample was siphoned down to approximately 20 mL (1000 / 20 = 50)

2. Determination of phytoplankton volume (μm^3 / L) was derived from the sum of multiplication of cells per litre (cells / L) of each species by the mean cell volume (μm^3).

3. Species were divided into their respective classes (Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cryptophyceae, Cyanobacteria, and Dinophyceae) and total particulate volume for each class determined.

4. Determination of the a diversity index by Shannon - Weiner Index (Smith, 1980)

$$H = -\sum_{i=1}^{s} p_i (\ln p_i)$$

where H - diversity index
s - total number of each species
i - for each species counted
p_i - proportion of individuals of the total sample belonging to the i^{th} species

4.5.3 Primary Productivity

Photosynthesis-irradiance (P vs I) relationships were determined for each station on each sampling day by *in vitro* incubations using a modification of the method outlined in Shearer and Fee (1973) and Platt *et al.* (1980).

Integrated epilimnetic water samples were placed on a stirring table to mix samples before dispensing into 60 mL BOD bottles. Two mL of the water sample was removed from each bottle to allow room for the radioactive tracer. One hundred μL of standardized 14-C $NaHCO_3$ (standardized on each sampling occasion) were added to each glass bottle (10 light and 2 dark) and the bottles incubated at known light intensities in a simple water-filled, temperature controlled laboratory incubator illuminated by a high-pressure sodium lamp (Sylvania Lumalux LU-70). This high-pressure sodium lamp created a light gradient from 2 - 1600 μmoles m^{-2} s^{-1} PAR. The exposure irradiance of each glass bottle location was determined by a LI-COR underwater quantum sensor. Following a four-hour incubation, each sample was filtered through a 0.45 μ membrane filter to separate phytoplankton and the filter acidified by fuming over concentrated HCL for one minute to remove residual inorganic 14-C. Filters were then placed into scintillation vials containing 5 mL ReadySafe® (Beckman Scientific) scintillation cocktail for subsequent determination of the specific radioactivity in each sample using a Beckman LS3801 Liquid Scintillation Counter, and 'H-number' quenching correction, at the University of Manitoba. A BOD bottle containing 14-C and GF-C filtered water was used to establish the exact specific radioactivity added on all occasions.

The *in vitro* photosynthetic rates (μg C/L/hour) were determined from dpm as follows:

$$\textbf{Productivity} = \frac{\textbf{dpm}_s \times \textbf{C} \times \textbf{1.05}}{\textbf{dpm}_t \times \textbf{T}}$$

where

Productivity	- mg C L^{-1} $hour^{-1}$
dpm_s	- specific radioactivity of each sample corrected for any dark 'uptake'(light sample dpm - dark samples dpm)
C	- Dissolved Inorganic Carbon (DIC mg/L) as determined from alkalinity (APHA, 1992), pH, and temperature (Wood, 1975)
1.05	- isotope discrimination factor
dpm_t	- specific radioactivity of added ^{14}C (control dpm)
T	- incubation duration (4 hours)

This was completed for each known light intensity. Specific photosynthetic rates (μg C/L/hour/μg chl-a) were also determined by dividing the photosynthetic rate (μgC/ L/hour) by biomass (μg Chlorophyll-a / L). Relationships between photosynthetic carbon assimilation and PAR could then be determined.

The photosynthetic rate, specific photosynthetic rate, and corresponding incubator light intensities were fitted into a nonlinear regression model (Systat 1986) to determine P_{max} (μgC/L/hour), α (μgC/L/hour/μmole PAR/m^2/sec), SP_{max} (chl-a normalized), and specific alpha (chl-a normalized). This estimation was done according to the relationship described by Geider and Osborne (1992):

$$P_s = P_{max} \times (1 - e^{(-\alpha \times I)/Pmax}) \times e^{(-\beta \times I)/Pmax}$$

where P_{max} - maximum observed rate of P_s
α - light limited slope of photosynthesis (photosynthetic efficiency)
I - incident PAR (incubator irradiance)
β - photoinhibition slope (although not observed, a value of 0 was assigned)

Once this was done, I_k, irradiance after which photosynthesis became saturated, was determined from the intersect of P_{max} and alpha.

4.5.4 Dissolved Inorganic Carbon

Dissolved inorganic carbon was estimated (APHA, 1992) from the pH of GF-C filtered lake water, alkalinity, and temperature. For alkalinity determination, 50 mL of filtered sample water was titrated with a standard acid (H_2SO_4) solution of standardized normality using Brom Cresol Green / Methyl Red indicator. Total alkalinity was determined by:

$$\text{mg } CaCO_3/L = \frac{B \times N \times 50{,}000}{S}$$

where B - volume titrated (mL)
N - precise normality of the titrate
S - amount of sample (50 mL)

Once pH and alkalinity were determined, dissolved inorganic carbon (DIC) could then be calculated. A conversion factor (read from a table of temperature and pH) was multiplied by the total alkalinity to obtain DIC (mg C/L) (APHA, 1992).

4.5.5 Nitrogen Debt

Physiological indicators that indicate nitrogen deficiency, based on the rate of nutrient assimilation, include nitrogen debt assays. Healy (1977) states the nitrogen debt can be determined by ammonium uptake during a 24-hour period in the dark. All glassware used for this assay was acid washed. On each sampling occasion a total of 100 mL of stirred sample water was added to a 250 mL Erlenmeyer flask. A background ammonium level was determined by transferring a 10 mL aliquot to a test tube. Then 0.5 mL of 1.0 mM NH_4Cl was added to the flask and mixed. Three 10 mL aliquots of enriched sample were then transferred to test tubes. The flask was covered with aluminium foil and placed into a dark drawer for 24 hours. A set of ammonium standards (1-10 μM) was prepared by dilution with distilled water of a stock solution (10 mM NH_4Cl). For analysis (Stainton *et al.*, 1977), each 10 mL sample had the following reagents added in sequence:

1. 0.4 mL phenol-alcohol solution (10 g phenol dissolved in 100 mL of 95% ethanol)
2. 0.4 mL 0.5% sodium nitroprusside (0.25 g Na-Nitroprusside dissolved in 50 mL of distilled water and stored in a dark container)
3. 1.0 mL fresh oxidizing solution (20 mL alkaline solution {20 g sodium citrate and 1 g sodium hydroxide dissolved in 100 mL of distilled water} and 5 mL sodium hypochlorite {refrigerated Javex})

Between the addition of each reagent, the test tubes were vortexed. The samples and standards were set aside in a clean dark place for 2 hours for the coloration to appear. A spectrophotometer (LKB Biochrom Ultraspec II) was used to measure absorbance at 640 nm. This was repeated in 24 hours with new standards and 3 aliquots of sample water from the flask with 0.5 mL of 1.0 mN NH_4Cl added the previous day. Nitrogen debt (μM N/24 hours) was determined though a linear calibrated regression based on standards, and ammonium uptake values were normalized per unit chlorophyll-a (μM N/ug Chl-a/24 hours). A number greater than 0.15 μM N/ug Chl-a/24 hours suggests severe nitrogen deficiency. The above method is outlined in Healey (1977) and Healey and Hendzel (1979 and 1980).

4.5.6 Phosphorous Debt

Physiological indicators of the phytoplankton phosphorous deficiency include phosphorous debt assays. Phosphorous debt was determined at all sampling occasions from the phosphate taken up in a 24-hour period in the dark. All glassware used for the assay was again acid washed. For each assays a total of 100 mL of stirred sample water was added to a 250 mL Erlenmeyer flask. A background phosphorous (SRP) level was determined by transferring 10 mL aliquot of sample water to a test tube. Then 0.5 mL of 1.0 mN KH_2PO_4 was added to the flask and mixed. Three 10 mL aliquots of sample water were then transferred to test tubes. The flask was covered with aluminium foil and placed into a dark drawer for 24 hours. A set of standards (1-10 μM of P) was prepared by dilution with distilled water of a stock solution (10 mN KH_2PO_4). Each 10 mL sample had 1 mL of the following reagents added within 6 hours of preparation:

1. 6 mL ammonium molybdate (3 g $(NH_4)6Mo_7O_{24}4H_2O$ dissolved in 100 mL distilled water and stored in a dark container)

2. 15 mL dilute sulphuric acid (14 mL concentrated H_2SO_4 to 90 mL of distilled water)

3. 6 mL ascorbic acid solution (0.54 g ascorbic acid powder dissolved in 10 mL distilled water)

4. 3 mL potassium-antimony tartrate (0.068 g K-antimony tartrate dissolved in 50 mL of distilled water)

The samples were set aside for 15 minutes for the coloration to appear. Absorbance at 885 nm was determined. This was repeated in 24 hours with new standards and 3 aliquots of sample water from a flask with 0.5 mL of 1.0 mN KH_2PO_4 added the previous day. Phosphorous debt (µM P/24 hours) was determined from a linear calibrated regression developed from the standards, then values were normalized per unit chlorophyll-a (µM P/ug Chl-a/24 hours). A number greater than 0.75 µM P/ug Chl-a/24 hours suggests severe phosphorous deficiency. The above method is outlined in Healey and Hendzel (1979 and 1980) and the analytical procedure are most of Stainton *et al.* (1977).

4.5.7 Alkaline Phosphatase

A second indicator of phosphorous deficiency is the degree of alkaline phosphatase activity. The alkaline phosphatase method used here was broken down into four sections. The first section consisted of making an autoclaved algal medium that lacked phosphorous. The recipe modified after Guillard and Lorenzen (1972), is included in Appendix (Table A.4.4). After the medium was autoclaved it was dispensed into 5 mL vials for later use.

The second section included the preparation of the substrate, 3-O-methylfluorescein phosphate (O-MFP) (MW=511) (Sigma catalogue # M2629). Three separate reagents were prepared:

1. 10 mM Tris Buffer (0.242 g Tris dissolved in 200 mL of distilled water and brought to pH 8.5 with HCL). The buffer was autoclaved and dispensed into 10 mL amounts.
2. 1.0 mM O-MFP stock (5.11 mg O-MFP dissolved in 10.0 mL of 10 mM Tris Buffer). It was made fresh and frozen in 1 mL amounts.
3. 100 μM O-MFP (1 mL 1.0 mM O-MFP stock diluted with 10 mL of 10 mM Tris Buffer). This is used for the assay.

The third section included the preparation of a set of standards using 3-O-methylfluorescein (O-MF) (MW=346) (Sigma catalogue # M7004). Seventeen point three mg of O-MF in 50 mL were dissolved in absolute MeOH to make 1.0 mM O-MF (stored at -5°C). Then 1.0 mM O-MF was diluted 1.0 mL to 10.0 mL with 0.05 N NaOH solution (1.0 g NaOH dissolved in 500 mL in distilled water) to standardize the fluorometer. Standardization was done at the beginning of each field season with differing sensitivity settings and neutral density filters.

The fourth section is the assay. For each sampling, there were 2 phosphatase samples: 1. unfiltered (for total phosphatase), and 2. filtered with a 0.45 μ membrane filter (for soluble phosphatase). Three 4.5 mL sub samples of unfiltered and three sub samples of filtered water were pipetted into sterile fluorometer tubes. In addition, a sample 4.5 mL control or sterile culture medium lacking phosphorous was treated in the same way. All seven fluorometer tubes were then placed into a hot water bath (35°C) for 5 minutes. Once the substrate was added (0.5 mL) to the fluorometer tubes, they were capped and shaken. Timing commenced and the fluorometer tubes were read every 3 to 5 minutes, depending on the phosphatase activity level, against the control sample using 1% filter and 10% neutral density filter. A number greater than 0.005 μM P/ug Chl-a/24 hours suggests severe phosphorous deficiency. The above method is outlined in Perry (1972) and Healey and Hendzel (1980).

4.6 Water Chemistry

Water samples (2m depth) were taken at both stations at approximately two week intervals for chemical analysis by Norwest Lab (Winnipeg) in 1996. Samples were stored at 4°C and delivered to Norwest Lab within 24 hours of sampling. The chemical analyses included total kjeldahl nitrogen, total phosphorous, total organic carbon, dissolved silica, dissolved organic carbon, nitrate-nitrite (NO_4-NO_3), and dissolved phosphorous. Particulate nitrogen, particulate phosphorous, and particulate organic carbon could then be derived. Chemical analysis methods follow "Standard Methods for Analysis of Water and Wastewater" (APHA, 1992).

4.7 Whole Lake Productivity Modelling

To estimate *in situ* productivity by phytoplankton in Clear Lake the following variables were used in the calculation:

1. Photosynthesis parameters (α, P_{max} , and 'beta' (β)) derived from *in vitro* experiments (incubator)

2. Euphotic depth - The mean euphotic depths at Station 1 and Station 2 were 14.04m and 14.11m respectively. These mean values were used throughout the modelling.

3. the extinction of PAR within the lake (determined at each sampling interval)

4. hourly integrations of PAR falling on the lake surface (data from the University of Manitoba Field Station (Delta Marsh)), corrected for reflective loss, which was estimated as 24.99%.

5. Isobath area (m^2) for each successive meter in the euphotic zone (Frey, 1997 pers comm).

The model was developed using a series of steps:

1. *In situ* PAR - hourly integration of PAR reduced by the mean light extinction (25.08%) for each successive meter in the euphotic zone. Values were adjusted from μmoles / m^2 /hour to μmoles / m^2 /second for the application of the next step.

2. *In situ* Productivity - Photosynthesis parameters (α, P_{max} , and 'beta' (β)) derived from in vitro experiments and *In situ* PAR were used in

$$P_s = P_{max} \times (1 - e^{(-\alpha \times I)/P_{max}}) \times e^{(-\beta \times I)/P_{max}}$$

Values were adjusted from mg C / L / hour to g C / m^3 / hour.

3. *In situ* Productivity was multiplied by the area (m^2) of the isobath for each

successive meter in the euphotic zone for each hour of the day.

4. Hourly Euphotic column productivity - sum of all the values obtained in Step 3 for the entire euphotic depth.

5. Daily Productivity - sum of all the values obtained in Step 4 for the entire day. Values were expressed as g C / m^3 / day.

This model was applied for each sampling day. For the period between sampling days (e.g. June 9, 1996 to June 15, 1996), this process was followed using the equation from the first sampling (June 9, 1996) but the incident light changed to correspond with the actual intervening days. In other words, the equation developed on June 9, 1996 was used from June 10, 1996 to June 14, 1996. For the day of the next sampling (June 15, 1996), a new solution of the model was developed. This was completed for each station from June 9, 1996 till October 6, 1997.

Three models of increasing simplicity were developed. The models are as follows:

1. Developed using hourly integrations of light from the University of Manitoba Field Station (Delta Marsh). Once the model was completed, the productivity data were smoothed using a smoothing function to account for cloudy and cloudless days.

2. Developed using total daily light from the University of Manitoba Field Station (Delta Marsh). This light data was smoothed and corrected for ice and snow, which reduces incident light through the water column (will be discussed in the Total Light section).

3. Developed using all the photosynthesis parameters (α, P_{max}, and 'beta' (β)) derived from a combination of data from all in vitro experiments (incubator) to develop one single equation.

4.8 Analysis

4.8.1 Thermal Gradient

The thermal gradient is the slope of the thermocline. The thermocline is the plane of a maximum rate of decrease of temperature with depth (Wetzel, 1983). Once stratification is established, nutrient replenishment from deep waters is extremely limited. Since nutrient limitations can influence the P-I curve knowledge of the thermal structure of a lake may well be important. The calculation of the thermal gradient was accomplished by:

1. Determination of the depth of thermocline - the zone of maximum changes, in which decrease in temperature was greater than 1°C per meter.
2. Determination of the difference between temperature above the thermocline and below the thermocline. This value was then divided by the depth in which a change occurred. Table 4.3 displays examples of the calculation for Station 2 on June 15 and August 5, 1996.

Table 4.3 - Sample calculations of the thermal gradient in Clear Lake Manitoba. The thermocline is indicated by the shaded area.

June 5			August 5		
Depth	Temperature		Depth	Temperature	
2	16.9		10	19.4	
3	[illegible]		11	18.7	
4	14.6		12	17.3	
5	[illegible]		13	15.6	
6	12.6		14	13.9	
7	11.7		15	12.2	
8	11.4		16	11.4	
Gradient	(16.9-11.4)/6	0.9/m		(1194-11.4)/6	1.3/m

4.8.2 Thermocline depth

The thermocline depth was recorded as the depth of the plane of maximum rate of decrease of temperature per unit of depth.

4.8.3 Surface Temperature

The surface temperature (0 m depth) was determined by lowering a temperature probe into the water column until totally immersed.

4.8.4 Euphotic Depth and Mean Light Extinction

Light extinction is an expression of the attenuation of irradiance through a water column. Light attenuation is the diminution of radiant energy with depth, due to both absorption and scattering mechanisms (Wetzel, 1983). At each sampling period, measurements were taken of light extinction within the water column and the depth of the euphotic zone, which is the region within the water column from the surface to the depth where 99% of the light has been attenuated (Cole, 1983). Measurements of PAR were taken simultaneously on board the boat (surface) and within the water column at 1 m depths until no light was available (light extinction was complete).

Light extinction in the water column was calculated in several steps. The first step was to determine irrandiance in the water column as a percentage of surface irradiance.

$$I\% = \frac{I_{depth}}{I_{surface}} \times 100$$

where I% -light at depth expressed as a percentage of surface irradiance
I_{depth} - irradiance within the water column at given depth (μmoles m^{-2} s^{-1})
$I_{surface}$- irradiance at the surface (μmoles m^{-2} s^{-1})

The second step is to determined light extinction at each 1 m depth interval. Wetzel (1983) developed a relationship of light extinction within the euphotic zone:

$$\textbf{Light Extinction \%} = \frac{(I\%_x - I\%_{x+1})}{I\%_x} \times 100$$

where
Light Extinction- percentage of light extinction at given depth
$I\%_x$ - percentage of light at given depth (μmoles m^{-2} s^{-1})
$I\%_{x+1}$ - percentage of light at given depth available 1m below (μmoles m^{-2} s^{-1})

The final step was to develop a mean value of light extinction per meter. Values were calculated between 3 m and 10 m. The average value was then used as the light extinction value through the water column at that station and sampling date. An overall mean for the lake was 25.08% / m.

4.8.5 Compensation Point

Irradiance passing through a water column is exponentially reduced and eventually extinguished. As irradiance decreases with depth the light compensation point is reached when photosynthetic oxygen liberation equals respiratory oxygen consumption (Kirk, 1983). No net photosynthesis occurs below this point. The light compensation point denotes the lower limit of the euphotic zone. A general field study rule suggests the compensation depth to occur when light is 1% of the surface light or 2-3 times the secchi disc depth (Darley, 1982). On each sampling occasion the depth at which surface irradiance had been reduced to 1% was recorded as the compensation point.

4.8.6 Total Light

Hourly PAR integrations were recorded at the University of Manitoba Field Station (Delta Marsh, Manitoba). To determine daily integrated PAR (when needed), hourly values were totalled over a 24 hour period.

For the generation of daily integrated radiation values, which were not subjected to irregular cloud events, the measured radiation data were smoothed (using a lag distance of every 5 days for the lowess curve) (Figure 4.9) and the smoothed pattern of incident light used to generate daily values.

Light transmission through ice and snow can be greatly impaired and influenced by ice thickness, quality and overlying snow depth and condition. To account for this, the percent transmission and snow and ice thickness were measured on a number of dates (Table 4.4).

Table 4.4 - Percent transmission of irradiance through ice and snow during the ice covered period from January to May 1997 at Station 2 in Clear Lake, Manitoba

Date	% Transmitted
January 1, 1997	98.0
January 20, 1997	55.0
February 15, 1997	5.6
March 17, 1997	8.2
April 26, 1997	31.0
May 9, 1997	100.0

Based on these data, two general trends were observed (Figure 4.10):

1. During January 1, 1997 to February 15, 1997 there occurred a linear decrease of transmission when compared with Julian day (Figure 4.10 (A)). To calculate percent transmission for January 1, 1997 to February 15, 1997 the following equation was used:

$$\mathbf{y = 98.9053 - 2.04651\,x}$$

where y - % transmission
x - Julian day

2. And during February 15, 1997 to May 9, 1997 there occurred a curvilinear increase in transmission. When percent transmission was compared with Julian day, no strong linear relationship was apparent (Figure 4.10 (B)) Data were then transformed by 1 / ln (% transmission). This transformation of the data produced a strong linear

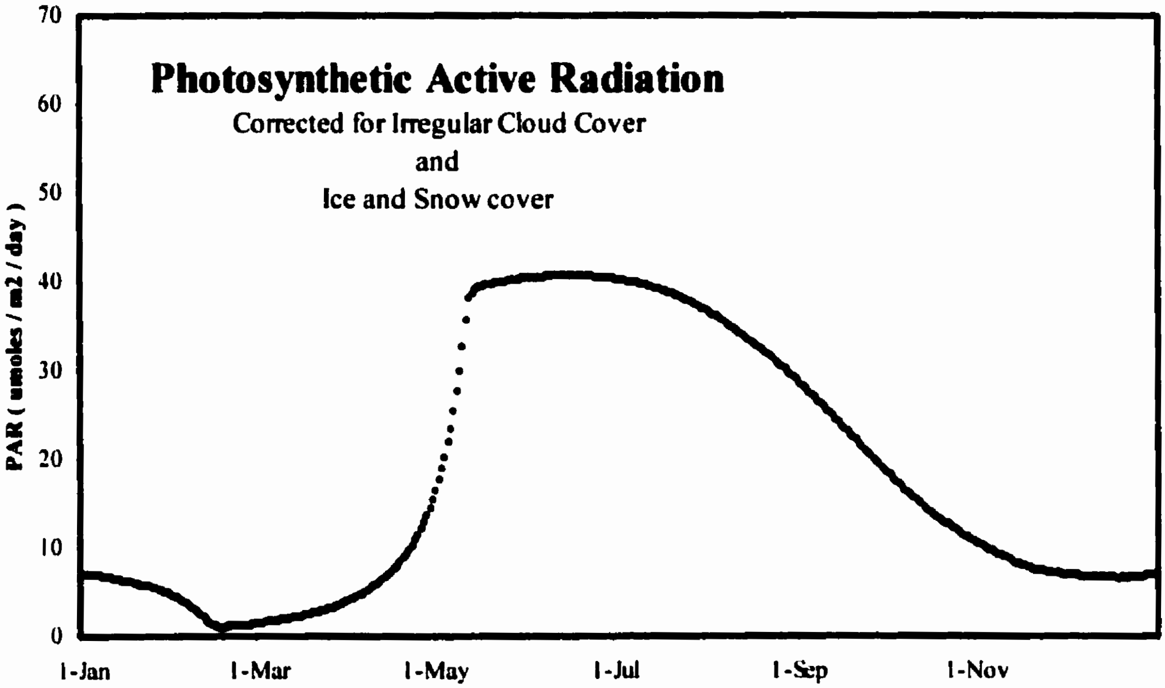


Figure 4.9 - Time series plot of photosynthetically active radiation corrected for irregular cloud cover and ice and snow cover. Plotted values are the output of smoothed data from the University of Manitoba Field Station (Delta Marsh).

decrease of transmission when compared with Julian day (Figure 4.10 (C)). To calculate percent transmission for February 15, 1997 to May 9, 1997 the following equations were used:

$$Y' = 0.7888832 - 0.004332\,x$$

where Y' - 1 / ln (% transmission)
x - Julian day

Then by definition of a logarithmic function, the values required to be transformed to the antilogarithm.. Values were changed to exponential form to isolate the variable.

$$Y' = \frac{-1}{\ln(\%\ \text{transmission})}$$

$$Y' * \ln(\%\ \text{transmission}) = -1$$

$$\ln(\%\ \text{transmission}) = \frac{-1}{Y'}$$

$$\%\ \text{transmission} = e^{-1/Y'}$$

These two equations were then applied to the PAR to estimate how much light that would reach the water surface through ice and snow (Figure 4.11).

4.8.7 Light History

Measurements of the light history involved recording the total incident daily light and adding the total daily light for the six previous days. For example, if a sample were taken

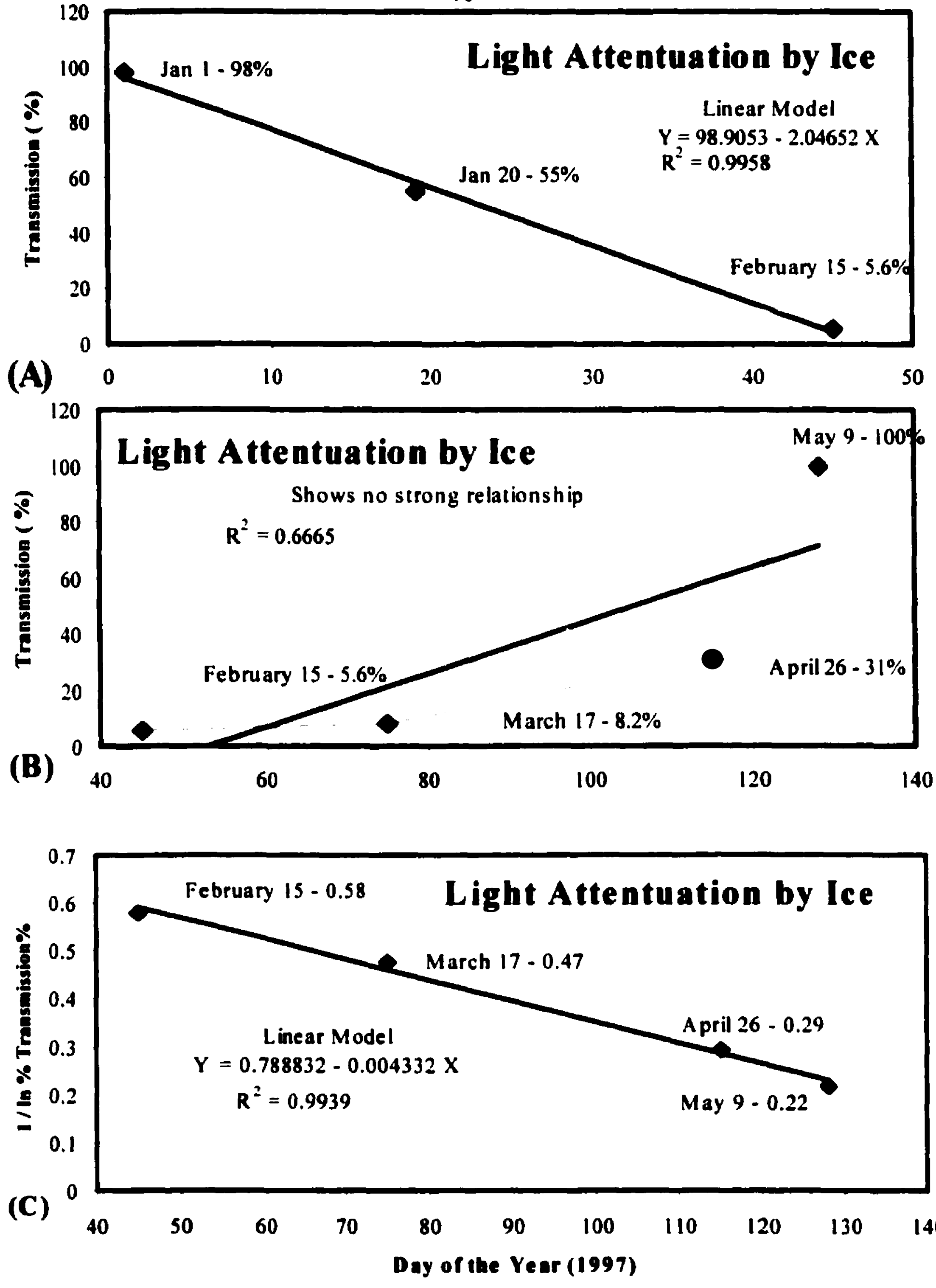


Figure 4.10 - Time series plots of Photosynthetically Active Radiation correction factor steps for Ice and Snow Cover. (A) demonstrates a first 'stage' (January to February) displays a linear relationship between Julian Day and transmission r2= 0.9985, (B) demonstrates a second 'stage' (February to May) with no relationship between Day of the Year (1997) and transmission r2= 0.6665, and (C) demonstrates a third 'stage' in which the data was linearly transformed to produce a relationship between Julian Day and transmission r2=0.9939. Data were collected at Station 2 in Clear Lake, Manitoba.

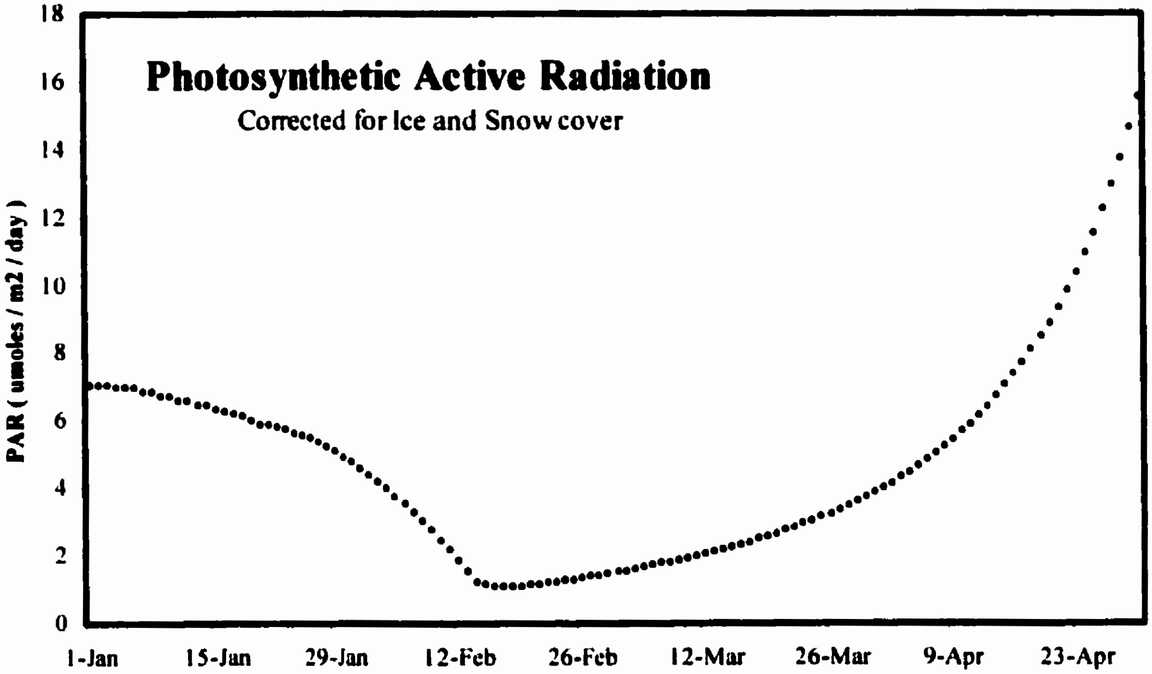


Figure 4.11 - Time series plot of PAR corrected for ice and snow cover as described above during the ice - covered period of 1997 at Clear Lake, Manitoba.

Sunday, June 10, the light history would include the addition of the total daily light for Monday, June 4, Tuesday, June 5, Wednesday, June 6, Thursday, June 7, Friday, June 8, Saturday, June 9, and Sunday, June 10.

4.9 Statistical Methods

Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA), compiled on Datadesk (version 6), provides a method for comparing several 'population' means through the F-statistic, which tests the null hypothesis ($\mu_1 = \mu_2 = ... = \mu_p$) against the alternative (at least one mean is not equal to the others). Rejection of the null hypothesis occurred when the $p \leq 0.05$. The groups were said to be different. Larger F-values supported rejection because the means differ more than expected on the basis of sample to sample variability within the groups.

Principle Components Analysis

Principal Components Analysis (PCA.), compiled on SYN-TAX (version 5), provides a multivariate description of the data. More specifically, it allows the data (many variables) to describe variability within the multivariate dataset by redistributing the variance to the first few dimensions or axes. It is a graphically and mathematically based statistical approach that uses eigenvalues and eigenvectors. Eigenvalues are the variances of the projections of the points along each of the principal axes with the largest eigenvalue projected onto the first principal axis. Eigenvectors are viewed as an ordered set of coordinates on the original axes of the data. A line drawn from the origin to the point specified by these coordinates will trace the corresponding principal axis by drawing a line from the point of origin. The first axis passes through the center of the point cloud with the means of each data variable represented by (0,0) coordinates (DataDesk, 1988). This axis points in the direction of the greatest variability in the cloud of points and is estimated to be the line through the means along which the variance of the projection is considered the greatest. Each additional axis was perpendicular to the previous. (DataDesk, 1988). For this study, the first axis was typically selected with the 'success' of the redistribution of variance along the axis denoted as a percentage with Axis 1 used as the 'x' or independent axis. Typically, it was regressed against the productivity model to evaluate the correlation between a variety of variables (e.g. environmental variables like temperature or light) and primary production in the lake.

Multiple Stepwise Regression

Multiple Stepwise Regression, compiled on Datadesk (version 6), constructs a regression model by subtracting or deleting predictors. It is effective because it returns more information about the data than a single regression calculation. By adding and deleting predictors, control of the detailing of the regression model can occur. Relationships should be linear rather than curved and other regression assumptions should not be violated (DataDesk, 1988). The results of the regression table include the R-square statistics, correlations, the F-ratio for each predictor and the prob value associated with each F-ratio. For the purpose of this study, a stepwise multiple regression was utilized to examine correlations of light and temperature with productivity and other variables. This method is mathematically based not biologically. It does not determine controlling mechanisms but simply examines the highest correlations. The variables compared with modelled productivity were surface temperature, daily light, light history, chlorophyll-a, nitrogen debt, phosphorous debt, and alkaline phosphatase.

Chapter 5 Results

5.1 Introduction

The objective of this chapter is to identify the variability in the physical, chemical, and phytoplankton parameters throughout the sampling period. All primary data can be found in Appendix Tables A.5.1 to A.5.8.

5.2 Laboratory Procedures

All field and laboratory data are presented in the Appendix section: Table A.5.1 is for Station 1 Field Data, Table A.5.2 is for Station 1 variables and parameters compiled, Table A.5.3 is for Station 2 Field Data, and Table A.5.4 is for Station 2 variables and parameters compiled.

5.2.1 Chlorophyll-a (Phytoplankton Biomass)

Yearly and seasonally differences were found (Figure 5.1). The mean Chlorophyll-a was 2.15 μg / L with a minimum value of 0.82 μg / L and maximum value of 5.47 μg / L. The mean was used in the single equation Productivity Model using chlorophyll normalized productivity. The Spring of 1997 displayed the highest mean chlorophyll-a levels (3.05 μg / L), while the lowest (1.23 μg / L) were in the winter of 1996. Generally, the trends displayed were peaks in the spring due to the diatom assemblages just as or after ice-out occurred, which was followed by a dramatic decrease. Through the summer season, levels gradually increased until late August / early September followed by a slight decrease. A major peak in

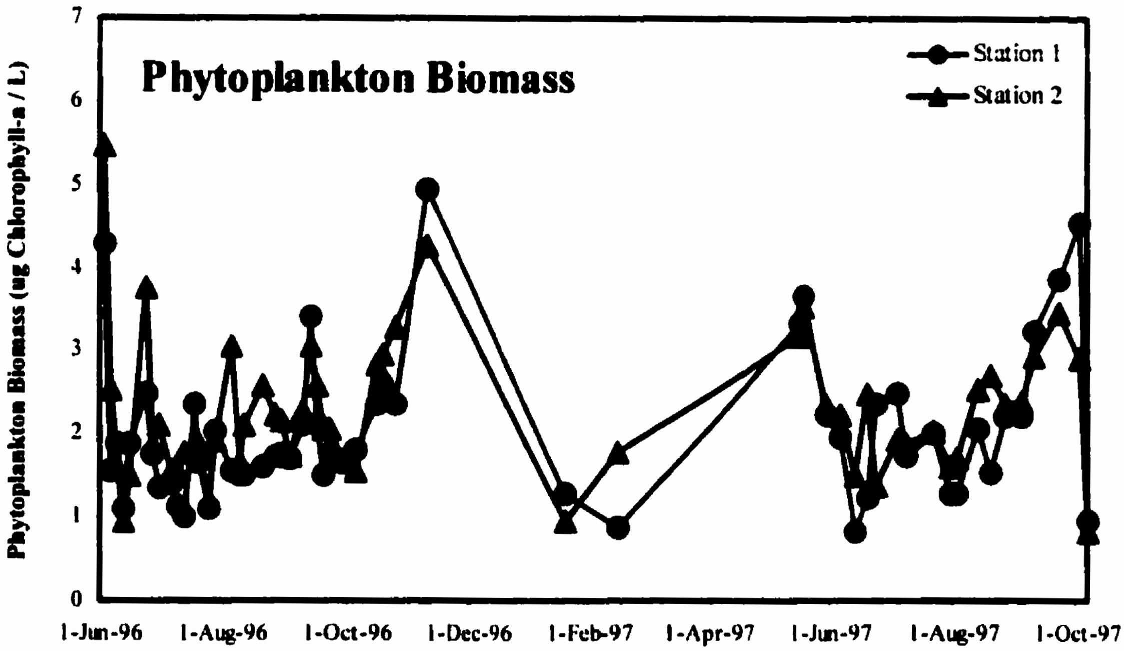


Figure 5.1 - Time series plot of Phytoplankton Biomass (Chlorophyll-a) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

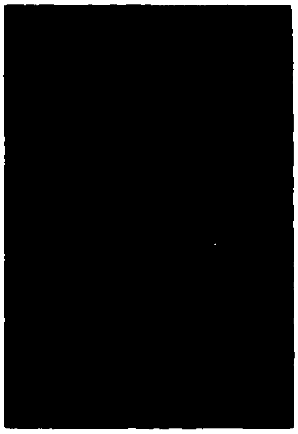
chlorophyll-a occurred just before ice in.

Chlorophyll-a is used as an indicator of the biomass of algae present within the water column. Manitoba Surface Water Quality Objectives have no established guideline for Chlorophyll-a levels (Williamson, 1988) but a level more than 50 μg / L suggests an algal bloom. Elevated levels can be aesthetically displeasing, being associated with filtration clogging, and poor odour and taste. Rapid decomposition of algal blooms may cause decreases in oxygen levels, which can lead to anaerobic conditions. Clear Lake levels were, however, extremely low.

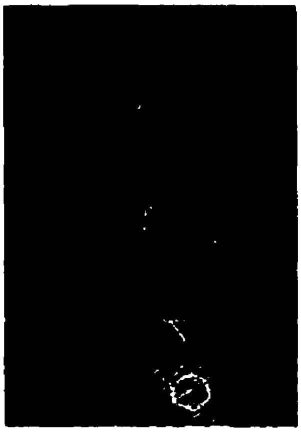
5.2.2 Phytoplankton and Net samples

As indicated in Chapter 4, Table 4.2, a detailed algal species list with corresponding authorities was developed. The common species found in Clear Lake were *Dinobryon sociale, Fragilaria crotonensis, Pediastrium duplex, Stephanodiscus niagarae, Cyclotella bodanica, Tabellaria fenestrata,* and *Peridinium sp.* (Figure 5.2). Species were divided into their respective classes of Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cryptophyceae, Cyanobacteria, and Dinophyceae. Note that the term 'dominance' will be used to describe the most abundant species and 'common' to describe non-dominant species that were present at each sampling.

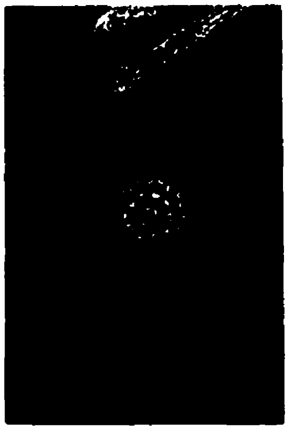
Total particulate phytoplankton biovolume (Station 1 and Station 2 combined) demonstrated (Table 5.1) yearly and seasonal trends. The mean total particulate biovolume was determined to be 1.06 mm^3 / L with a minimum value of 0.04 mm^3 / L and maximum value of 7.99 mm^3 / L. The Spring of 1997 displayed the highest mean total particulate



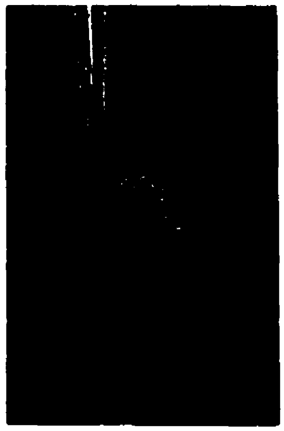
Dinobryon sociale (cyst)



Fragilaria crotonensis



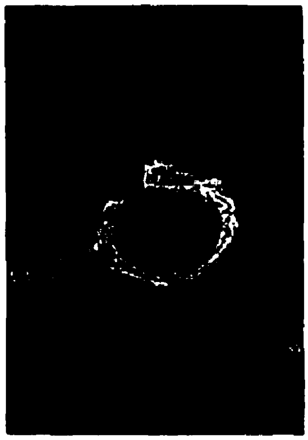
Pediastrum duplex



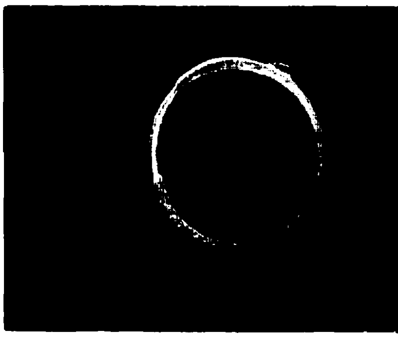
Stephanodiscus niagarae

Cyclotella bodanica

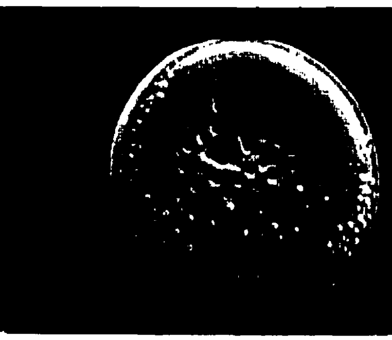
Tabellaria fenestrata



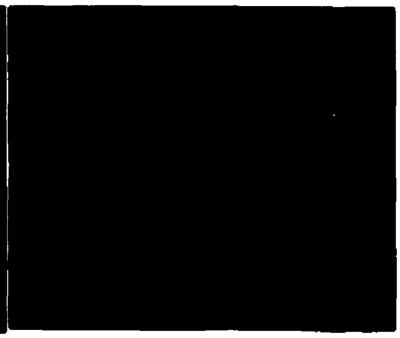
Peridinium



Electron micrograph of *Cyclotella meneghiniana*



Electron micrograph of *Cyclotella meneghiniana*



Electron micrograph of *Stephanidiscus sp.*

Figure 5.2 - Common phytoplankton species found in Clear Lake, Manitoba. Electron Micrographs are courtesy of Hedy Kling (DFO, Winnipeg).

Table 5.1 - Average Particulate Biovolume (um3/L) of each major taxonomic group at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997.

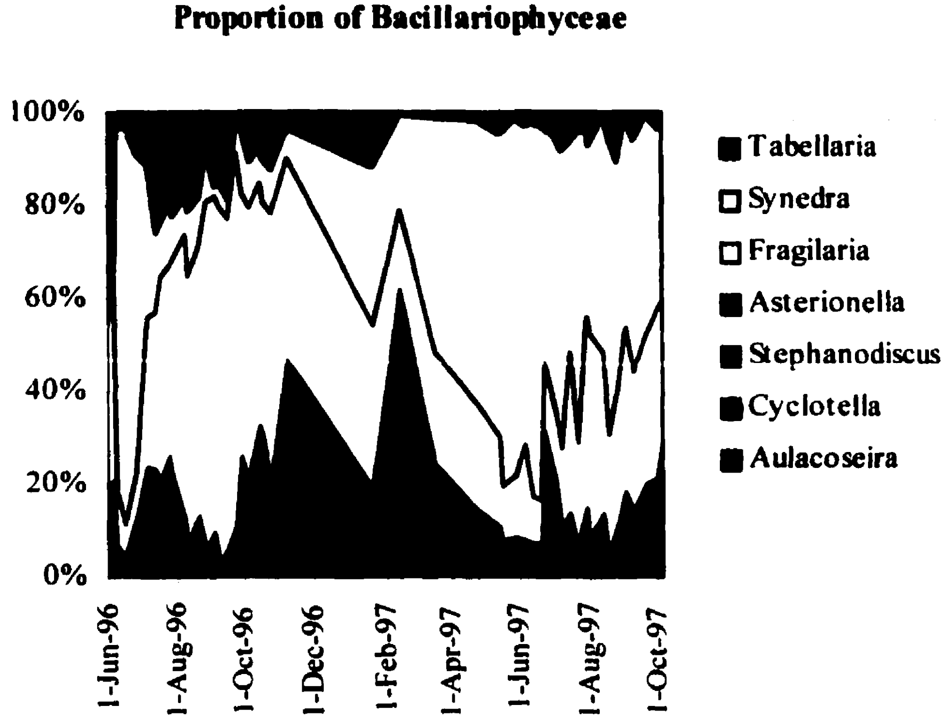
average	Bacillariophyceae	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria	Dinophyceae	total
1-Jun-96	119182753	3393086	3528569	0	92050	1875440355	2001636813
6-Jun-96	56375336	3424528	6892599	0	34578	1121517790	1188244832
9-Jun-96	548574834	3422556	17953896	0	90768	392698789	962740843
15-Jun-96	460446281	2934680	7533001	0	65527	215069469	686048958
26-Jun-96	267094865	2603049	16703610	0	87063	211242104	497730691
6-Jul-96	263399969	2933668	38516560	0	500204	422105662	727456062
12-Jul-96	367919158	12456286	14976232	0	985131	113397653	509734460
17-Jul-96	298967097	2937970	4838074	0	1114015	9755536	317612692
24-Jul-96	211769625	3937624	3930261	0	1419129	26965950	248022589
28-Jul-96	304922116	18538415	5765924	0	381159	1244750	330852364
9-Aug-96	508525973	64858896	6400635	0	1707636	4772769	586265908
11-Aug-96	262827097	18060836	4293326	0	386616	12461366	298029241
20-Aug-96	428486368	64400620	412441	0	1257282	847365882	1341922592
27-Aug-96	247465462	27698918	278355	0	661436	293140952	569245123
3-Sep-96	138565811	27926103	726061	0	1689094	270970393	439877462
9-Sep-96	147487680	33866101	0	0	826235	35249873	217429890
16-Sep-96	277005112	30135170	549921	0	2781406	390145937	700617547
23-Sep-96	148680456	41952347	2749604	0	2352155	129988508	325723070
29-Sep-96	141990064	58166700	5286068	0	3813900	149416049	358672781
5-Oct-96	210656006	54863478	16979653	0	4557994	340089050	627146180
15-Oct-96	172055407	86020254	30306790	0	3939971	285055356	577377777
19-Oct-96	136816350	43920092	46020425	0	3421190	4021205	234199262
25-Oct-96	134607831	43305384	40831619	0	4932971	18520823	242198628
9-Nov-96	322128083	74289600	85037443	32870091	3514168	33734550	551573934
20-Jan-97	53712692	11102772	0	0	373338	8890220	74079023
15-Feb-97	74958916	6207519	309283	11413226	997885	410556097	504442925
17-Mar-97	58984368	8217067	0	0	625178	274545884	342372496
26-Apr-97	318931356	59730142	258935	0	15698	2596826512	2975762642
16-May-97	547041158	157018370	2921070	22060136	308004	1881540298	2610889036
18-May-97	624670744	3056658	3907676	13571927	526641	1221007339	1866740985
30-May-97	1057340079	288999	2532826	0	420063	1128189274	2188771241
6-Jun-97	896816500	21355721	54191957	0	629106	224645317	1197638601
13-Jun-97	988363650	3434887	146136359	0	1528253	262645798	1402108947
20-Jun-97	795742416	19536812	103129412	0	1154197	663329903	1582892740
24-Jun-97	821300646	14506291	18959364	20807189	1038117	1573928367	2450539973
4-Jul-97	487033093	28324451	3175712	0	2229469	658250192	1179012916
8-Jul-97	413815115	13234518	1656293	0	1051202	871351633	1301108762
15-Jul-97	334961599	34952010	13010716	35117619	5641963	665960365	1089644273
22-Jul-97	463868417	54354259	24844402	13335454	4551382	355068135	916022048
30-Jul-97	439456129	93754163	71444442	23599040	5361455	2163707246	2797322475
2-Aug-97	259238395	89788693	4489259	76460034	3851202	904822874	1338650456
13-Aug-97	308828507	94030554	6494949	41087614	2957594	1489190488	1942589706
18-Aug-97	233812789	20763595	150572	8890302	3696226	3192032237	3459345722
26-Aug-97	163867375	36575076	1172021	34600096	1800110	1348010358	1586025036
3-Sep-97	179386055	41932424	2551587	70305473	1483385	1737040967	2032699891
9-Sep-97	197329152	42489690	6309379	60261834	1532897	1713592859	2021515811
22-Sep-97	360514820	79740723	4165091	78247736	3184343	733811079	1259663792
2-Oct-97	406721022	62520859	5969623	61094328	2697438	716317304	1255320574
6-Oct-97	450339901	69517270	6022885	88903025	3211134	845001933	1462996147

Table 5.2 - Shannon Weiner diversity index (Station 1 and 2 combined) for each algal class of phytoplankton found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

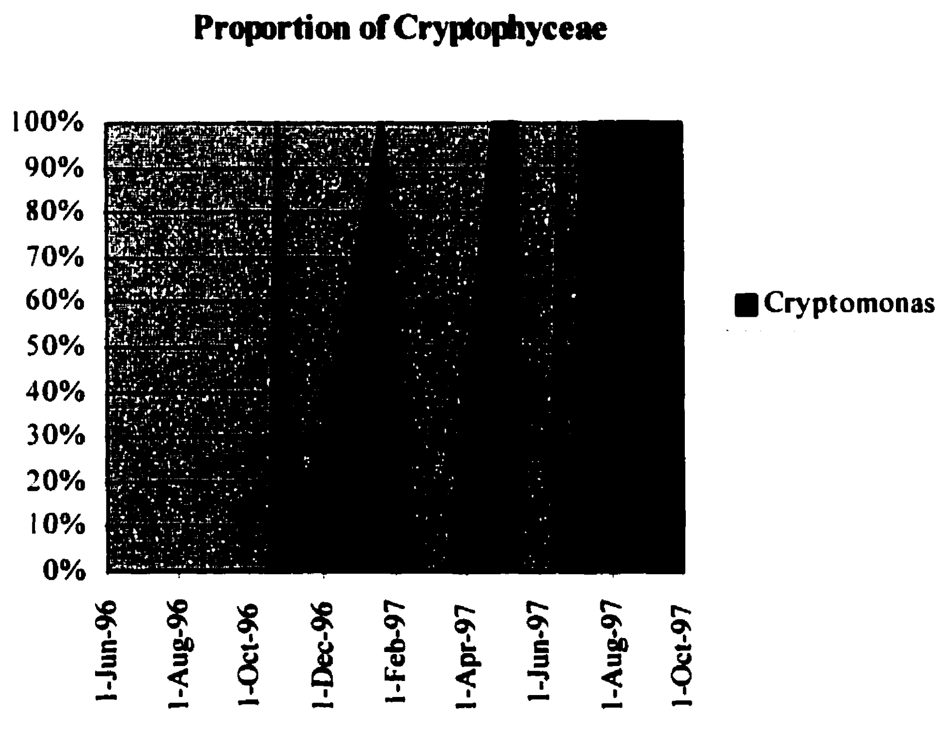
average	Bacillariophyceae	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria	Dinophyceae	Diversity
1-Jun-96	0.168	0.011	0.011	0.000	0.000	0.061	0.251
6-Jun-96	0.145	0.017	0.030	0.000	0.000	0.055	0.246
9-Jun-96	0.320	0.020	0.074	0.000	0.001	0.366	0.781
15-Jun-96	0.268	0.023	0.050	0.000	0.001	0.364	0.705
26-Jun-96	0.334	0.027	0.114	0.000	0.002	0.364	0.841
6-Jul-96	0.368	0.022	0.156	0.000	0.005	0.316	0.866
12-Jul-96	0.235	0.091	0.104	0.000	0.012	0.334	0.776
17-Jul-96	0.057	0.043	0.064	0.000	0.020	0.107	0.291
24-Jul-96	0.135	0.066	0.066	0.000	0.030	0.241	0.537
28-Jul-96	0.075	0.161	0.071	0.000	0.008	0.021	0.336
9-Aug-96	0.123	0.244	0.049	0.000	0.017	0.039	0.472
11-Aug-96	0.111	0.170	0.061	0.000	0.009	0.133	0.483
20-Aug-96	0.365	0.146	0.002	0.000	0.007	0.290	0.810
27-Aug-96	0.362	0.147	0.004	0.000	0.008	0.342	0.863
3-Sep-96	0.364	0.175	0.011	0.000	0.021	0.298	0.869
9-Sep-96	0.263	0.290	0.000	0.000	0.021	0.295	0.869
16-Sep-96	0.367	0.135	0.006	0.000	0.022	0.326	0.856
23-Sep-96	0.358	0.264	0.040	0.000	0.036	0.367	1.064
29-Sep-96	0.367	0.295	0.062	0.000	0.048	0.365	1.137
5-Oct-96	0.366	0.213	0.098	0.000	0.036	0.332	1.045
15-Oct-96	0.361	0.284	0.155	0.000	0.034	0.348	1.182
19-Oct-96	0.314	0.314	0.320	0.000	0.062	0.000	1.009
25-Oct-96	0.326	0.308	0.300	0.000	0.079	0.000	1.014
9-Nov-96	0.314	0.270	0.288	0.168	0.032	0.171	1.244
20-Jan-97	0.233	0.284	0.000	0.000	0.027	0.000	0.544
15-Feb-97	0.283	0.054	0.005	0.086	0.012	0.000	0.440
17-Mar-97	0.303	0.090	0.000	0.000	0.012	0.000	0.404
26-Apr-97	0.239	0.078	0.001	0.000	0.000	0.000	0.319
16-May-97	0.327	0.169	0.008	0.040	0.001	0.236	0.782
18-May-97	0.366	0.011	0.013	0.036	0.002	0.000	0.428
30-May-97	0.351	0.001	0.008	0.000	0.002	0.000	0.362
6-Jun-97	0.217	0.072	0.140	0.000	0.004	0.000	0.432
13-Jun-97	0.246	0.015	0.236	0.000	0.007	0.314	0.818
20-Jun-97	0.346	0.054	0.178	0.000	0.005	0.364	0.948
24-Jun-97	0.366	0.030	0.038	0.040	0.003	0.284	0.762
4-Jul-97	0.365	0.090	0.016	0.000	0.012	0.325	0.808
8-Jul-97	0.364	0.047	0.008	0.000	0.006	0.269	0.694
15-Jul-97	0.363	0.110	0.053	0.111	0.027	0.301	0.965
22-Jul-97	0.345	0.168	0.098	0.062	0.026	0.367	1.065
30-Jul-97	0.291	0.114	0.094	0.040	0.012	0.199	0.749
2-Aug-97	0.316	0.181	0.019	0.164	0.017	0.265	0.963
13-Aug-97	0.292	0.147	0.019	0.082	0.010	0.204	0.753
18-Aug-97	0.182	0.031	0.000	0.015	0.007	0.074	0.310
26-Aug-97	0.235	0.087	0.005	0.083	0.008	0.138	0.556
3-Sep-97	0.214	0.080	0.008	0.116	0.005	0.134	0.559
9-Sep-97	0.227	0.081	0.018	0.105	0.005	0.140	0.577
22-Sep-97	0.358	0.175	0.019	0.173	0.015	0.315	1.054
2-Oct-97	0.365	0.149	0.025	0.147	0.013	0.320	1.020
6-Oct-97	0.363	0.145	0.023	0.170	0.013	0.317	1.031

biovolume results (3.54 mm^3 / L), while the lowest mean total particulate biovolume results (0.26 mm^3 / L) were in the winter of 1996. The occurrence of dominant species in each class and is presented in Figures 5.3a to f. In the Bacillariophyceae (Figure 5.3A), *Fragilaria* sp. dominated in 1996 and *Synedra* sp. dominated the 1997 season. *Cryptomonas* sp. was the only Cryptophyte found (Figure 5.3B) and during the 1996 season, no *Cryptomonas* sp. was seen. A shift in dominance was seen in the Chlorophyceae (Figure 5.3C). *Scenedesmus* sp. dominated in the spring in both 1996 and 1997.On the other hand, during the ice-in season peak levels of *Elaktothrix* sp. were displayed. The summer and fall seasons of 1996 and 1997 showed *Staurastrum* sp. to dominate. In the Cyanobacteria (Figure 5.3D), a shift in dominance was also displayed. Summer peaks were of *Anabaena* sp. On the other hand, during the ice season peak levels of *Chroococcus* sp. were displayed. The rest of the time *Ceolosphaerium* sp. dominated. *Dinobryon* sp. was the only species seen in the Chrysophyceae (Figure 5.3E) and thus was extremely common throughout the study. *Peridinium* sp. and *Ceratium* sp. were the only species seen in the Dinophyceae (Figure 5.3F). In 1996, a *Ceratium* sp. peak was displayed and to a lesser extend in 1997. For most of the time, *Peridinium* sp. dominated the Dinophyceae .

When examining dominance of the entire assemblage (based on biovolume), a variety of trends were seen: Station 1 showed *Peridinium* sp. to dominate during the ice season and summer of 1997; *Fragilaria* sp. dominated during the summer of 1996; and Spring of 1996 and 1997 displayed dominance of *Synedra* sp. Station 2 showed *Peridinium* sp. to dominate during the ice season and summer of 1997; *Fragilaria* sp. and *Peridinium* sp. dominated



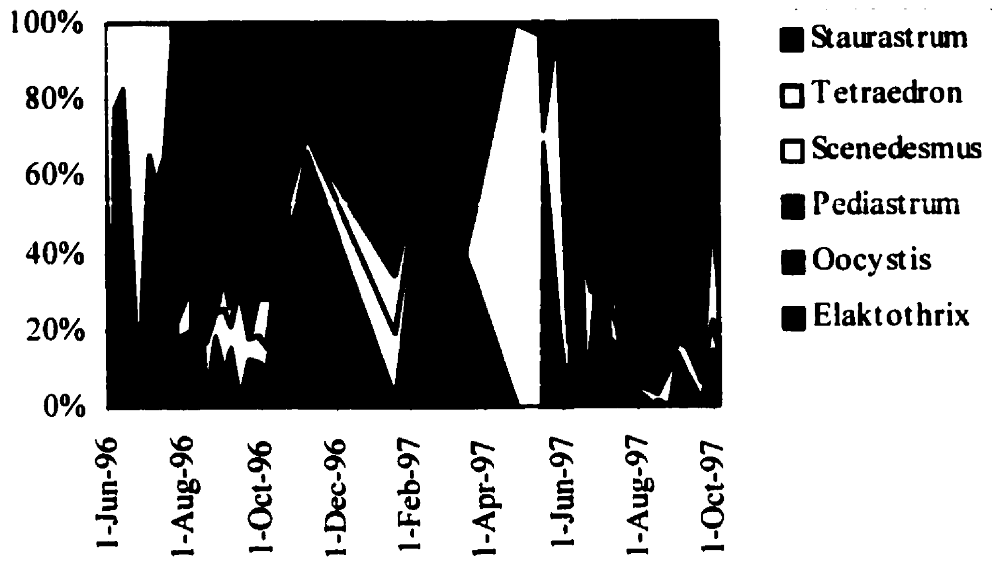
(A)



(B)

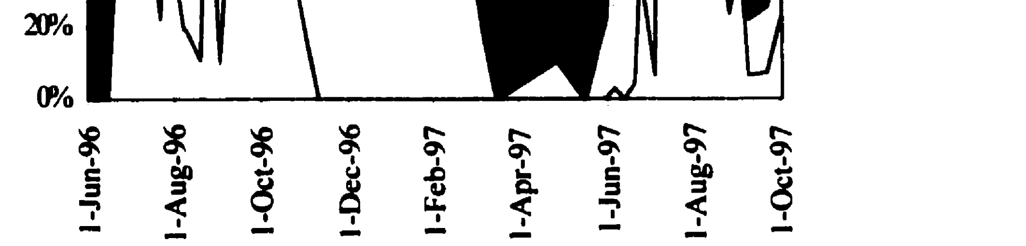
Figure 5.3 - Time series plots of proportion (based on biovolume) of the taxonomic composition of each major taxonomic group at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997. (A) Bacillariophyceae, (B) Cryptophyceae.

Proportion of Chlorophyceae



(C)

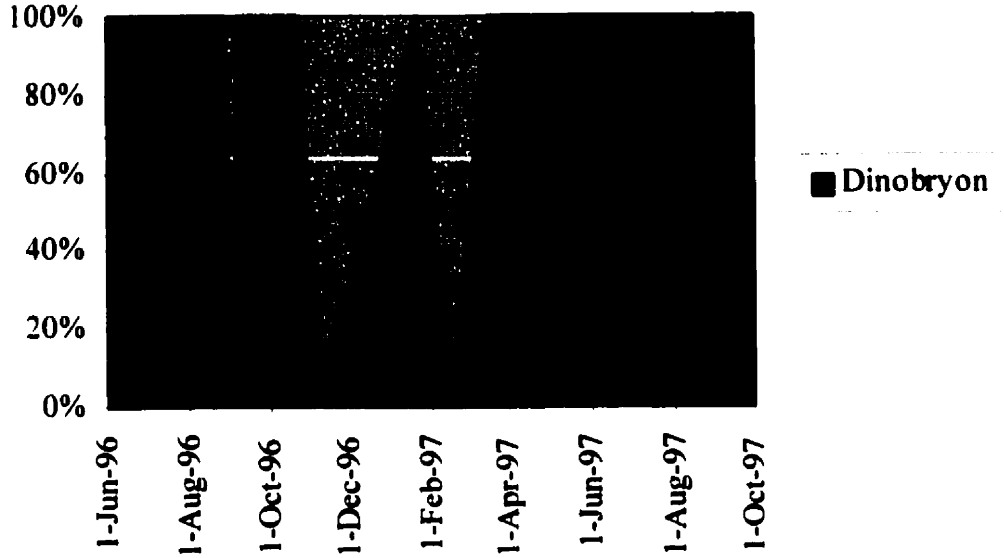
Proportion of Cyanobacteria



(D)

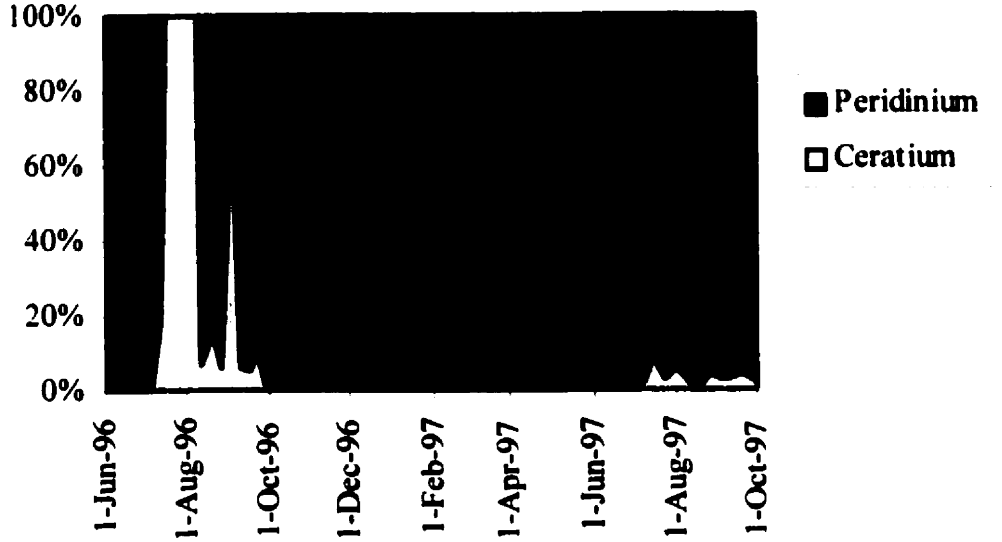
Figure 5.3 - Time series plots of proportion (based on biovolume) of the taxonomic composition of each major taxonomic group at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997. (C) Chlorophyceae, (D) Cyanobacteria.

Proportion of Chrysophyceae



(E)

Proportion of Dinophyceae



(F)

Figure 5.3 - Time series plots of proportion (based on biovolume) of the taxonomic composition of each major taxonomic group at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997. (E) Chrysophyceae, (F) Dinophyceae.

during the spring and summer of 1996; Spring 1997 displayed dominance in *Fragilaria* sp. but then switched to *Peridinium* sp. dominance in the summer of 1997. Average of Station 1 and Station 2 showed *Peridinium* sp. to dominate during the ice season and summer of 1997; *Fragilaria* sp. dominated during summer of 1996; Spring 1997 displayed dominance in *Synedra* sp.; and *Tabellaria* dominated in the spring of 1996.

Total particulate volumes averaged for Station 1 and Station 2 were higher in the 1997 season with the Dinophyceae dominating (Figure 5.4). Bacillariophyceae shifted to dominance in June 1997. In 1996, the Bacillariophyceae dominated especially during July / August and November to January (Figure 5.5). Station 1 mirrored the trends displayed in the averaged total particulate volumes of Station 1 and Station 2 (Figures 5.6 and 5.7). There were some exceptions: the Bacillariophyceae shifted to dominance in June and July in 1997 (Figure 5.7) and two major peaks in Dinophyceae during the Spring of 1997 (Figure 5.6). Station 2 also mirrored the trends displayed in the averaged total particulate volumes of Station 1 and Station 2(Figures 5.8 and 5.9). There were some exceptions: the Bacillariophyceae shifted to dominance by displaying distinct peaks in May, June, and July in 1997 (Figure 5.9).

Species diversity (Shannon Weiner Index) is a measure of community information with respect to number (richness) and/or relative abundance of the species making up the community. The main drawback of this calculation is it does not account for ecological interpretation but considers species richness and heterogeneity. Smith (1980) describes the Shannon Weiner Index as a measure of uncertainty. In other words, the higher the value, the greater the uncertainty that the next bit of information will be the same as the previous.

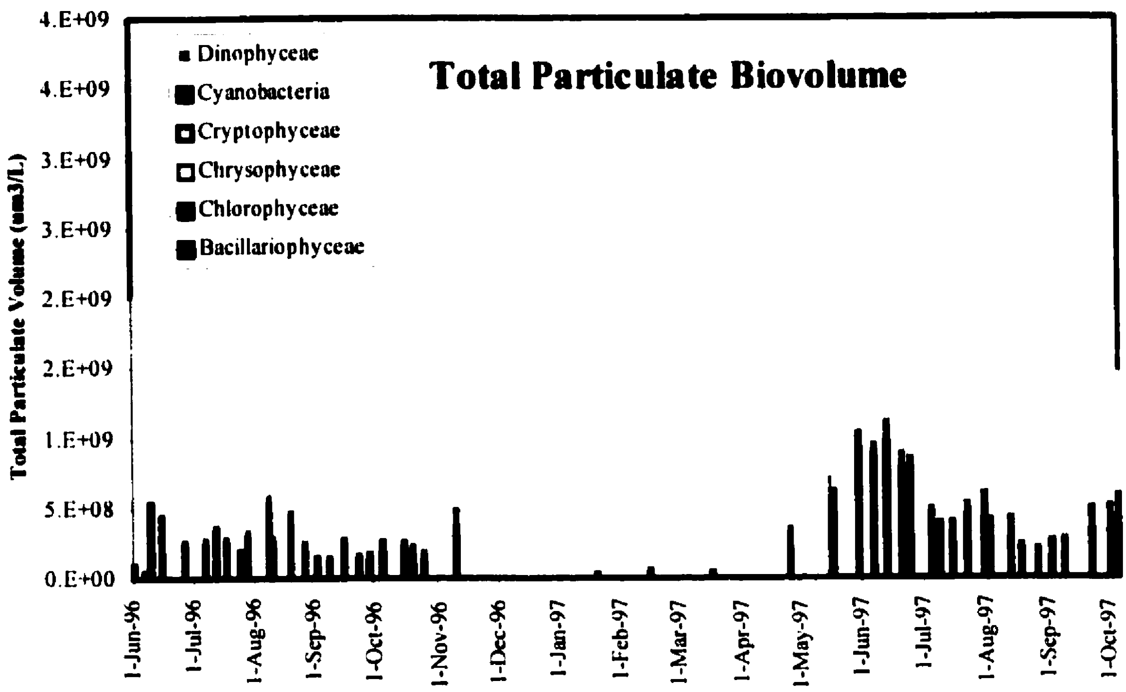


Figure 5.4 - Time series plot of total particulate volume (biovolume) for each major taxonomic group at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997. Data from Station 1 and Station 2 have been averaged.

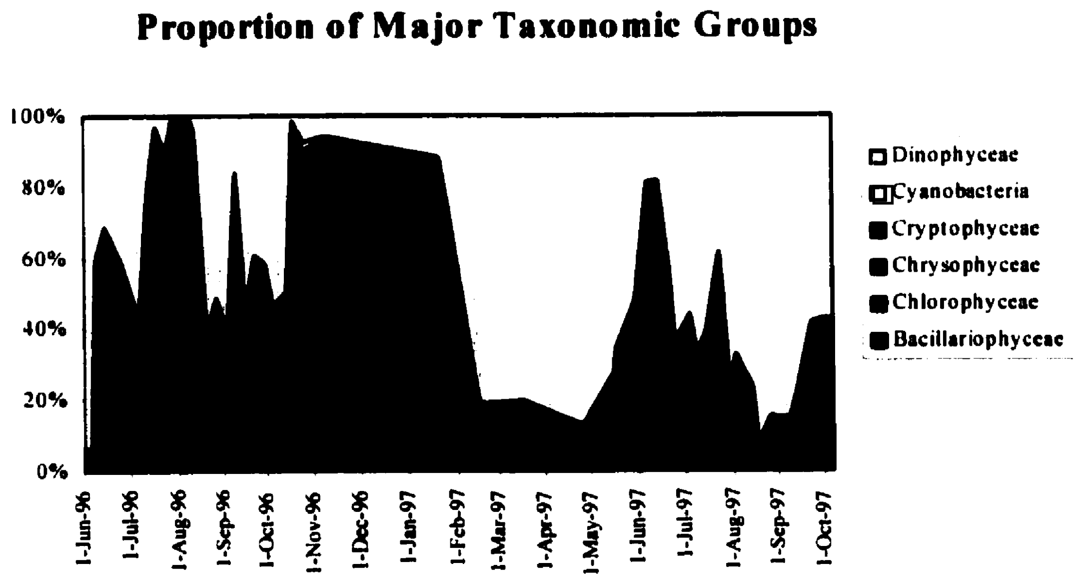


Figure 5.5 - Time series plot of proportion of major taxonomic group at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997. Data from Station 1 and Station 2 have been averaged.

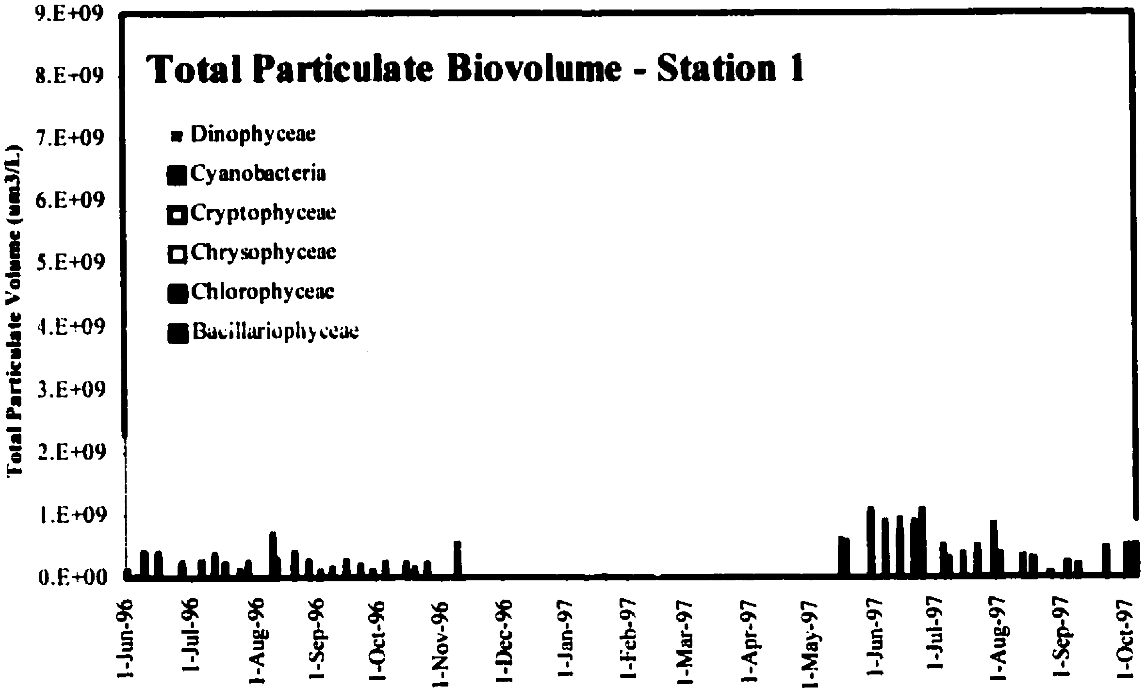


Figure 5.6 - Time series plot of total particulate volume (biovolume) for each major taxonomic group at Station 1 in Clear Lake, Manitoba for the period of June 1996 to October 1997.

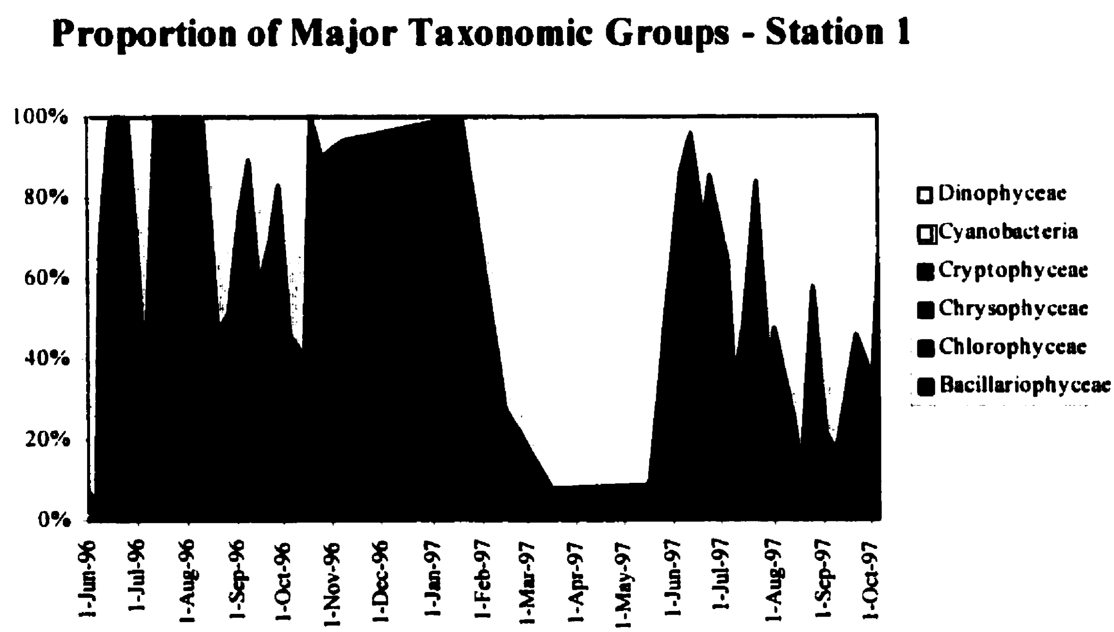


Figure 5.7 - Time series plot of proportion of major taxonomic group at Station 1 in Clear Lake, Manitoba for the period of June 1996 to October 1997.

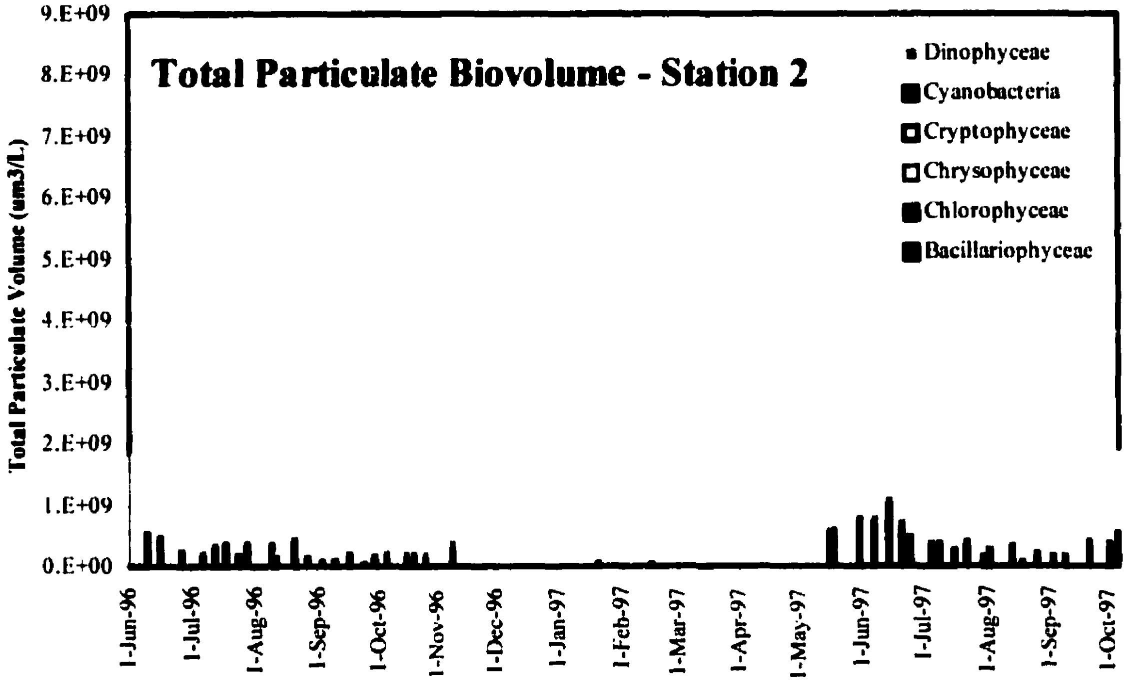


Figure 5.8 - Time series plot of total particulate volume (biovolume) for each major taxonomic group at Station 2 in Clear Lake, Manitoba for the period of June 1996 to October 1997.

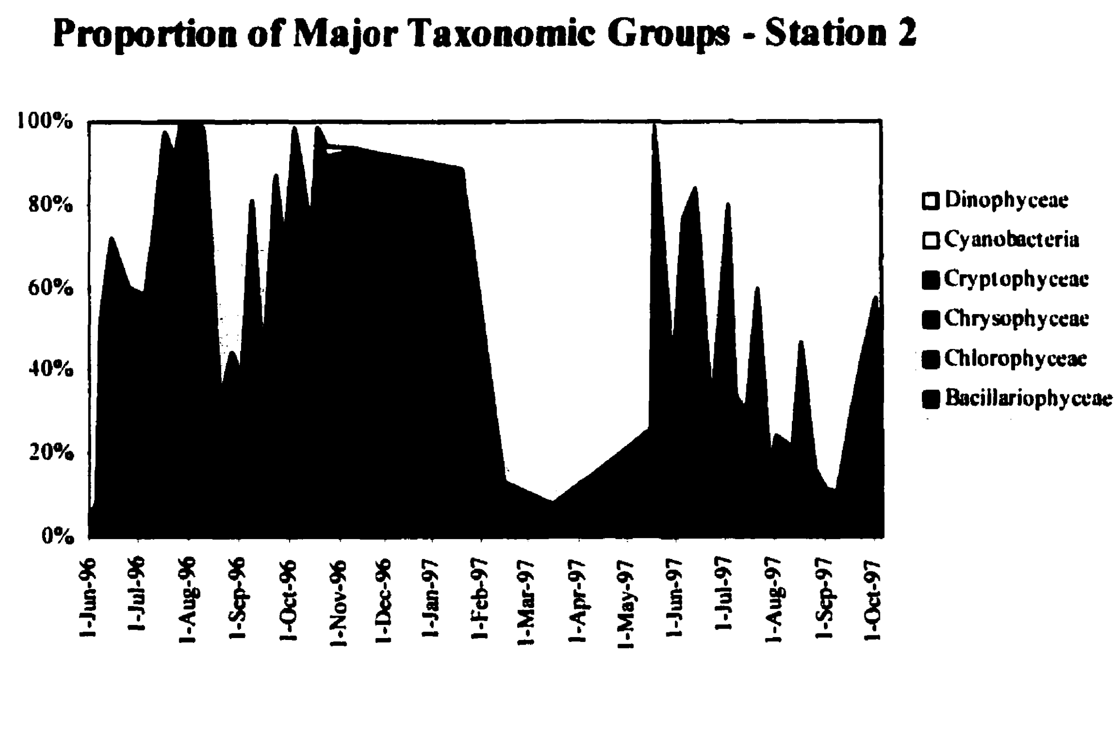


Figure 5.9 - Time series plot of proportion of major taxonomic group at Station 2 in Clear Lake, Manitoba for the period of June 1996 to October 1997.

Diversity was lowest during the winter ice season when the number of species and heterogeneity were both low. Whereas, in the late summer / early fall values increased (Figure 5.10). The Bacillariophyceae displayed the highest proportion of the species diversity throughout the study (Figure 5.11).

Both richness and diversity displayed seasonal differences (Figure 5.12). In 1996, total particulate volume was lower but diversity was higher. Whereas in 1997, diversity was low and total particulate volume was higher from May to July then diversity increased as total particulate volume decreased.

Chlorophyll-a and species richness displayed similarities but with some seasonal differences (Figure 5.13). The general trend for 1996 was as chlorophyll-a increased, species richness followed suit. A major in peak in both was observed just before ice in. The opposite trend was seen in 1997. When chlorophyll-a decreased, species richness increased, especially during May to June and mid August to October. In July chlorophyll-a increased and species richness increased.

5.2.3 Primary Productivity

Since estimates of daily productivity, *in situ* primary productivity, depend on measures of *in vitro* photosynthesis and the availability of light within the water column both measures will be discussed. Primary Productivity parameters are presented in the Appendices section: Table A.5.2 for Station 1 and Table A.5.4 for Station 2.

A comparison of the parameters P_{max}, α, SP_{max} (chl-a normalized), α (chl-a normalized), I_k, and biomass was conducted to determine if Station 1 and Station 2 were true

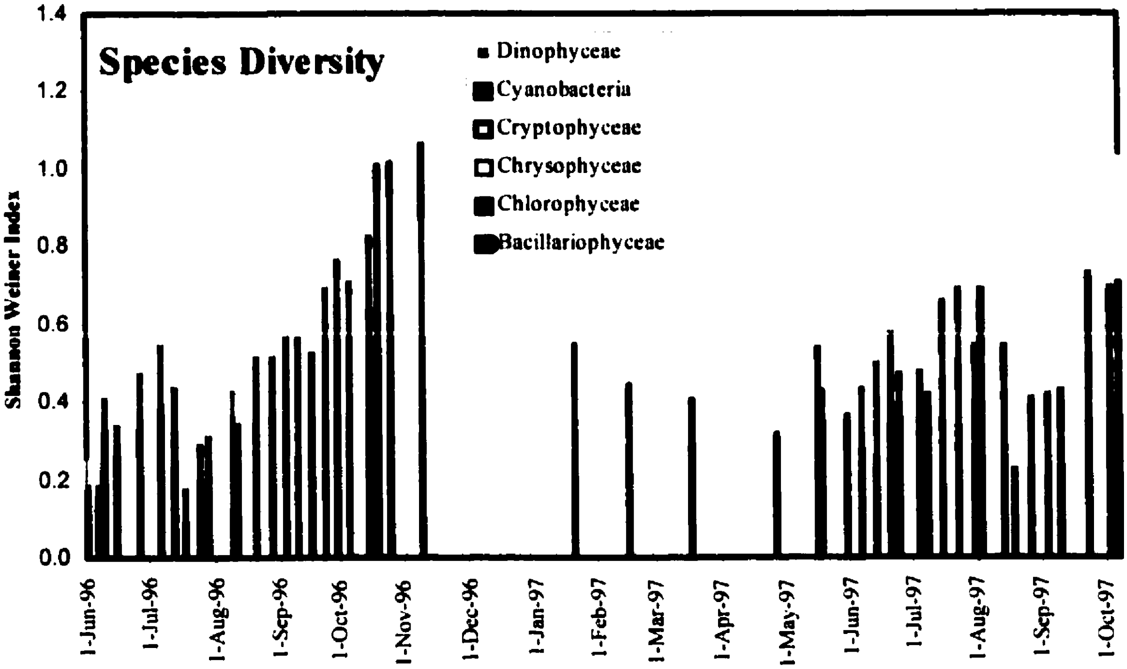


Figure 5.10 - Time series plot of Species Diversity (Shannon Weiner Index) for Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997.

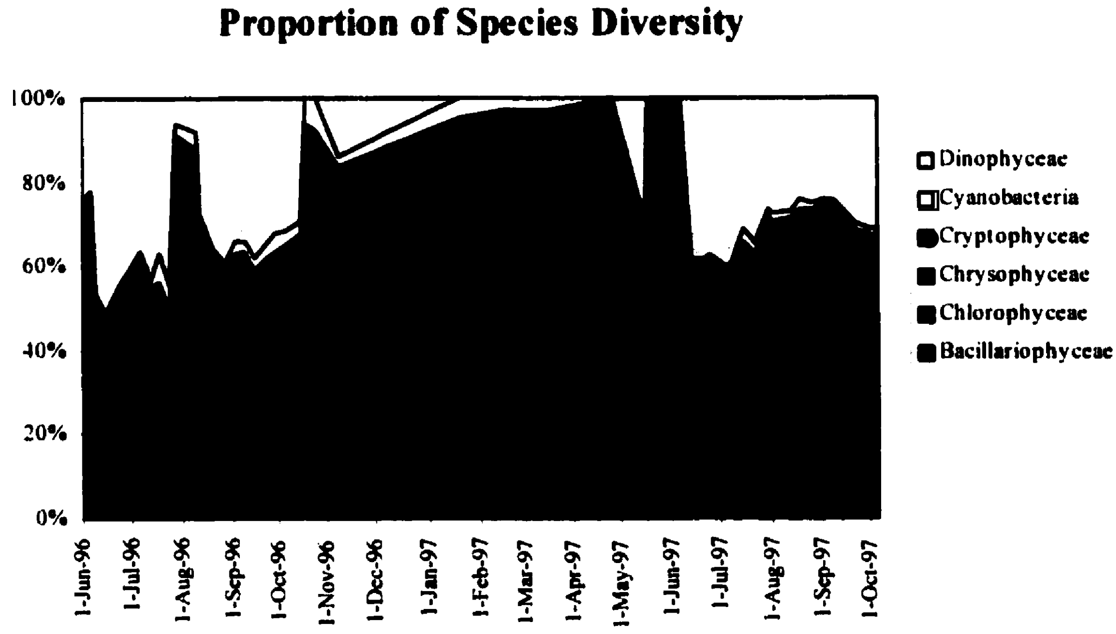


Figure 5.11 - Proportion of Species Diversity (Shannon Weiner Index) attributed to individual algal classes at Station 1 and Station 2 combined in Clear Lake, Manitoba for the period of June 1996 to October 1997.

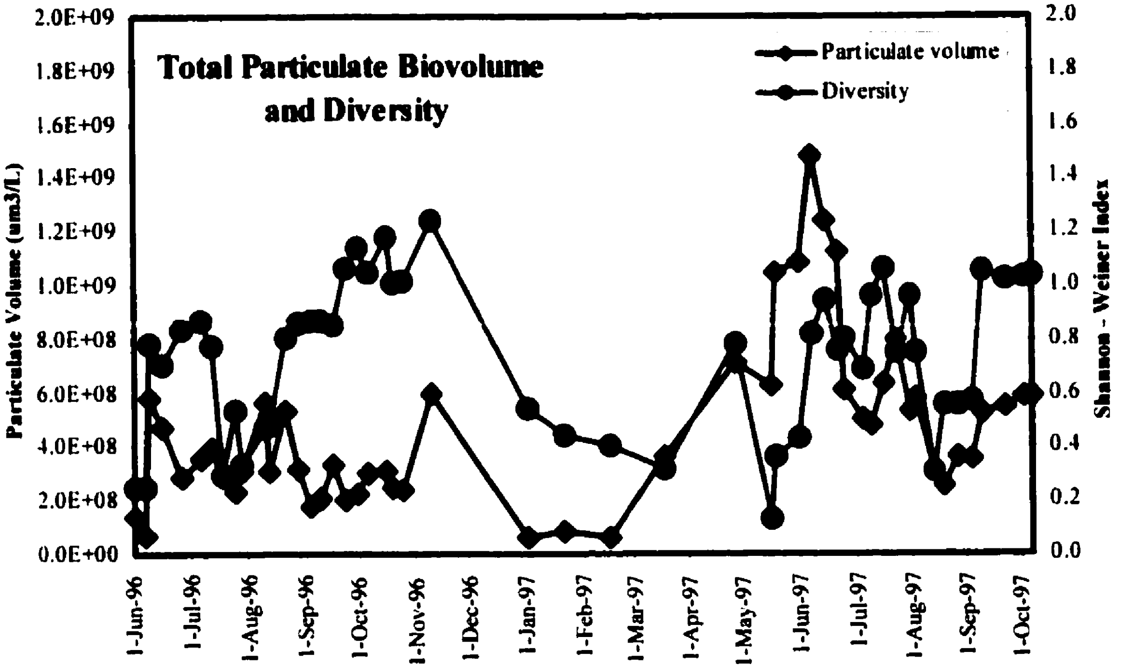


Figure 5.12 - Time series plot of total particulate volume and species diversity (Shannon Weiner Index) for Station 1 and Station 2 (averaged) in Clear Lake, Manitoba for the period of June 1996 to October 1997.

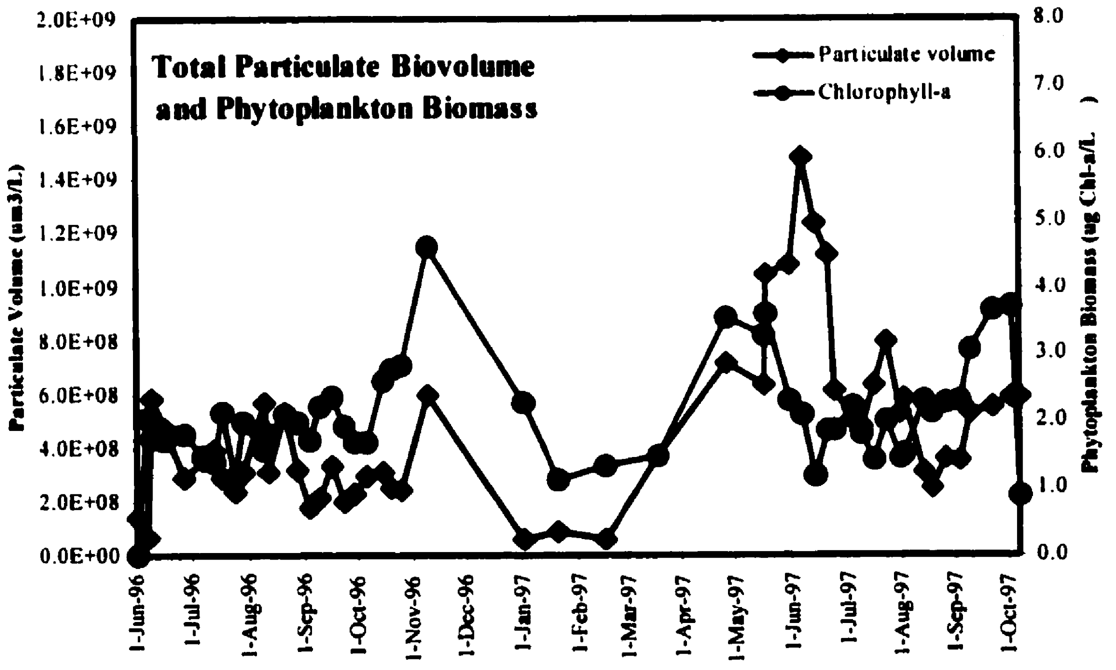


Figure 5.13 - Time series plot of total particulate volume and phytoplankton biomass (chlorophyll-a) for Station 1 and Station 2 (averaged) in Clear Lake, Manitoba for the period of June 1996 to October 1997.

replicas of each other. Initial comparisons displayed outliers that needed further investigation Four dates were eliminated because:

1. September 6, 1996 - major outlier for P_{max}, and biomass. The water was extremely rough and considerable drift by the boat was occurring.
2. January 1, 1997 - major outlier for α, I_k , and biomass. Equipment malfunctioning due to cold temperatures and late afternoon sampling.
3. March 17, 1997 - too few points used in the nonlinear model due to major outliers.
4. July 15, 1997 - major outlier for SP_{max}, and I_k. The water was extremely rough and considerable drift by the boat was occurring.

Table 5.3 outlines the results of the comparison between stations (without above outlier data) compiled on DataDesk (version 6). Statistical analysis (regression analysis, Pearson Product Moment, and Paired T-test) show that Station 1 and Station 2 were indeed statistically similar. I_k tended to show a lower correlation although it was calculated from P_{max} and alpha. When the data were normalized for biomass (chlorophyll-a), the correlation decreased slightly. This decrease can be accounted for by differences in biomass, which could be attributed to morphometry, environmental conditions (wind), sampling error, and a possible differences in assemblage composion.

Table 5.3 - A statistical comparison with regression analysis, Pearson Product Moment, and Paired T-test to compare Station 1 and Station 2 productivity parameters in Clear Lake, Manitoba

Parameter	Regression r^2	Correlation Pearson Product Moment	Paired T-test alpha = 0.05
P_{max}	77.7%	0.881	failed to reject H_o at alpha (0.05) p = 0.5445
alpha	78.1%	0.884	failed to reject H_o at alpha (0.05) p = 0.6076
I_k	41.9%	0.647	failed to reject H_o at alpha (0.05) p = 0.1444
SP_{max}	62.4%	0.790	failed to reject H_o at alpha (0.05) p = 0.1249
alpha / biomass	69.7%	0.835	failed to reject H_o at alpha (0.05) p = 0.0293
biomass	60.4%	0.777	reject H_o at alpha (0.05) p = 0.0073

Table 5.4 displays comparisons between the parameters and chlorophyll-a normalized parameters. Two trends were displayed in this analysis. First, the correlation values increased from P_{max} - SP_{max} to alpha - alpha / biomass. Both stations displayed this trend. Secondly, the correlation values for each of the parameter comparisons were similar.

Table 5.4 - A statistical comparison with Pearson Product Moment and Paired T-test to compare productivity parameters and chlorophyll-a normalized parameters for Station 1 and Station 2 in Clear Lake, Manitoba.

	Parameter	Correlation Pearson Product Moment	Paired T-test alpha = 0.05	
Station	P_{max} to SP_{max}	0.688	reject H_o at alpha (0.05)	$p < 0.0001$
1	alpha to alpha / biomass	0.763	reject H_o at alpha (0.05)	$p < 0.0001$
Station	P_{max} to SP_{max}	0.690	reject H_o at alpha (0.05)	$p < 0.0001$
2	alpha to alpha / biomass	0.744	reject H_o at alpha (0.05)	$p < 0.0001$

Once the whole lake productivity model 1 was compiled for each of the two stations separately, additional comparisons were done to determine similarities between the stations. Regression analysis between Station 1 and Station 2 daily productivity displayed a r^2 = 0.4768. Individual value comparisons confirmed that low values found in Station 1 were mimicked in Station 2 and high values followed suit. It was at this point the decision was made that Station 1 and Station 2 were comparable, such that data could be combined, which expanded the data set from 55 sample points to 110 sample points and thus increased 'n' in subsequent analyses. Data were combined. Even though June 1, 1996 station selection showed significant differences between stations, Productivity (p=0.014), Pmax (p=0.137), SPmax (p=0.051), alpha (p=0.019), and chlorophyll normalized alpha (p=0.028) were similar.

Measures in phytoplankton parameters displayed similarities but some seasonal differences. The mean P_{max} was determined to be 5.341 mg C / L /hour with a minimum value of 0.259 mg C / L /hour and maximum value of 11.616 mg C / L /hour. The fall of 1997 displayed the highest P_{max} results (8.933 mg C / L /hour), while the lowest P_{max} results (0.969 mg C / L /hour) were in the winter of 1996. The mean chlorophyll normalized P_{max} (SP_{max})was determined to be 2.787 mg C / L /hour / µg Chl-a / L with a minimum value of 0.168 mg C / L /hour / µg Chl-a / L and maximum value of 10.322 mg C / L /hour / µg Chl-a / L. The fall of 1997 displayed the highest SP_{max} (4.705 mg C / L /hour / µg Chl-a / L), while the lowest SP_{max} (0.789 mg C / L /hour / µg Chl-a / L) were in the winter of 1996. Values in 1997 were higher for P_{max} and SP_{max} than for 1996. In 1996, the trend displayed was a gradual increase until late August and early September followed by a decrease. Low levels were seen throughout the ice season. This trend was repeated in 1997 but without a decrease. Figures 5.14 and 5.15 illustrate these trends for P_{max} and SP_{max} respectively. The 95% confidence levels are illustrated for P_{max} in Figure 5.16 for Station 1 and Figure 5.18 for Station 2. The 95% confidence levels are illustrated for SP_{max} in Figure 5.17 for Station 1 and Figure 5.19 for Station 2.

'Alpha' (α), is the slope of the light limited photosynthesis and is often described as 'photosynthetic efficiency'. The mean α was 0.049 mg C / L / hour /µmole PAR / m^2 / sec with a minimum value of 0.002 mg C / L / hour /µmole PAR / m^2 / sec and maximum value of 0.115 mg C / L / hour /µmole PAR / m^2 / sec. The fall of 1996 displayed the highest α (0.094 mg C / L / hour /µmole PAR / m^2 / sec), while the lowest α (mg C / L / hour /µmole PAR / m^2 / sec) occurred in the spring of 1996. The mean chlorophyll normalized α was 0.026 mg C / L / hour /µmole PAR / m^2 / sec /µg Chl-a / L with a minimum value of

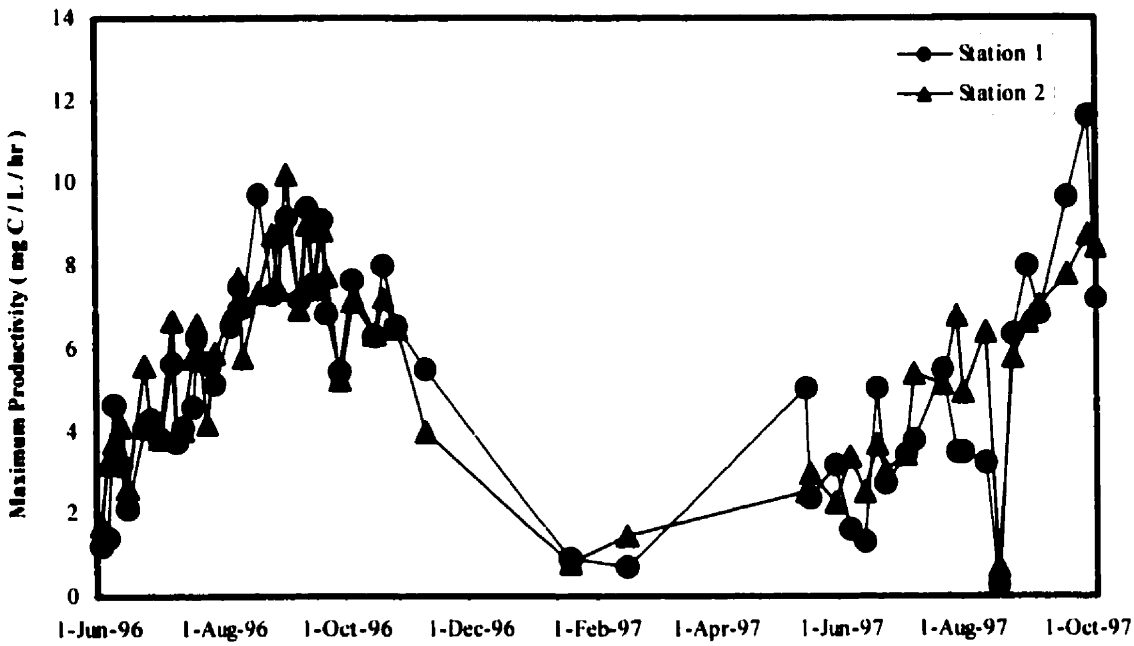


Figure 5.14 - A time series plot comparison of Pmax (productivity at light saturation) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

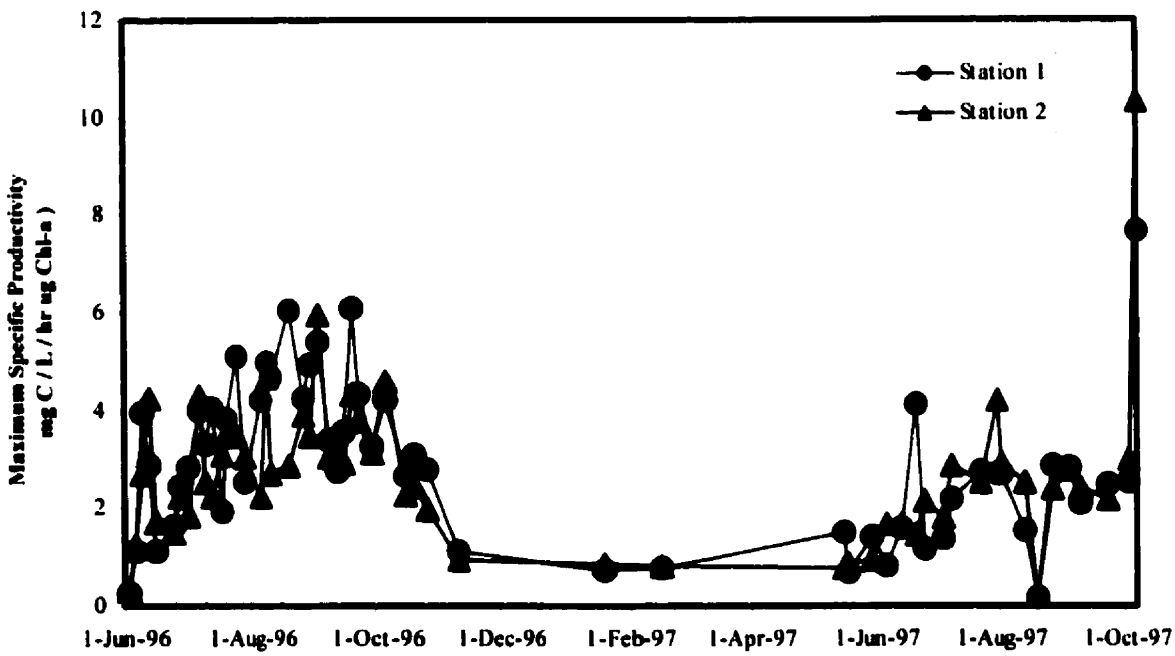


Figure 5.15 - A time series plot comparison of SPmax (chlorophyll normalized productivity at light saturation) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

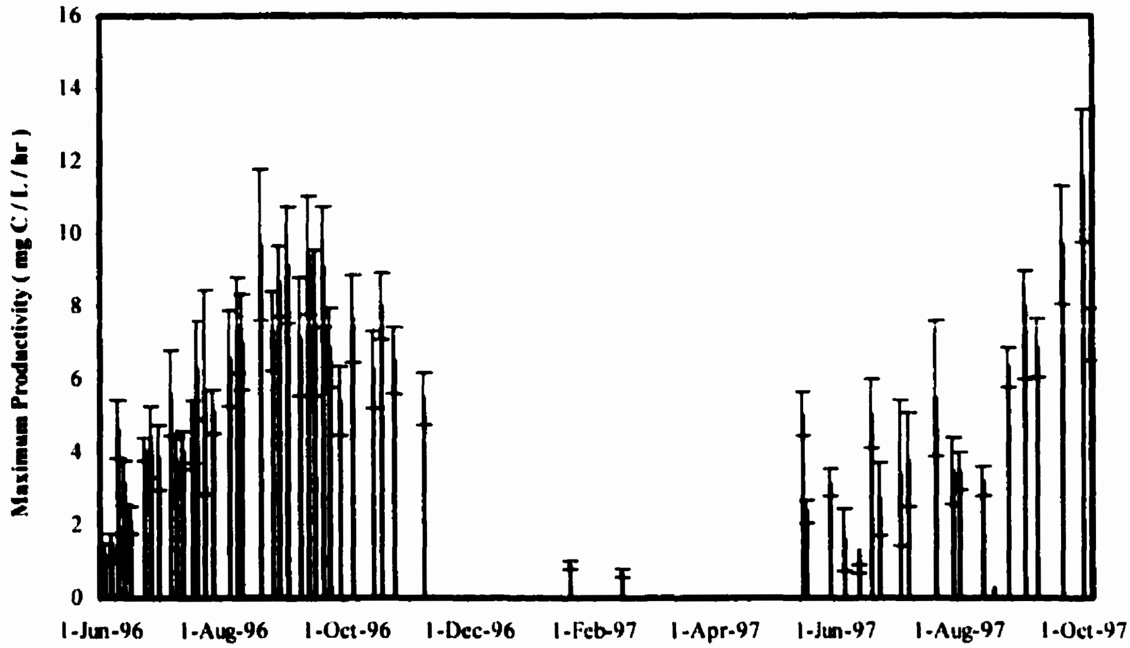


Figure 5.16 - A time series plot comparison of Pmax (productivity at light saturation) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 1) from June 1996 to October 1997.

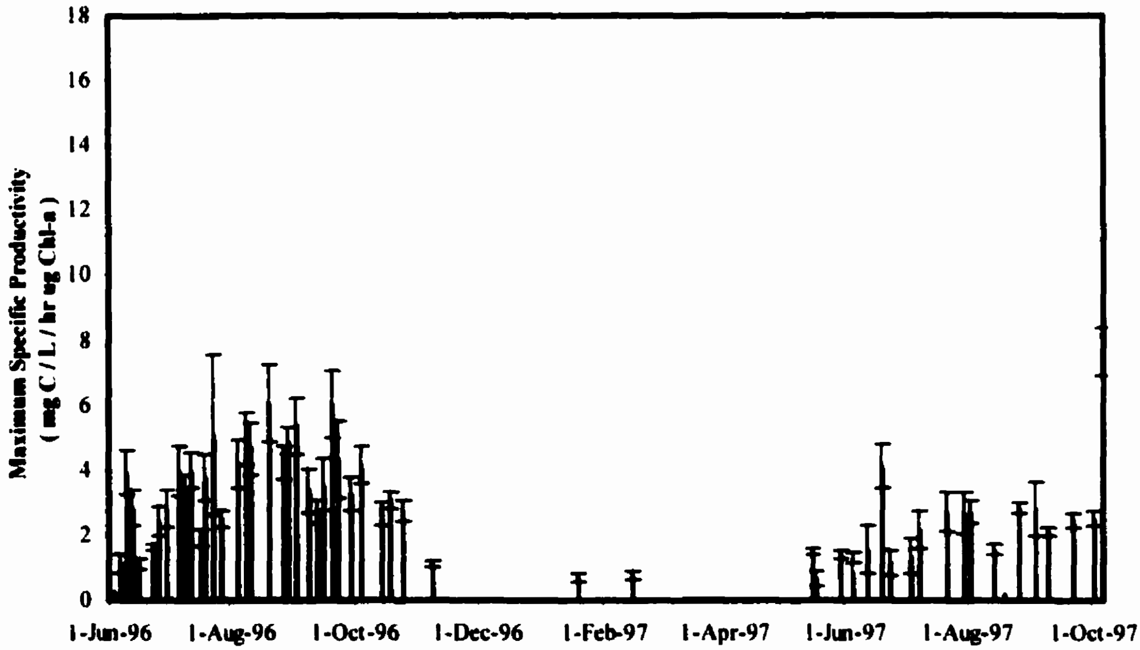


Figure 5.17 - A time series plot comparison of SPmax (chlorophyll normalized productivity at light saturation) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 1) from June 1996 to October 1997.

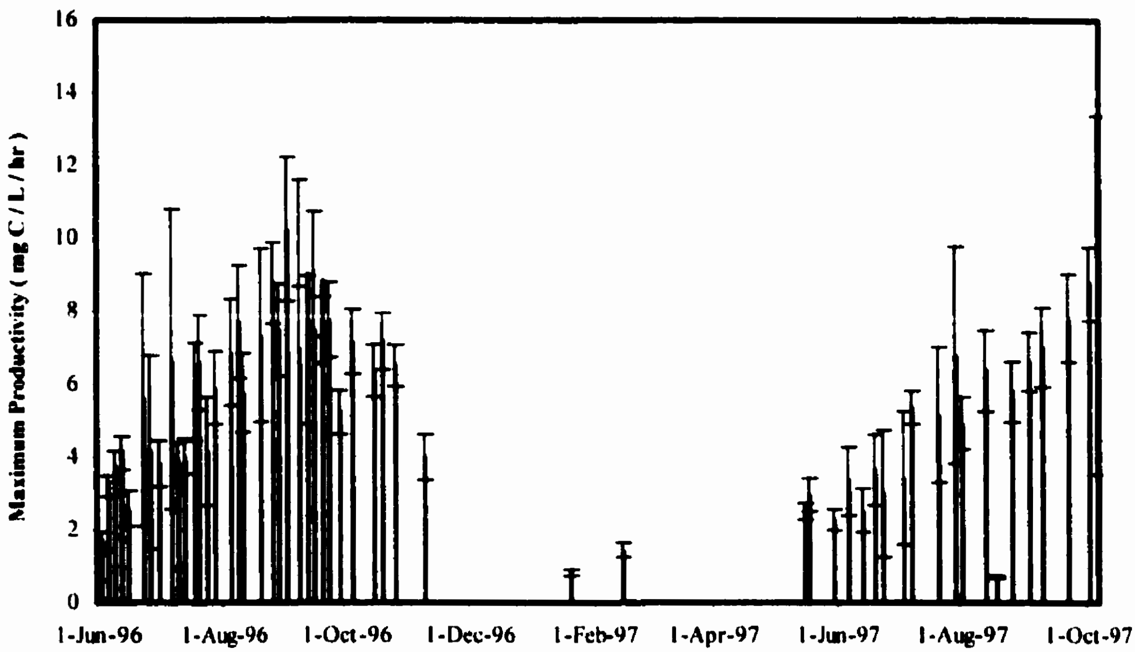


Figure 5.18 - A time series plot comparison of Pmax (productivity at light saturation) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 2) from June 1996 to October 1997.

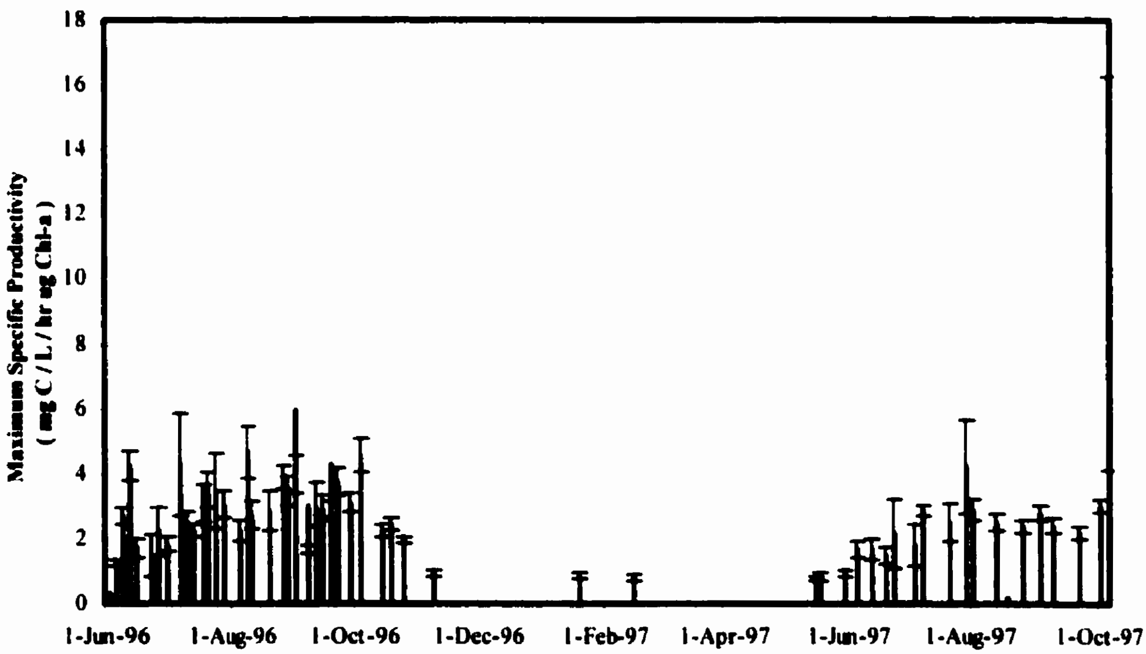


Figure 5.19 - A time series plot comparison of SPmax (chlorophyll normalized productivity at light saturation) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 2) from June 1996 to October 1997.

0.001 C / L / hour /μmole PAR / m^2 / sec /μg Chl-a / L and maximum value of 0.105 C / L / hour /μmole PAR / m^2/ sec /μg Chl-a / L. The fall of 1996 displayed the highest chlorophyll normalized α (0.044 C / L / hour /μmole PAR / m^2 / sec /μg Chl-a / L), while the lowest chlorophyll normalized α (0.012 C / L / hour /μmole PAR / m^2/ sec /μg Chl-a / L) occurred in the spring of 1997. Values in 1996 were higher for α and chlorophyll normalized α than during 1997, a trend that was opposite to that of P_{max} and SP_{max}. Generally, the trend displayed was a gradual increase until late August early September following by a decrease. Low levels were seen throughout the ice season but followed by a spring peak. This trend was mirrored in 1997 but no decrease was seen. Figures 5.20 and 5.21 illustrates these trends for α and chlorophyll normalized α respectively. The 95% confidence levels are illustrated for α in Figure 5.22 for Station 1 and Figure 5.23 for Station 2. The 95% confidence levels are illustrated for chlorophyll normalized α in Figure 5.24 for Station 1 and Figure 5.25 for Station 2.

I_k is the light intensity at which P_{max} is achieved (intercept of P_{max} with α). The mean I_k was126.686 μmole PAR/m^2/sec with a minimum value of 24.184 μmole PAR/m^2/sec and a maximum value of 421.333 μmole PAR/m^2/sec. The summer of 1997 displayed the highest I_k (163.436 μmole PAR/m^2/sec), while the lowest I_k (29.272 μmole PAR/m^2/sec) was in the winter of 1996. Values in 1996 were higher for I_k values as compared with 1997, being opposite to P_{max}. Generally, the trend for I_k values displayed a gradual increase until late August early September followed by a decrease. Low levels were seen throughout the ice season and followed by a spring peak especially in Station 2 in 1997. In 1997, no trend was observed. Figures 5.26 illustrates the trends observed for I_k.

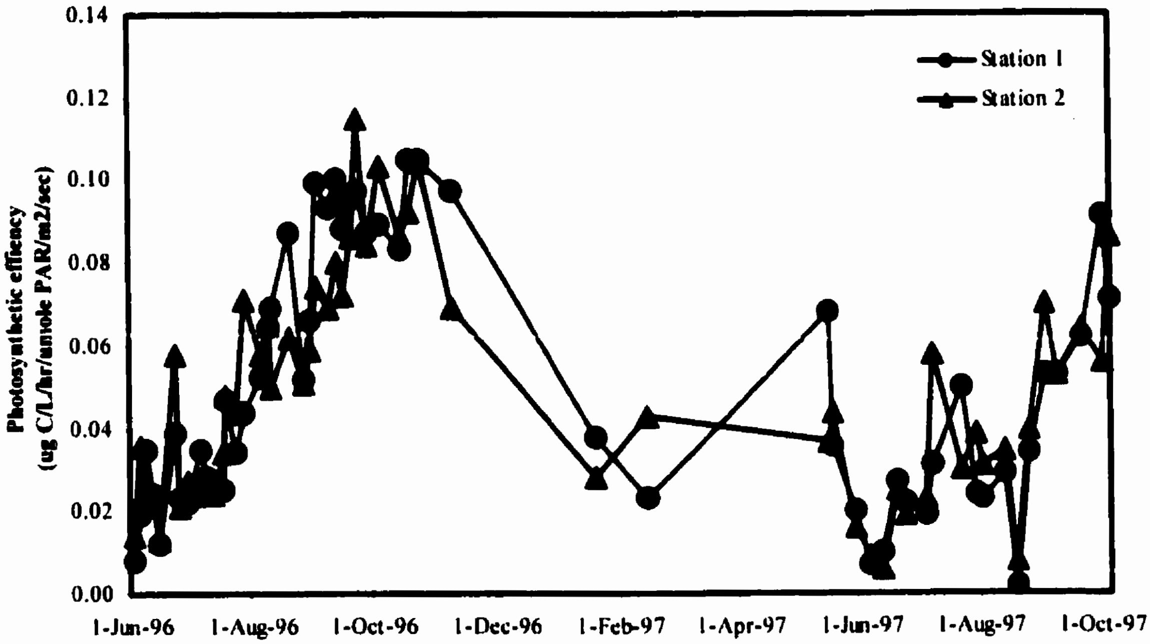


Figure 5.20 - A time series plot comparison of α (photosynthetic efficiency - slope of the light limited productivity) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

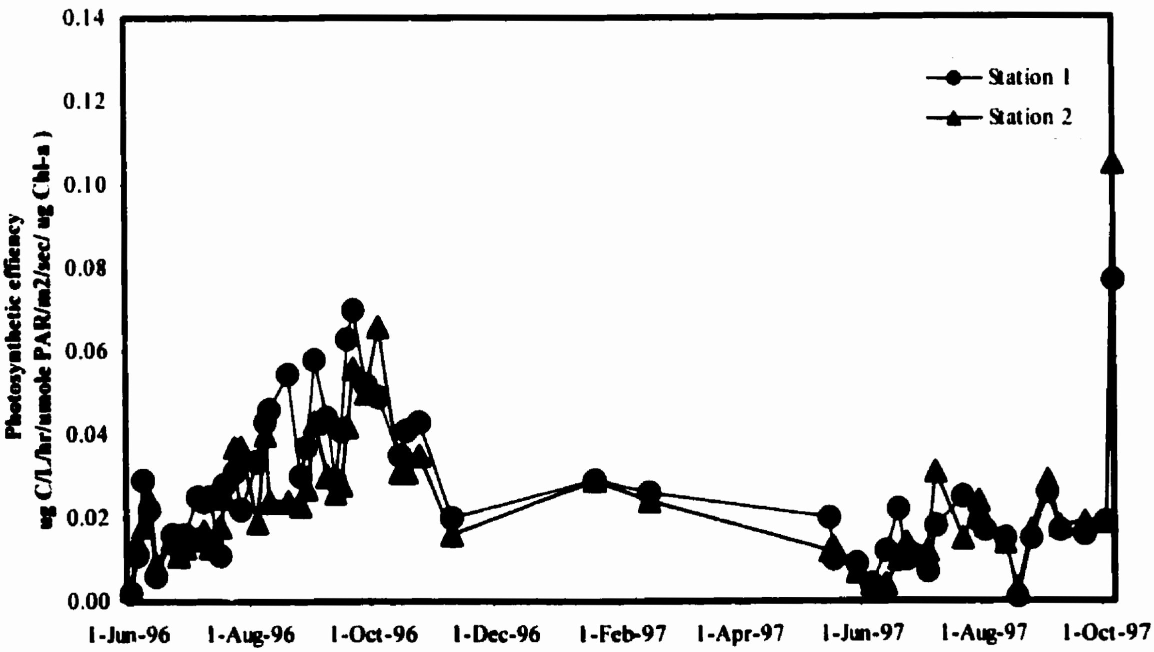


Figure 5.21 - A time series plot comparison of chlorophyll normalized α (photosynthetic efficiency - slope of the light limited productivity) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

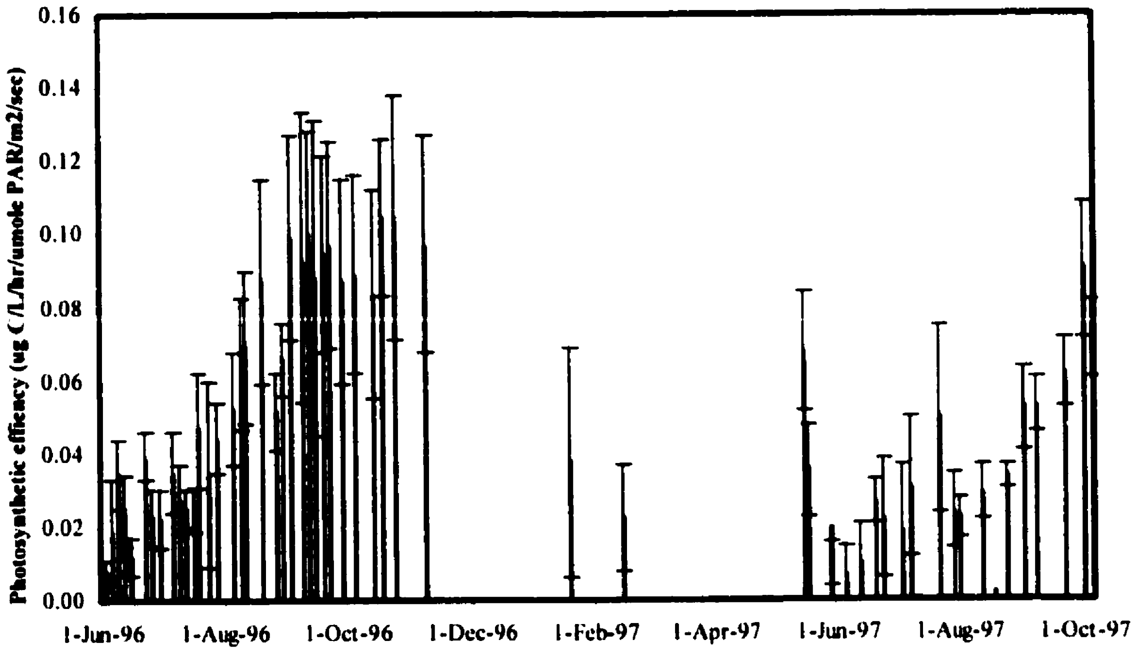


Figure 5.22 - A time series plot comparison of α (photosynthetic efficiency - slope of the light limited productivity) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 1) from June 1996 to October 1997.

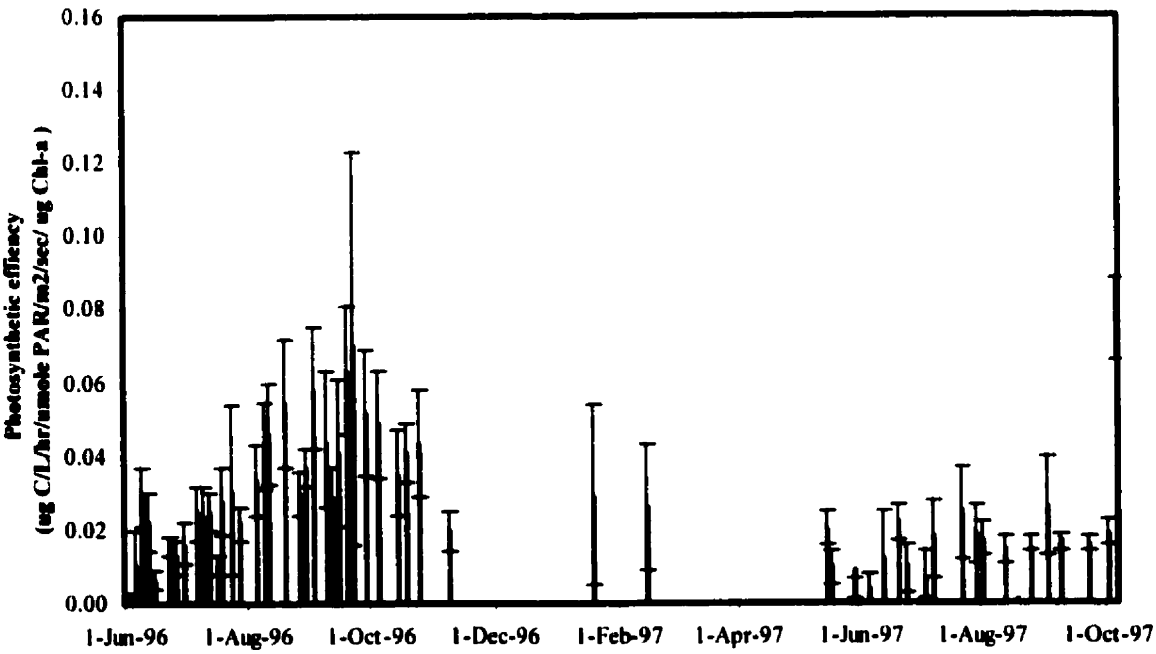


Figure 5.23 - A time series plot comparison of chlorophyll normalized α (photosynthetic efficiency - slope of the light limited productivity) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 1) from June 1996 to October 1997.

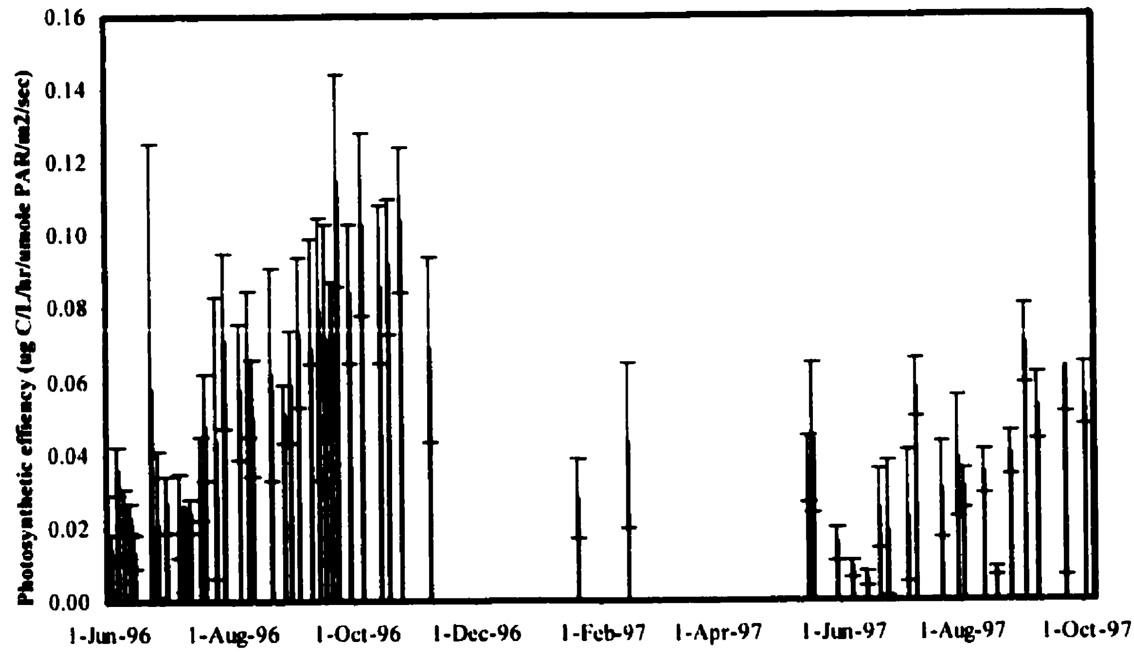


Figure 5.24 - A time series plot comparison of α (photosynthetic efficiency - slope of the light limited productivity) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 2) from June 1996 to October 1997.

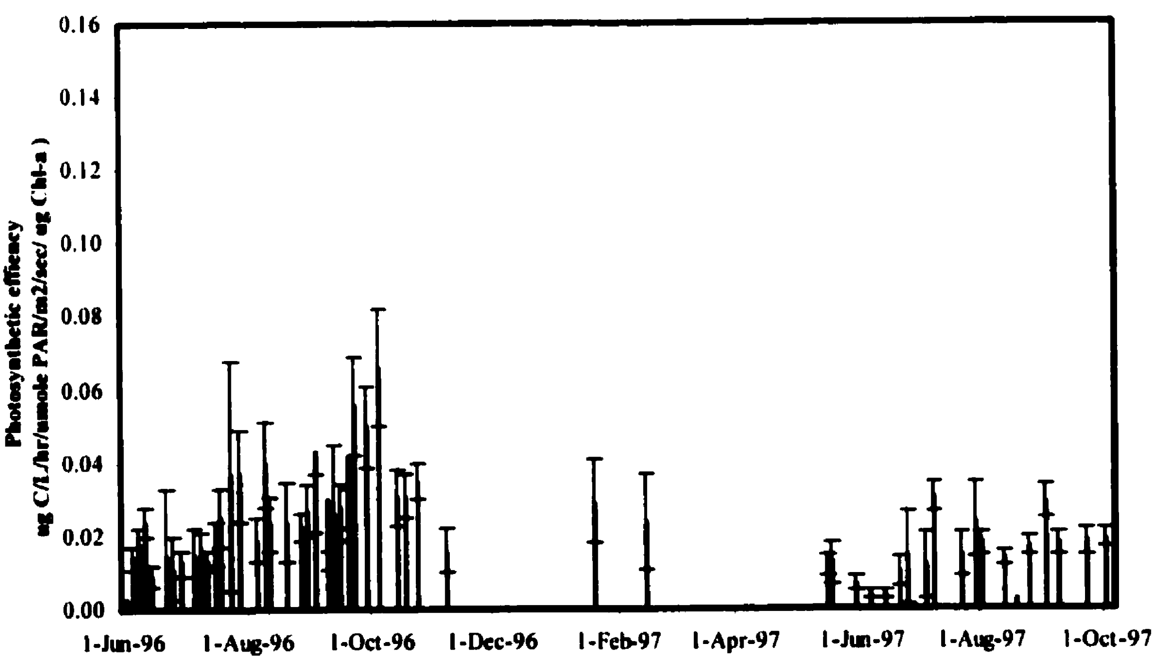


Figure 5.25 - A time series plot comparison of chlorophyll normalized α (photosynthetic efficiency - slope of the light limited productivity) error bars indicate the lower and upper 95% confidence intervals for Clear Lake, Manitoba (Station 2) from June 1996 to October 1997.

5.2.4 Dissolved Inorganic Carbon, Alkalinity, and pH

Mean dissolved inorganic carbon (DIC) was 48 mg C/L with a minimum value of 44 mg C/L and maximum value of 56 mg C/L. The winter of 1996 displayed the highest DIC (54 mg C/L), whereas the lowest DIC results (46 mg C/L) were in the spring of 1996. DIC levels were generally lower in 1996 than in 1997. In 1996, levels gradually increased until August followed by a slight decrease in September. A major peak in DIC occurred in January 1997. From this peak, a gradual decrease was seen till June 1997. In 1997, levels gradually increased until July followed by a slight decrease in September. The last few samples of the study showed a gradual increase. Figure 5.27 illustrates these trends.

Total Alkalinity displayed a trend similar to DIC, which is to be expected since the latter as derived from the former. Mean total alkalinity was determined to be 201.74 $CaCO_3$ mg /L with a minimum of 182.60 $CaCO_3$ mg/L and maximum of 222.60 $CaCO_3$ mg/L. The winter of 1996 displayed the highest total alkalinity (216.825 $CaCO_3$ mg/L), while the lowest (192.150 $CaCO_3$ mg/L) being in the spring of 1996. Total alkalinity levels were generally lower in 1996 as compared with 1997. In 1996, levels gradually increased until August followed by a slight decrease in September. A major peak in DIC occurred in January 1997. From this peak, a gradual decrease was seen till June 1997. In 1997, levels gradually increased until July followed by a slight decrease September. The last few samples of the study showed a gradual increase. Figure 5.28 illustrates these trends. Manitoba Surface Water Quality Objectives suggest the normal alkalinity range for domestic consumption is 30 mg/L - 500 mg/L based on aesthetic consideration (Williamson, 1988).

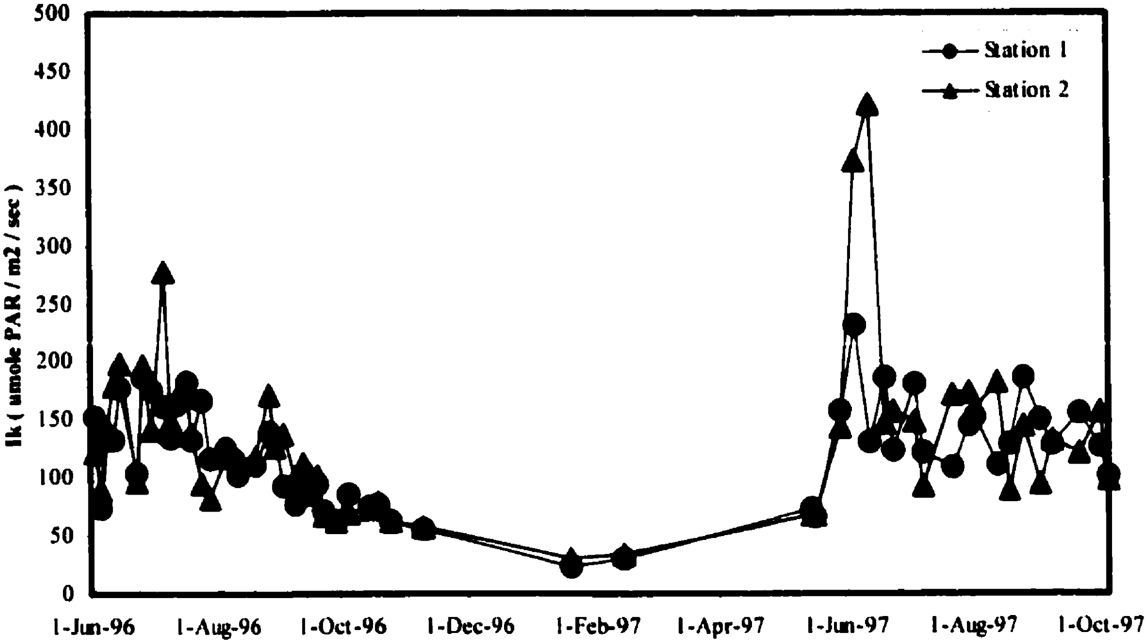


Figure 5.26 - A time series plot comparison of I_k (the light intensity at which P_{max} is achieved) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

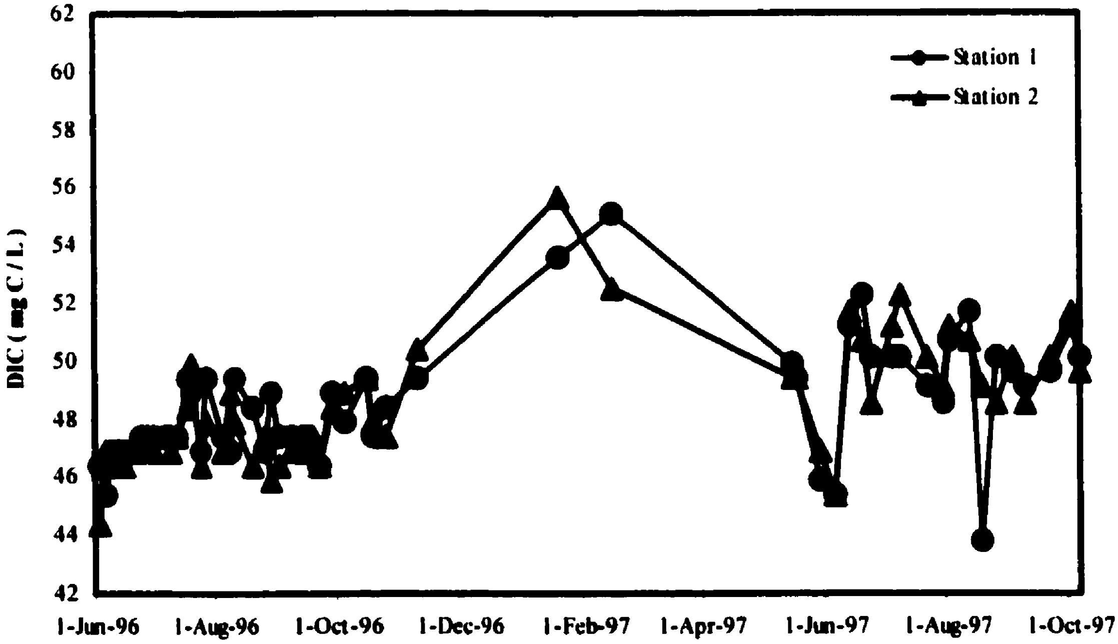


Figure 5.27 - A time series plot comparison of dissolved inorganic carbon (DIC) at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

Mean pH was 8.37 with a minimum of 7.35 and maximum of 8.50. The spring of 1997 displayed the highest pH (8.467), while the lowest pH (8.088) being in the spring of 1996. pH levels were similar in 1996 and 1997 with very slight variations. Winter showed a slight decrease. Figure 5.29 illustrates these trends. Manitoba Surface Water Quality Objectives suggest the normal pH range for aquatic life is 6.5 - 9.0 and recreation is 6.5 - 8.5 (Williamson, 1988). Clear Lake falls well within these ranges. If the pH level were to go above 8.5, less success might be seen with chlorination for disinfection of drinking water.

5.2.5 Nitrogen Debt

The mean nitrogen debt was determined to be 0.27 μM N/ug Chl-a/24 hours with a minimum of 0.00 μM N/ug Chl-a/24 hours and maximum of 1.52 μM N/ug Chl-a/24 hours. The fall of 1997 displayed the highest nitrogen debt (0.502 μM N/ug Chl-a/24 hours), while the lowest (0.081 μM N/ug Chl-a/24 hours) being in the spring of 1996. No trend was seen over the study. The values obtained in 1997 were higher than in 1996. Figure 5.30 illustrates these data. A number greater than 0.15 μM N/ug Chl-a/24 hours suggests severe nitrogen deficiency.

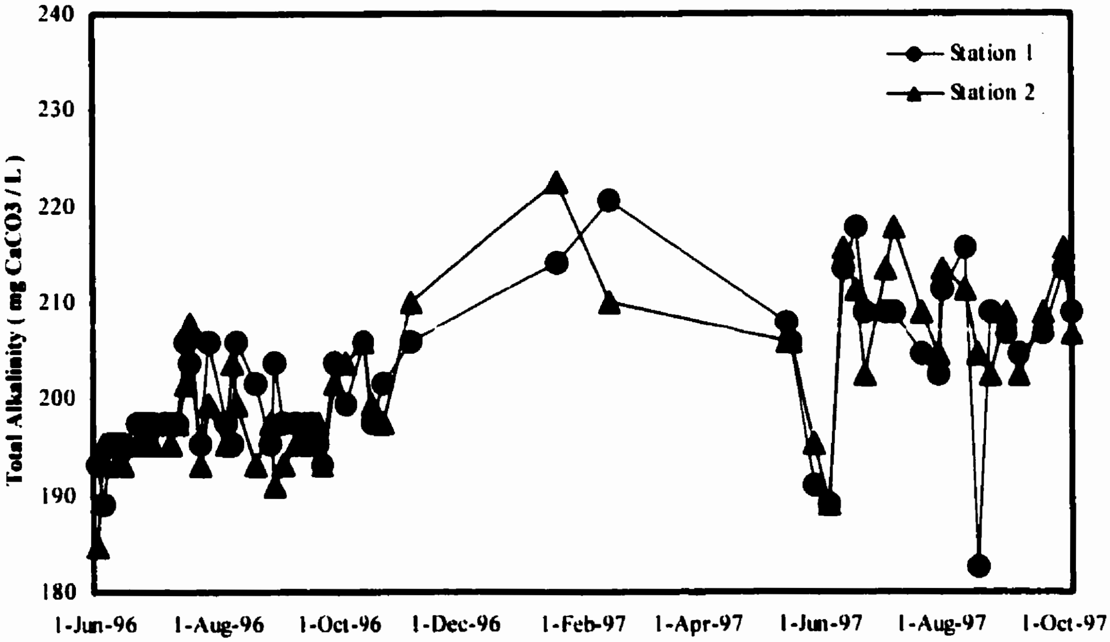


Figure 5.28 - A time series plot comparison of total alkalinity at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

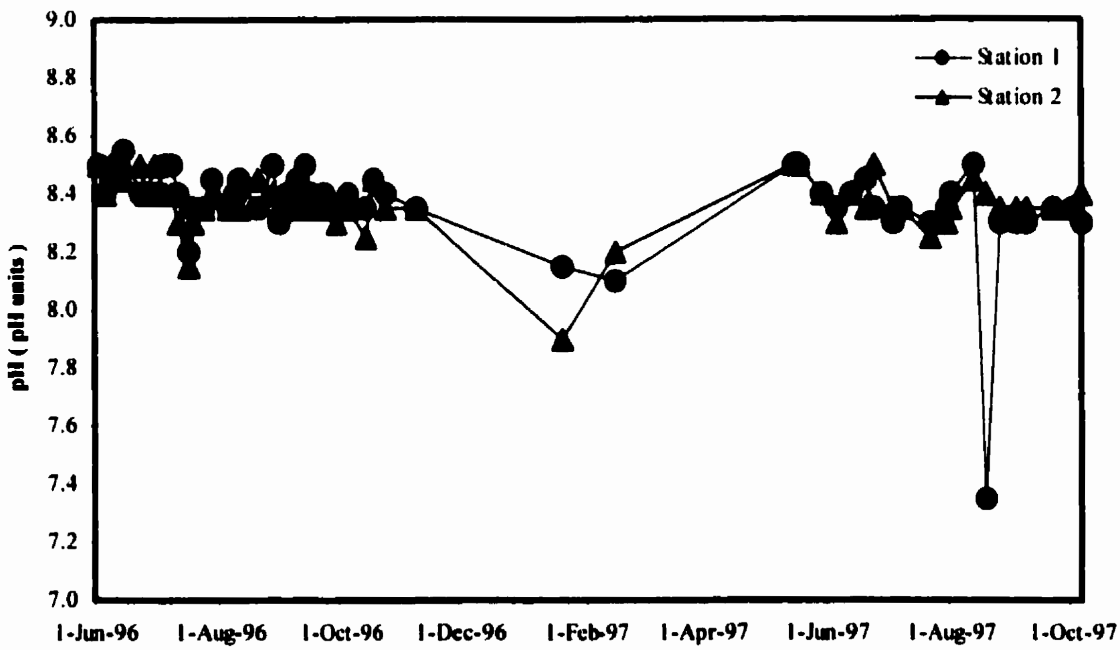


Figure 5.29 - A time series plot comparison of pH at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

Table 5.5 - Summary of the occurrence of nitrogen debt levels which exceeded the indicator level of severe nitrogen deficiency (0.15 µM N/ug Chl-a/24 hours).

	Nitrogen Debt
number of exceeded samples	55
total number of samples	107
percent exceeded	51%
nitrogen debt limit	0.15 µM N/ug Chl-a/24 hours
mean exceeded value	0.48 µM N/ug Chl-a/24 hours
minimum exceeded value	0.17 µM N/ug Chl-a/24 hours
maximum exceeded value	1.52 µM N/ug Chl-a/24 hours

Clear Lake experienced Nitrogen debt 51% of the time (Table 5.5). In most natural freshwaters the underlying limiting nutrient is phosphorous (Schindler, 1971).

5.2.6 Phosphorous Debt

The mean phosphorous debt was 0.26 µM P/ug Chl-a/24 hours with a minimum of 0.00 µM P/ug Chl-a/24 hours and maximum of 1.63 µM P/ug Chl-a/24 hours. The winter of 1996 displayed the highest phosphorous debt (0.579 µM P/ug Chl-a/24 hours), while the lowest (0.128 µM P/ug Chl-a/24 hours) was in the fall of 1996. No overall trend was seen over the study. The values obtained in 1997 were higher than in 1996. Figure 5.31 illustrates these data. A number greater than 0.75 µM P/ug Chl-a/24 hours suggests severe phosphorous deficiency.

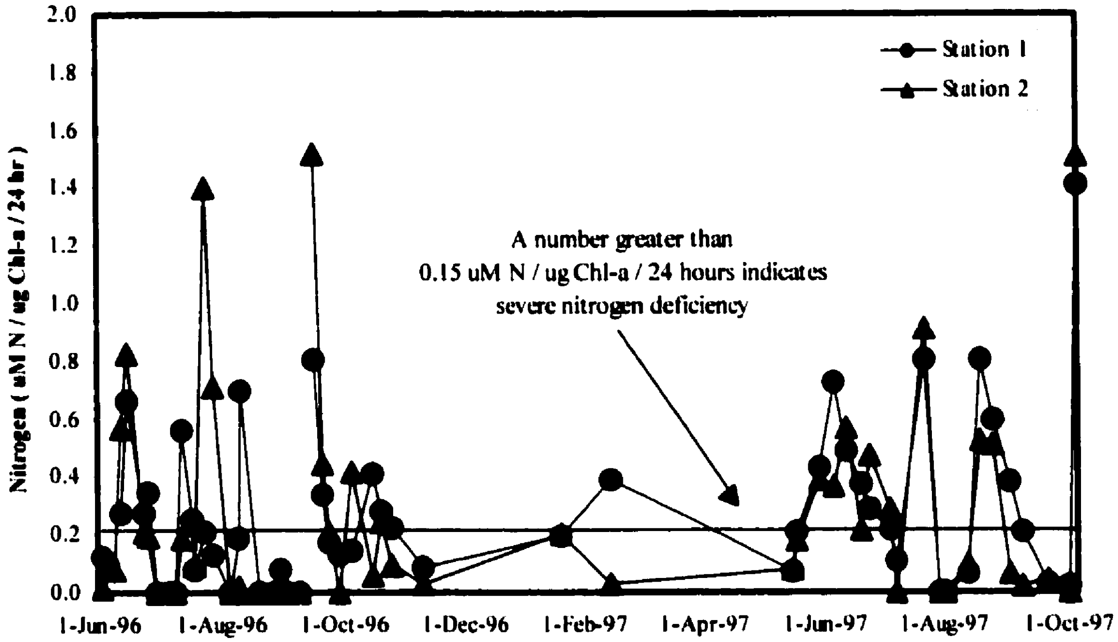


Figure 5.30 - A time series plot comparison of nitrogen debt assay at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

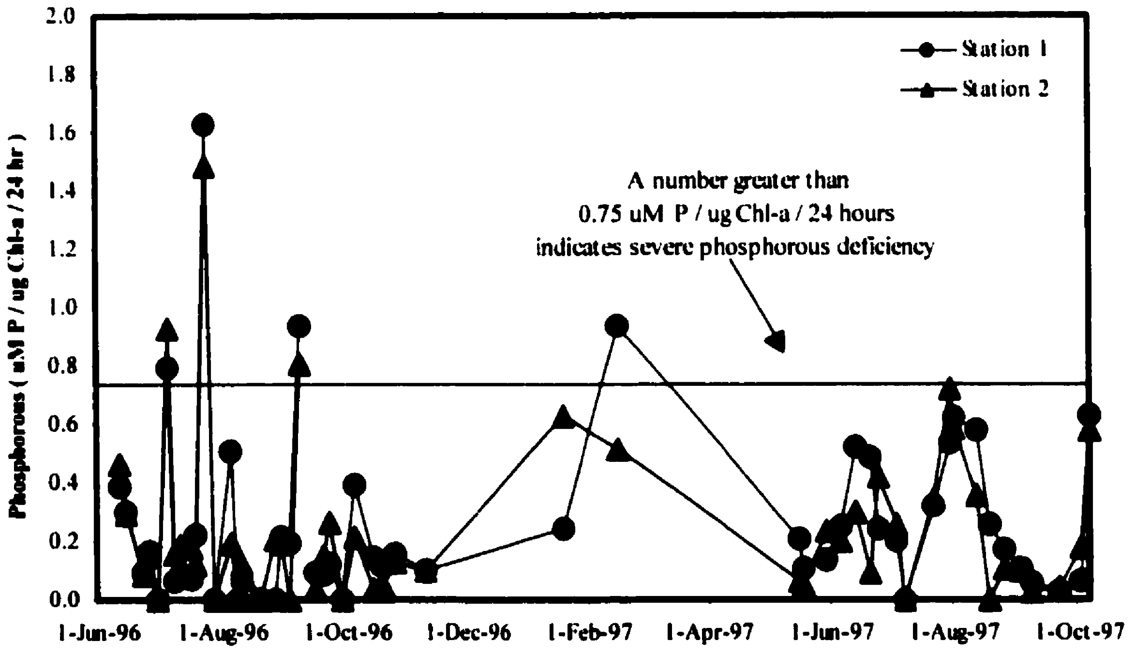


Figure 5.31 - A time series plot comparison of phosphorous debt assay at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

Table 5.6 - Summary of the occurrence of phosphorous debt levels which exceeded the indicator level of severe phosphorous deficiency (0.75 μM P/ug Chl-a/24 hours).

	Phosphorous Debt
number of exceeded samples	5
total number of samples	101
percent exceeded	5%
phosphorous debt limit	0.75 μM P/ug Chl-a/24 hours
mean exceeded value	1.15 μM P/ug Chl-a/24 hours
minimum exceeded value	0.79 μM P/ug Chl-a/24 hours
maximum exceeded value	1.63 μM P/ug Chl-a/24 hours

Clear Lake experienced Phosphorous debt 5% of the time (Table 5.6).

5.2.7 Alkaline Phosphatase

Alkaline phosphatase activity is considered a more sensitive method of determining phosphorous deficiency (Healey and Hendzel, 1979b). The mean alkaline phosphatase activity was 0.009 μM P/ug Chl-a/24 hours with a minimum of 0.001 μM P/ug Chl-a/24 hours and maximum of 0.020 μM P/ug Chl-a/24 hours. The winter of 1996 displayed the highest alkaline phosphatase activity (0.015 μM P/ug Chl-a/24 hours), while the lowest (0.004 μM P/ug Chl-a/24 hours) was in the fall of 1996. No trend was seen over the study. The values obtained in 1996 were higher than for 1997. Figure 5.32 illustrates these data. A number greater than 0.005 μM P/ug Chl-a/24 hours suggests severe phosphorous deficiency (Perry,1972 and Healey and Hendzel, 1980).

Table 5.7 - Summary of the occurrence of alkaline phosphatase activity which exceeded the indicator level of severe phosphorous deficiency (0.005 μM P/ug Chl-a/24 hours).

	Alkaline Phosphatase Activity
number of exceeded samples	70
total number of samples	82
percent exceeded	85%
alkaline phosphatase assay limit	0.005 μM P/ug Chl-a/24 hours
mean exceeded value	0.095 μM P/ug Chl-a/24 hours
minimum exceeded value	0.045 μM P/ug Chl-a/24 hours
maximum exceeded value	0.204 μM P/ug Chl-a/24 hours

Clear Lake experienced Phosphorous debt 85% of the time (Table 5.7).

5.3 Water Chemistry

The water chemistry data are presented in Appendix: Table A.5.2 and Table A.5.4.

5.3.1 Nitrogen

Three measurements of nitrogen were made: Total Kjeldahl Nitrogen (TKN), Particulate Nitrogen, and Nitrate-Nitrite (NO_4-NO_3) - Nitrogen. Detection limits for Total Kjeldahl Nitrogen (TKN) and Nitrate-Nitrite (NO_4-NO_3) - Nitrogen were 0.05 mg/L and 0.05 mg/L respectively. Table 5.8 summarizes the nitrogen data.

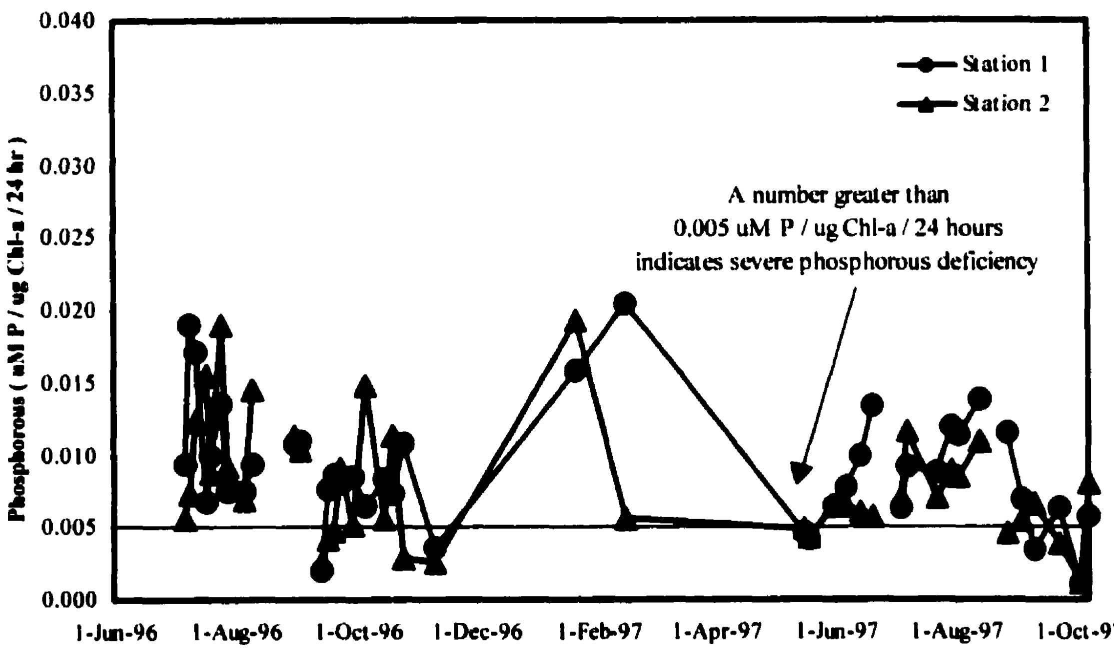


Figure 5.32 - A time series plot comparison of alkaline phosphatase assay at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

Table 5.8 - Summary of nitrogen determinations made in Clear Lake, Manitoba at Station 2 during 1996 and 1997.

	TKN mg/L	Nitrate-Nitrite mg/L	Particulate Nitrogen mg/L
mean	0.484	0.264	0.220
minimum	0.200	0.050	non detectible
maximum	1.250	3.580	1.200
high value season	summer 1997	spring 1997	summer 1997
high value	0.765	0.870	0.715
low value season	fall 1996	winter 1996	spring 1997
low value	0.345	0.050	0.000

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia. TKN can provide some indication of the biological production. There is no Manitoba Surface Water Quality Objective. Values in 1997 were higher than 1996.

Nitrate- Nitrite - N sources include ingredients in nitrogen fertilizers, decomposition of plant matter and animal wastes, and leachate from igneous rocks. The Manitoba Surface Water Quality Objective states that values should not exceed 10 mg/L for domestic consumption (Williamson, 1988). Elevated levels suggest poor sewage treatment. Blue Baby Syndrome or Methemoglobinema in infants can occur, and prolonged exposure can be fatal. Clear Lake levels were well below this objective.

5.3.2 Phosphorous

Three measures of phosphorous were made: Total Phosphorous, Dissolved Phosphorous, and Particulate Phosphorous. Detection limits for Total Phosphorous and Dissolved Phosphorous were 0.005 mg/L and 0.005 mg/L respectively. Table 5.9 summarizes the phosphorous data.

Table 5.9 - Summary of phosphorous determinations made in Clear Lake, Manitoba at Station 2 during 1996 and 1997.

	Total Phosphorous mg/L	Dissolved Phosphorous mg/L	Particulate Phosphorous mg/L
mean	0.054	0.026	0.028
minimum	0.005	0.005	non detectible
maximum	0.244	0.060	0.239
high value season	fall 1996	summer 1997	fall 1996
high value	0.243	0.060	0.233
low value season	spring 1997	summer 1997	spring 1997
low value	0.005	0.005	0.000

Sources of phosphorous include weathering of soil and rocks, decomposition of organic material, sewage, and cultivated/fertilized land runoff. Manitoba Surface Water Quality Objective states that total phosphorous level in lakes should not exceed 0.025 mg/L so excessive algal, fungal, and macrophyte growth do not occur (Williamson, 1988). No human health effects are seen with elevated levels.

Table 5.10 - Summary of total phosphorous in Clear Lake, Manitoba (1996 and 1997) and the exceedence of the Manitoba Surface Water Quality Objective.

	Total Phosphorous
number of exceeded samples	21
total number of samples	26
percent exceeded	81%
phosphorous limit	0.025 mg / L
mean exceeded value	0.069 mg / L
minimum exceeded value	0.030 mg / L
maximum exceeded value	0.244 mg / L

Although it would appear as if Clear Lake exceeds the Manitoba Surface Water Quality Object 81% of the time (Table 5.10), the incidence of phosphorous deficiency would indicate that phosphorous levels are not, in fact, high. Nitrogen debt suggests that nitrogen limitation does occur, alkaline phosphatase indicates a greater incidence of phosphorous deficiency. Certainly all of the 'total phosphorous' was not available for assimilation and indeed very little of the 'dissolved' fraction was immediately available.

Dissolved Phosphorous is the portion of phosphorous evident in the water after the water was filtered by a 0.45 micron filter. There is no Manitoba Surface Water Quality Objective.

5.3.3 Organic Carbon

Three measures of organic carbon were made: Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), and Particulate Organic Carbon (POC). Detection limits for Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC) were 0.5 mg/L and 0.5 mg/L respectively. Table 5.11 summarizes the organic carbon data.

Table 5.11 - Summary of organic carbon determinations made in Clear Lake, Manitoba at Station 2 during 1996 and 1997.

	TOC mg/L	DOC mg/L	POC mg/L
mean	5.327	5.060	0.266
minimum	4.100	2.900	non detectible
maximum	6.300	6.200	2.200
high value season	summer 1997	summer 1996	winter 1996
high value	5.700	5.498	0.700
low value season	fall 1996	fall 1996	spring 1996
low value	4.150	4.000	0.100

Total Organic Carbon is an indicator of the organic content in the water. Sources include photosynthesis, decaying plants and animal tissue, domestic sewage, industrial effluent, agricultural runoff. Anaerobic conditions can occur when total organic carbon is high because oxygen can be depleted when decomposition occurs. Trihalomethanes (THMs) can be formed during chlorine disinfection when high dissolved organic carbon is observed. The Surface Water Quality Initiative (SWQI) states that dissolved organic carbon values should not exceed 5 mg/L (PFRA, 1997). Ingestion of high levels of THMs over a time can increase the risk of acquiring cancer. The Guidelines for Canadian Drinking Water Quality suggest that THM levels below 100 μg /L reduce the carcinogenic risks (CCREM, 1987).

Table 5.12 -Summary of dissolved organic carbon in Clear Lake, Manitoba (1996 and 1997) and the exceedence of the Manitoba Surface Water Quality Objective.

	Dissolved Organic Carbon
number of exceeded samples	16
total number of samples	26
percent exceeded	62%
DOC limit	5 mg / L
mean exceeded value	5.463 mg / L
minimum exceeded value	5.000 mg / L
maximum exceeded value	6.200 mg / L

Clear Lake exceeds the Manitoba Surface Water Quality Object 62% of the time (Table 5.12).

5.3.4 Silica

Silica was measured because silica is an essential for Bacillariophyceae and Chrysophyceae. Detection limits for Silica were 0.02 mg/L. Table 5.13 summarizes the silica data.

Table 5.13 - Summary of silica determinations made in Clear Lake, Manitoba at Station 2 during 1996 and 1997.

	Silica mg/L
mean	7.118
minium	5.680
maximum	8.000
high value season	fall 1996
high value	7.605
low value season	spring 1996
low value	6.815

Kilham (1981) suggests an important ratio to examine is the Si / P atomic ratio. For diatoms to successfully outcompete blue-greens, silica levels have to be in proportion to available phosphorous (Cole, 1983). Schelske (1975) suggests a Si / P ratio of 100 is sufficient to support diatom dominance. The mean Si / P atomic ratio was determined to be 1443 (with a minimum of 32 and maximum of 7250) is well in excess of 100 and supporting diatom dominance in Clear Lake as indicated by total particulate biovolume.

5.3.5 Elemental Ratios

Determination of particulate carbon, nitrogen, and phosphorous allows for comparisons between atom : atom or atom : weight (dry weigh or chlorophyll-a) ratios (Healey and Hendzel, 1980). In Hecky *et al.* (1993), Goldman described nutrient sufficiency by C : P ratios ranging from 75 : 1 to 150 : 1 and N : P ratios ranging from 10 : 1 to 20 : 1. Changes in nutrient deficiency / sufficiency should therefore be seen in ratio variations. Table 5.14 summarizes the particulate compositional ratios calculated.

Table 5.14 - Particulate compositional ratios as indicators of determine nutrient deficiency / sufficiency in Clear Lake, Manitoba in 1996 and 1997 (μmole:μmole for particulate values and μmole:μg /L). 'ND' indicates no data were available.

Date	Station	N/P	C/P	C/N	C/Chl-a
03-Jun-96	st1	151	43	0.28	2
03-Jun-96	st2	166	ND	ND	ND
06-Jun-96	st1	ND	ND	0.54	11
06-Jun-96	st2	ND	ND	0.30	3
23-Jun-96	st1	ND	ND	ND	ND
23-Jun-96	st2	258	ND	ND	ND
09-Jul-96	st1	27	22	0.83	15
09-Jul-96	st2	9	23	2.50	33
24-Jul-96	st1	42	ND	ND	ND
24-Jul-96	st2	54	ND	ND	ND
11-Aug-96	st1	234	ND	ND	ND
11-Aug-96	st2	361	ND	ND	ND
03-Sep-96	st1	32	61	1.93	19
03-Sep-96	st2	227	284	1.25	21
16-Sep-96	st1	476	ND	ND	ND
16-Sep-96	st2	376	86	0.20	3
05-Oct-96	st1	2	2	1.37	9
05-Oct-96	st2	3	1	ND	5
20-Jan-97	st1	509	258	0.51	13
20-Jan-97	st2	208	52	0.25	9
15-Feb-97	st1	796	5673	7.12	207
15-Feb-97	st2	54	48	0.90	14
16-May-97	st1	ND	ND	ND	5
24-Jun-97	st1	66	71	1.07	39
24-Jun-97	st2	51	52	1.01	12
mean		164	267	0.82	17
min		2	1	0.25	2
max		796	5673	7.12	207

These particulate compositional ratios (Table 5.14) were compared with those in Chapter Three (Table 3.2) to detect nutrient deficiency (Table 5.15).

Table 5.15 - A summary of the incidence of severe phosphorous deficiency and severe nitrogen deficiency as indicated by particulate compositional ratios Clear Lake, Manitoba (1996 and 1997).

	N/P	C/P	C/N	C/Chl-a
number of exceeded samples	18	2	0	11
total number of samples	25	25	25	25
percent exceeded	72 %	8%	0%	44%
severe deficiency limit	22	258	14.6	8.3
nutrient	phosphorous	phosphorous	nitrogen	carbon
mean exceeded value	226.96	2973.38		35.44
minimum exceeded value	26.91	283.66		8.65
maximum exceeded value	795.80	5673.11		206.83

It should be emphasized that the above compositional ratios and interpretations are based on seston data, which raises two reasons for concern: The first is the influence of allochthonous detritus, and the second is the effects of secondary production because of the relatively fixed stoichiometry of zooplankton (Hecky *et al.*, 1993).

5.4 Whole Lake Productivity Modelling

Estimation of *in situ* productivity from phytoplankton in Clear Lake was determined from photosynthesis parameters (α, Pmax, and 'beta' (β)) derived from *in vitro* experiments (incubator), euphotic depth, the extinction of PAR within the lake, area of each 1 m isobath, and hourly integrations of PAR falling on the lake surface (data from the University of Manitoba Field Station (Delta Marsh)). Once these parameters were available, a whole lake Productivity Model was developed for the extent of the study. In fact, three models were developed to test the robustness of the data set and the variability of the photosynthetic parameters. These models were based on hourly integrated light, total daily light smoothed and corrected for ice and snow, photosynthetic parameters, and the use of one productivity equation. Compiled data are presented in the Appendix section: Table A.5.2 (Station 1) and Table A.5.4 (Station 2).

5.4.1 Productivity Model 1

Productivity Model 1 was developed using hourly integrations of light (University of Manitoba Field Station (Delta Marsh)). Once the model was completed, hourly productivity data were smoothed using a smoothing function to account for cloudy or cloudless days. This smoothing function was to minimize differences between cloudy and cloudless days by interpolating a smooth function between the range of measured incident radiation values. A smooth line traces through the 'center' of the data, which is between high cloudless-day irradiance and low cloudy-day irradiance. The smooth function was derived using Data Desk (version 6).Yearly and seasonal differences were found. The mean daily productivity for the entire period sampled was 31.0 Kg C /lake/day (1.1E-06 Kg C / m^2/day) with a minimum of 0.9 Kg C / lake /day (3.1E-08 Kg C / m^2/day) and maximum of 71.1 Kg C / lake /day (2.4E-06 Kg C / m^2/day). When one divides the sampling period into seasons, the summer of 1996 displayed the highest daily productivity (37.4 Kg C / lake /day), while the lowest daily productivity (9.4 Kg C / lake / day) was in the winter of 1996. In late spring 1996 / early summer 1996, the productivity within the lake was low (July 10, 1996) and it continued to increase as the summer progressed. A peak in productivity was seen late August 1996 /

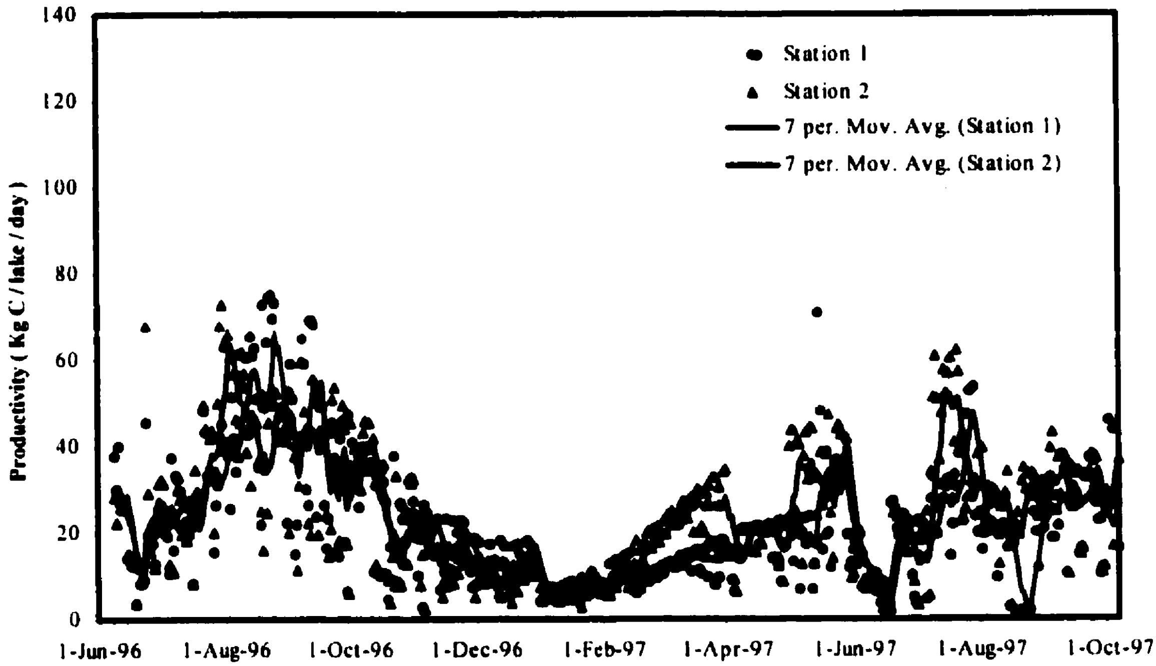


Figure 5.33 - A time series plot comparison of whole lake primary productivity at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 1 (hourly PAR values). Trends are illustrated by a moving average (7 day period).

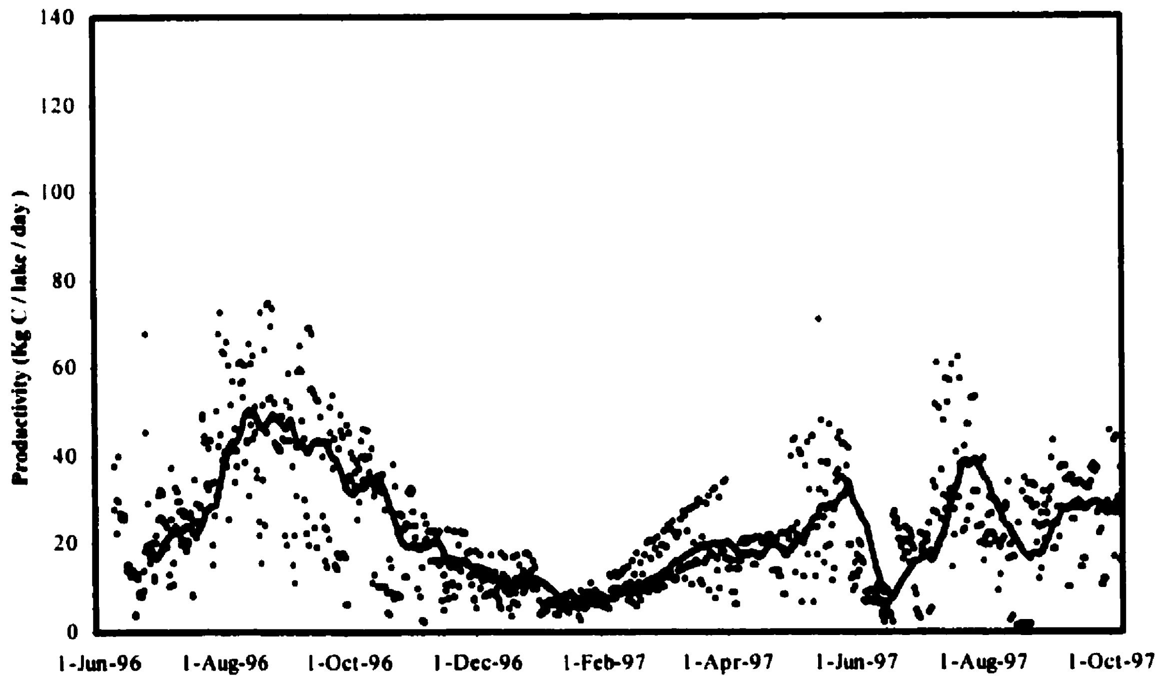


Figure 5.34 - A time series plot of whole lake primary productivity (Station 1 and Station 2 combined) in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 1 (hourly PAR values). Trend is illustrated by a moving average (30 day period).

early September 1996 (August 16, 1996) when conditions were approximately optimal. Once the peak was reached, productivity then decreased through the ice season reaching the lowest point just before ice break up (March 23, 1997). Productivity increased to a spring 1997 peak (May 5, 1997). This was followed by a gradual decrease (July 1, 1997) before an increase producing two consecutive peaks (August 13, 1997 and September 20, 1997). Both stations showed this trend (Figure 5.33). When the data for the two stations were combined, the trend became even more pronounced (Figure 5.34).

The daily results were analyzed in DataDesk (version 6) using a basic scatter plot and adding a 'lowess' smooth (locally weighted regression scatter plot smoothing), which adds a smooth trace to scatter plots. The lowess smooth displays the overall trend of the model (Figure 5.35). Smoothing options included a span value of 10%. Upon further examination of the lowess smooth, 6 distinctive stages or lines were seen. These stages were broken up and slopes were calculated to determine the rate of change in productivity (slope of the line) (Table 5.16 and Figures 5.36 A to 5.36 F).

Table 5.16 - Summary of the characteristics of the six different phases in the Whole Lake Productivity Model 1 for Clear Lake, Manitoba from June 1996 to October 1997. Units for mean, minimum, and maximum was Kg C / lake / day.

Stage	Date	Slope	Mean	Min	Max
1	June 9, 1996 - August 16, 1996	546.38	31.431	3.522	72.675
2	August 17, 1996 - November 9, 1996	-391.77	33.484	2.048	74.918
3	November 11, 1996 - May 9, 1997	63.91	14.314	2.751	43.839
4	May 10, 1997 - June 9, 1997	-766.75	24.747	6.734	71.076
5	June 10, 1997 - July 31, 1997	690.86	24.541	2.179	62.198
6	August 1, 1997 - October 6, 1997	164.69	25.130	0.970	45.943

Table 5.16 displays not only seasonal differences but yearly differences. In 1996 (Stage 1), the productivity was higher (about 5000 g C / lake / day) as compared to productivity values at the comparable time in 1997 (Stage 5). The end point difference between these two stages was a 2 week period, which in 1997 (August 1, 1997) ended two weeks earlier than in 1996.

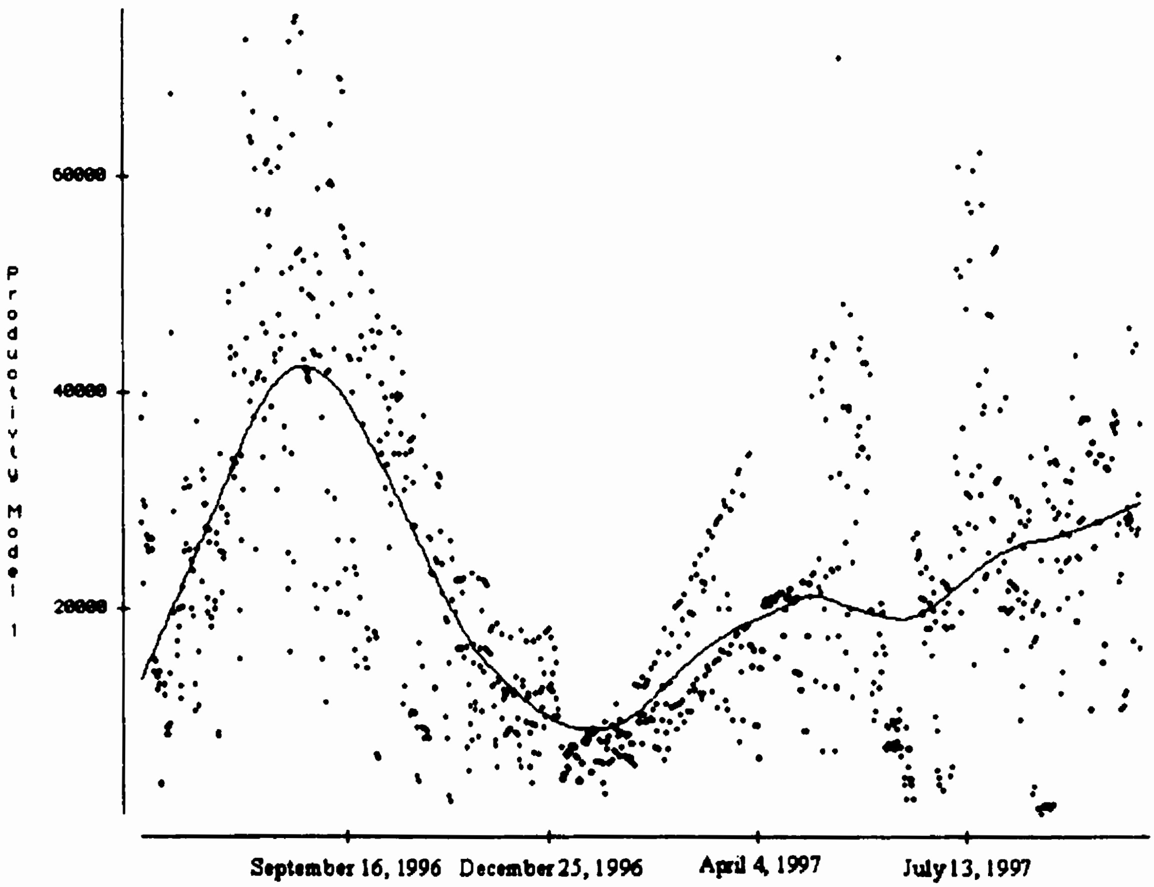


Figure 5.35 - Whole lake primary productivity (Station 1 and Station 2 combined) in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 1 (hourly PAR values). Lowess smooth curve (10%) characterizes trend (g C / lake / day).

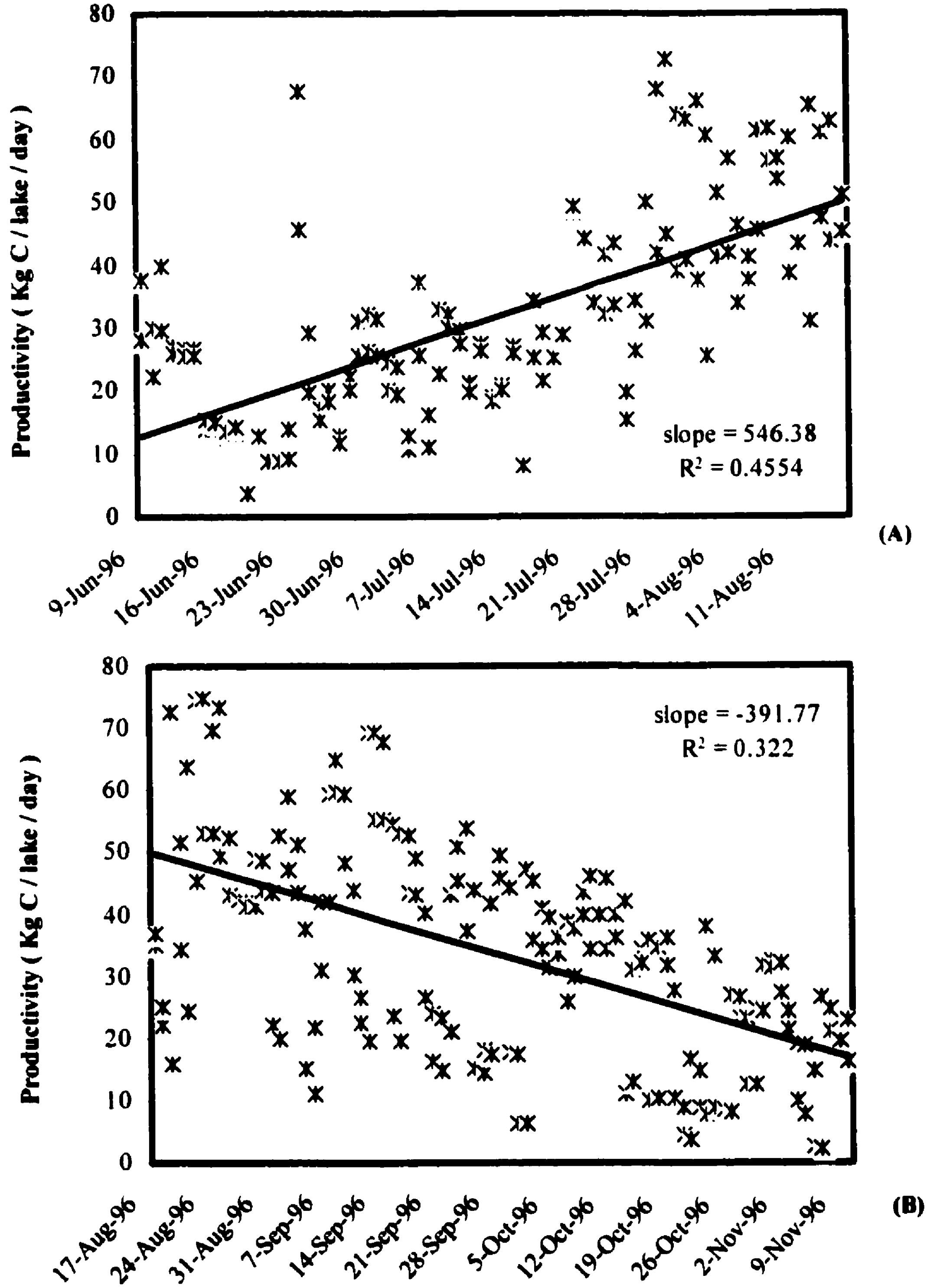
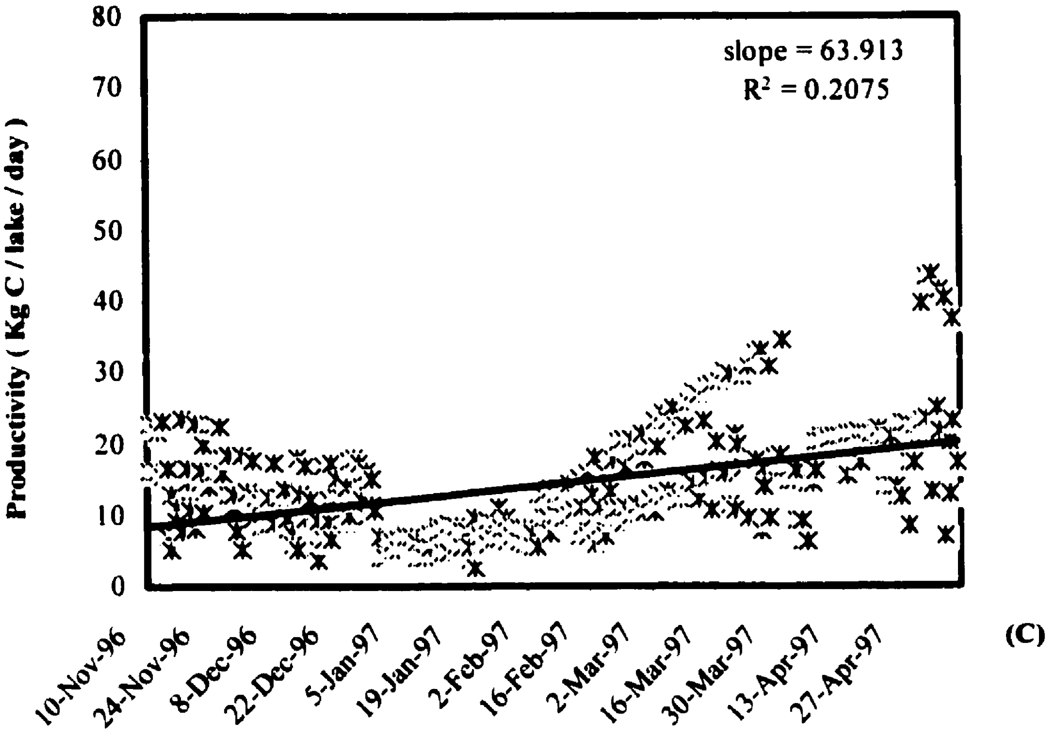


Figure 5.36 - A time series plots of the 6 stages (see Table 5.16) of the whole lake primary productivity (Station 1 and Station 2 combined) derived from Productivity Model 1 (hourly PAR values) in Clear Lake, Manitoba from June 1996 to October 1997. (A) Stage 1 - June 9, 1996 to August 16, 1996, (B) Stage 2 - August 17, 1996 to November 9, 1996 (ice in).



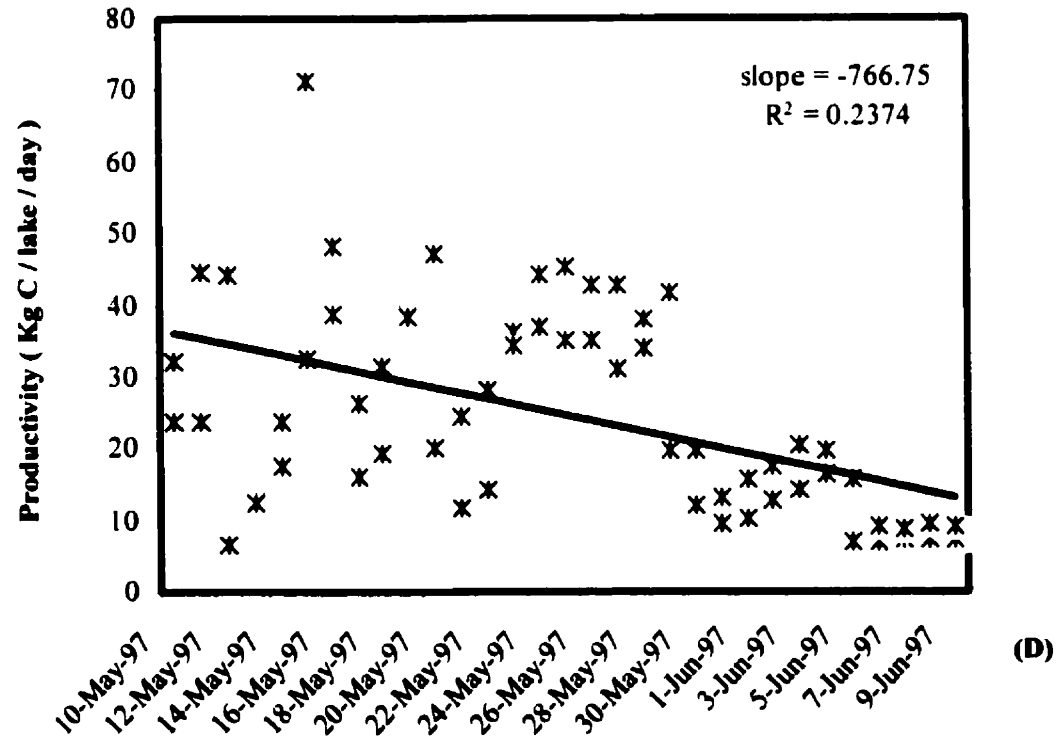
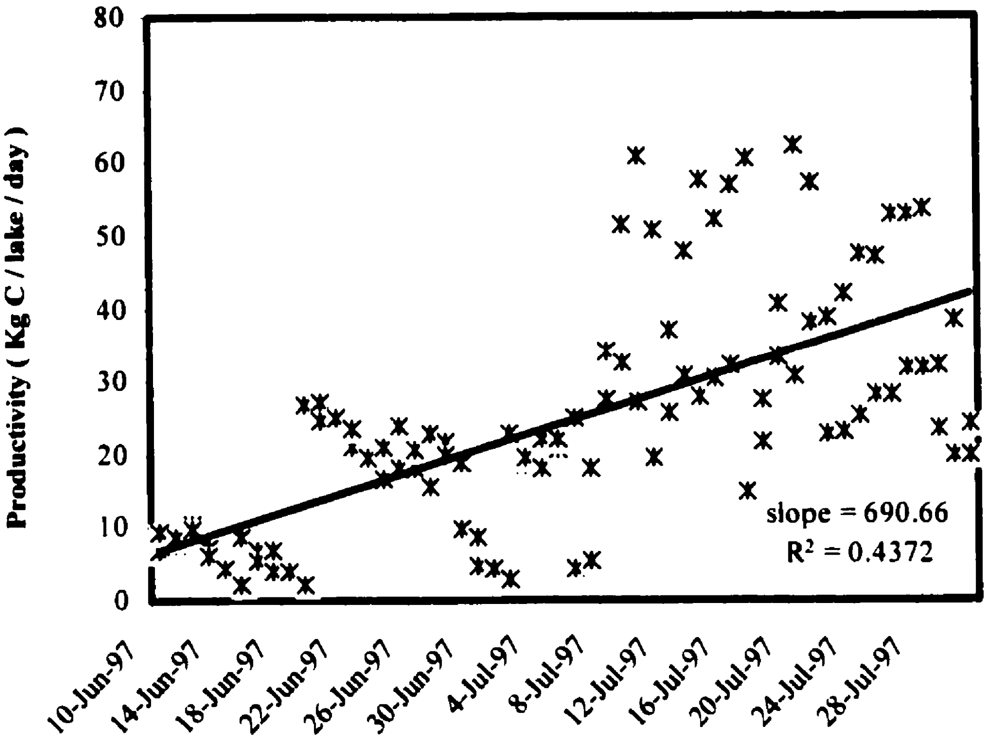
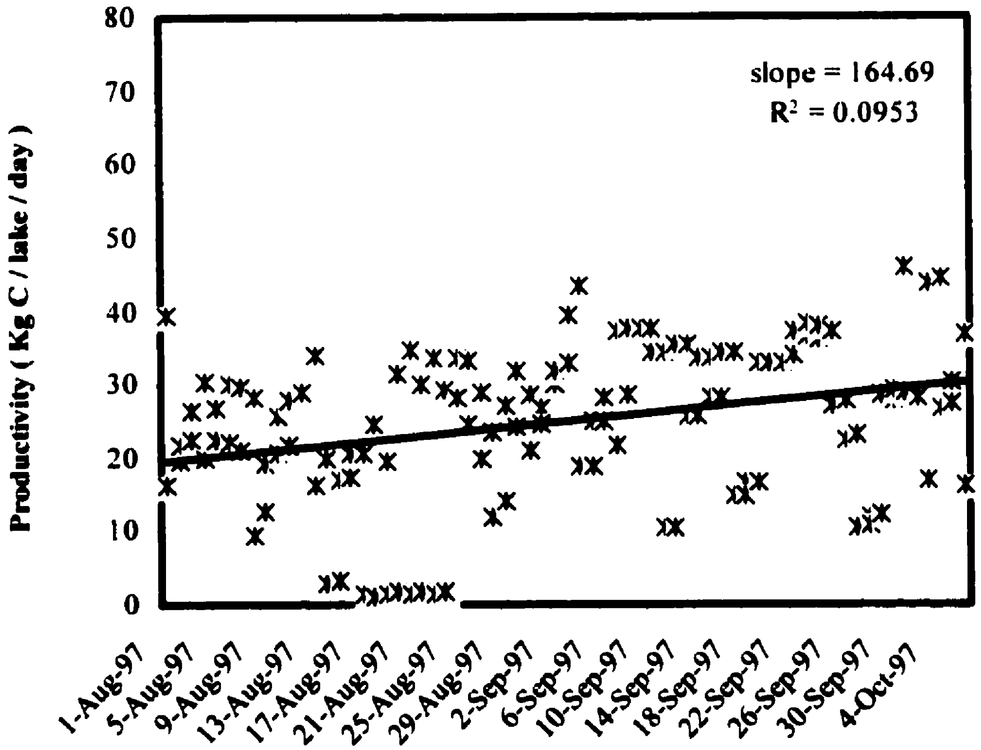


Figure 5.36 - A time series plots of the 6 stages (see Table 5.16) of the whole lake primary productivity (Station 1 and Station 2 combined) derived from Productivity Model 1 (hourly PAR values) in Clear Lake, Manitoba from June 1996 to October 1997. (C) Stage 3 - November 10, 1996 (ice in) to May 9, 1997 (ice out), (D) Stage 4 - May 10, 1997 (ice in) to June 9, 1997.



(E)



(F)

Figure 5.36 - A time series plots of the 6 stages (see Table 5.16) of the whole lake primary productivity (Station 1 and Station 2 combined) derived from Productivity Model 1 (hourly PAR values) in Clear Lake, Manitoba from June 1996 to October 1997. (E) Stage 5 - June 10, 1997 to July 31, 1997, (F) Stage 6 - August 1, 1997 to October 6, 1997.

(August 17, 1996), therefore making the slope steeper in 1997. The other difference between the years was seen in Stage 2 and Stage 6. In 1996, a decrease was seen after August 17, 1996. Whereas in 1997, an increase was seen after August 1, 1997. The mean productivity again was higher in 1996 as compared with 1997. Stage 3 represents the ice season (ice in to ice out). Productivity during this stage was low with very little change during this period. The latter part of the stage involved the spring peak in productivity that was occurring just as the ice started to leave. Therefore, Stage 4 represents the decrease in productivity from the spring bloom . In conclusion, 1996 was more productive as than 1997 and seasonal differences occurred.

5.4.2 Productivity Model 2

A second Productivity Model (Model 2) was developed using total daily light from the University of Manitoba Field Station (Delta Marsh) database. These light data were smoothed and corrected for ice and snow. As in Productivity Model 1, yearly and seasonal differences were found. The mean daily productivity was determined to be 61.8 Kg C /lake /day (2.1E-06 Kg C / m^2 /day) with a minimum of 1.2 Kg C /lake /day (4.1E-08 Kg C / m^2 /day) and maximum of 126.9 Kg C /lake /day (4.1E-07 Kg C / m^2 /day). The summer of 1996 displayed the highest mean daily productivity (73.6 Kg C / lake /day), while the lowest of (5.3 Kg C / lake /day) was in the winter of 1996. The overall trend was similar to that produced by Model 1 and Station 1 and Station 2 both showed the same trend (Figure 5.37). Once again, when the data for the two stations were combined, the trend became more defined (Figure 5.38). Two main differences existed between the 2 models. As the daily PAR

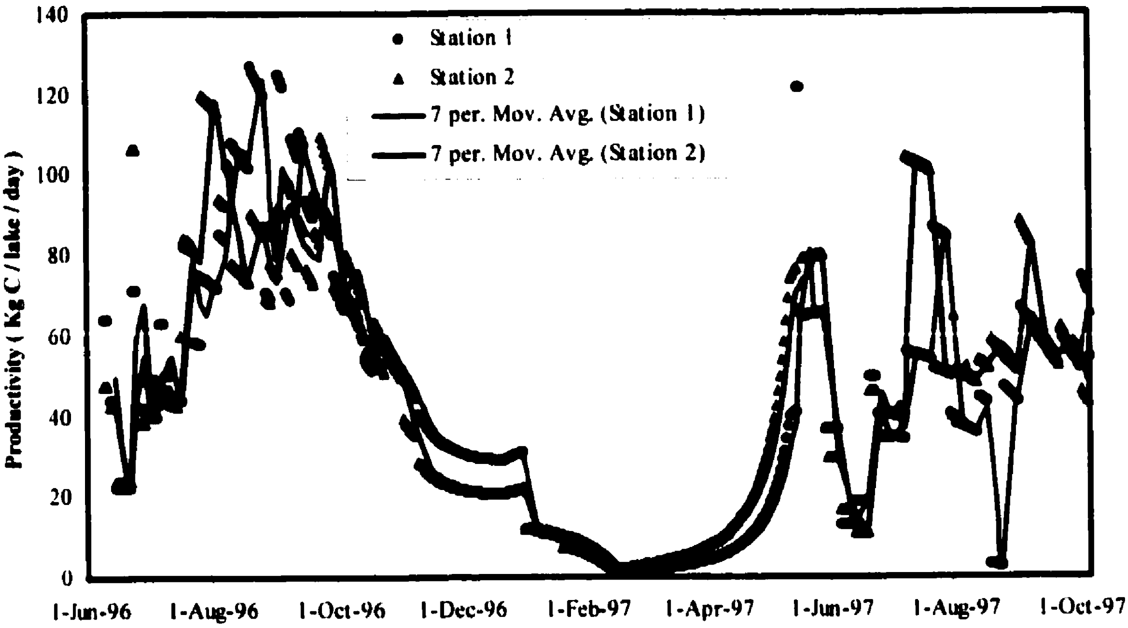


Figure 5.37- A time series plot comparison of whole lake primary productivity at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 2 (total daily PAR values from Delta Field Marsh that were smoothed and corrected). Trends are illustrated by a moving average (7 day period).

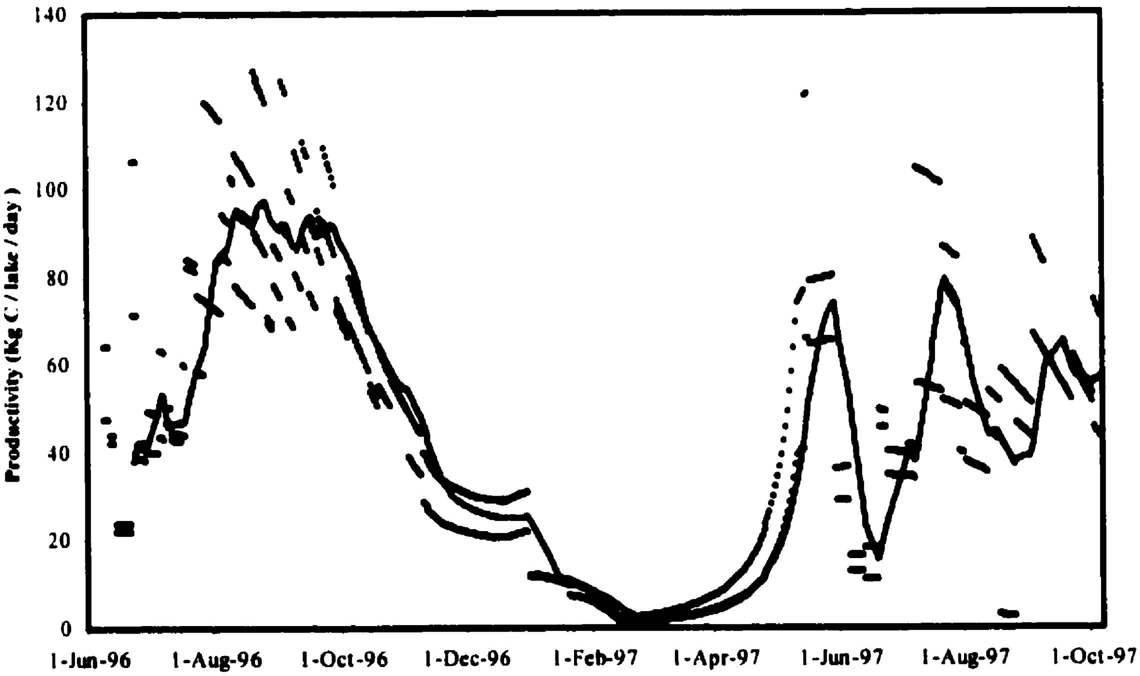


Figure 5.38 - A time series plot of whole lake primary productivity (Station 1 and Station 2 combined) in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 2 (total daily PAR values from Delta Field Marsh that were smoothed and corrected). Trend is illustrated by a moving average (7 day period).

was smoothed and corrected for ice and snow, the noise between days was decreased, producing a smoother curve. During the ice season, the curve resembled the curve produced by the light data corrected for ice and snow (Figures 4.9 and 4.10). The second difference was that the modelled productivity values were increased on average by a factor of 2.108 with a minimum factor of 0.098 and a maximum factor of 6.549. It is suggested that this type of whole lake modelling may be easier to compile (both collection of productivity parameters and calculations) but it overestimates the productivity occurring within the lake.

5.4.3 Productivity Model 3

A third Productivity Model was developed using all the photosynthesis parameters (α, P_{max}, and β) derived from all vitro experiments (incubator) to develop one equation with light data smoothed and corrected for ice and snow. This was done using P_{max} and chlorophyll-a normalized P_{max} (SP_{max}), with the latter method utilizing an overall mean chlorophyll-a value.

5.4.3.1 Productivity Model 3 using P_{max}

P_{max} was 10.564 µgC/L/hour with a minimum (95% confidence level) of 0.259 µgC/L/hour and maximum (95% confidence level) of 11.616 µgC/L/hour. Standard error (ASE) was 7.569 µgC /L /hour. Table 5.17 illustrates the photosynthesis / irradiance parameters derived from all *in vitro* experiments combine using for the calculation of Model 3.

Table 5.17 - Summary of photosynthesis / irradiance parameters derived from all *in vitro* experiments using for the calculation of Model 3 using P_{max} in Clear Lake, Manitoba at Station 2 during 1996 and 1997. (P_{max} µgC/L/hour, α µgC/L/hour/µmole PAR/m^2/sec, and β µgC/L/hour/µmole PAR/m^2/sec).

		Standard Error (ASE)	Lower 95% Confidence Level	Upper 95% Confidence Level
P_{max}	10.564	7.569	-4.332	25.460
α	0.988	1.384	-1.736	3.716
β	0.010	0.036	-0.061	0.081

Mean daily productivity was determined to be 2,690.7 Kg C /lake/day (49.1E-05 Kg C / m^2 /day) with a minimum value of 101.3 Kg C /lake/day (3.4E-06 Kg C / m^2/day) and maximum value of 3,556.2 Kg C /lake/day (1.2E-04 Kg C / m^2/day). The spring of 1996 displayed the highest mean daily productivity results (3,551.9 Kg C / lake /day), while the lowest mean daily productivity results (308.5 Kg C / lake /day) were in the winter of 1996. The overall trend was similar to the trend produced by smoothed and corrected PAR data (Figures 4.9 and 4.10). Figure 5.39 illustrates the trend developed from the single equation without chlorophyll normalization. Daily PAR, which was smoothed and corrected for ice and snow, produced a smooth curve. No difference was seen between the years. Productivity values were increased on average by a factor of 113.98 with a minimum factor of 8.270 and a maximum factor of 439.20. This type of whole lake modelling was simple to compile (both collection of productivity parameters and calculations) but it overestimates the productivity occurring within the lake by losing daily variability and seasonality dynamics.

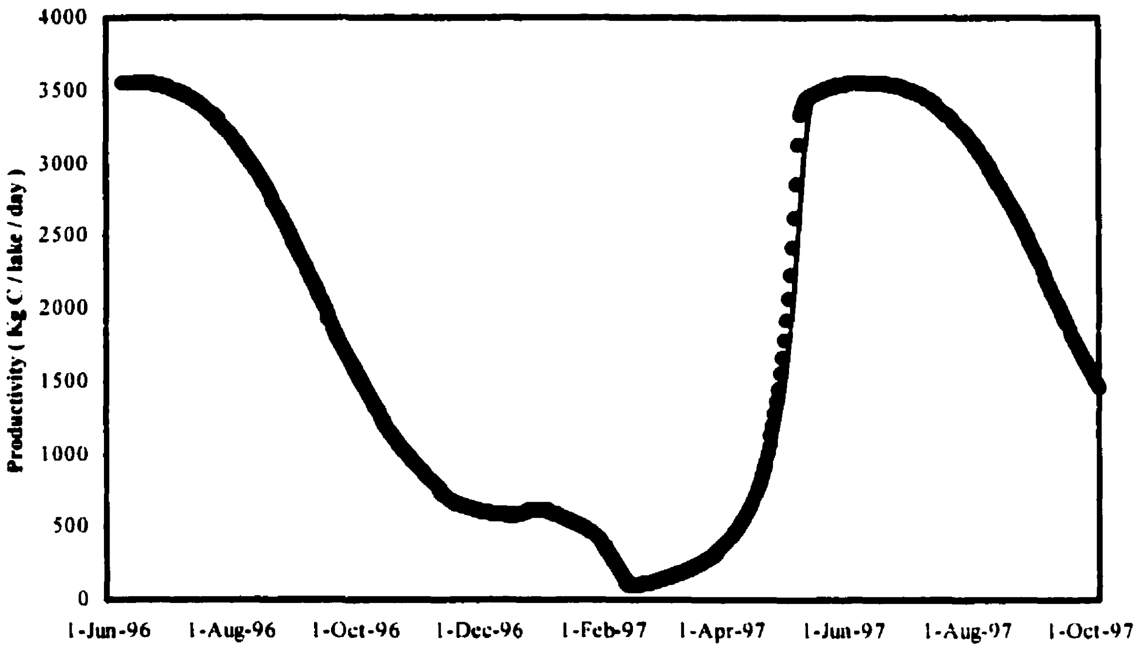


Figure 5.39 - A time series plot of whole lake primary productivity (a single equation) in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 3 using P_{max} Trend is illustrated by a moving average (7 day period).

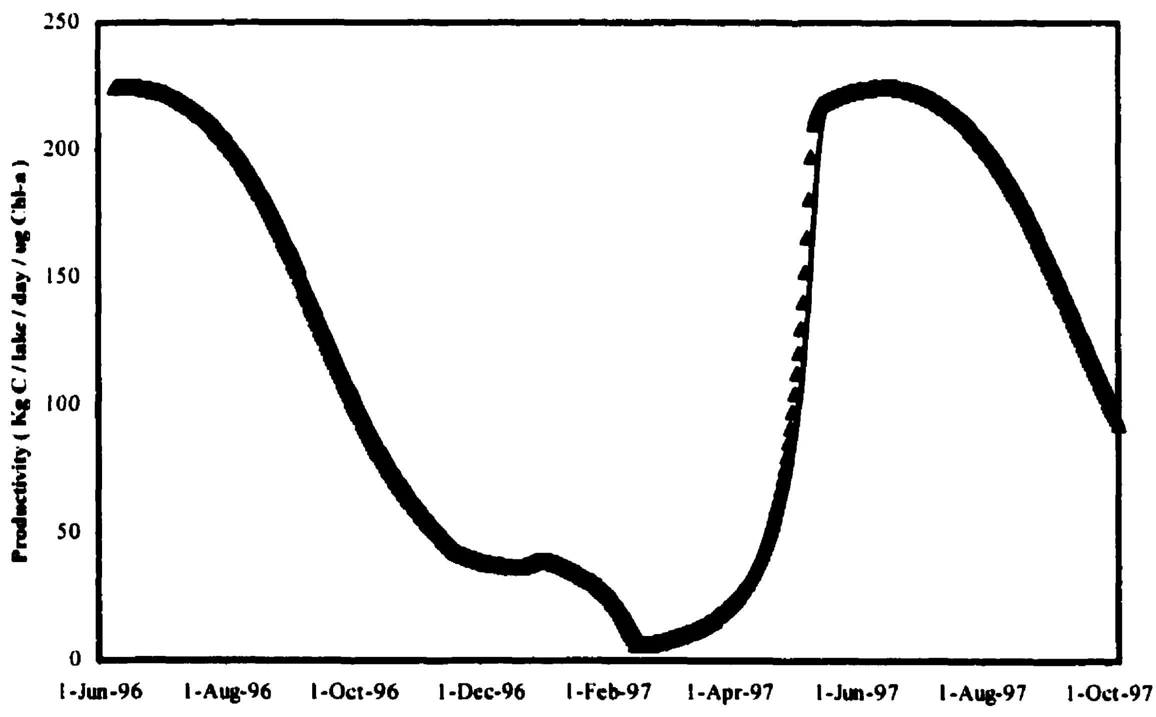


Figure 5.40 - A time series plot of whole lake primary productivity (a single equation) in Clear Lake, Manitoba from June 1996 to October 1997 derived from Productivity Model 3 using SP_{max} Trend is illustrated by a moving average (7 day period).

5.4.3.2 Productivity Model 3 using SP_{max}

An overall chlorophyll normalized P_{max} (SP_{max}) was 3.999 µgC/L/hour/µg Chl-a/L with a minimum (95% confidence level) of 3.612 µgC/L/hour/µg Chl-a/L and maximum (95% confidence level) of 4.387 µgC/L/hour/µg Chl-a/L. Standard error (ASE) was 0.197 µgC /L /hour. Table 5.18 illustrates the photosynthesis / irradiance parameters derived from all *in vitro* experiments using for the calculation of Model 3.

Table 5.18 - Summary of photosynthesis / irradiance parameters derived from all *in vitro* experiments using for the calculation of Model 3 using SP_{max} in Clear Lake, Manitoba at Station 2 during 1996 and 1997. (P_{max} µgC/L/hour, α µgC/L/hour/µmole PAR/m^2/sec, and β µgC/L/hour/µmole PAR/m^2/sec).

		Standard Error (ASE)	Lower 95% Confidence Level	Upper 95% Confidence Level
SP_{max}	3.999	0.197	3.612	4.387
α	0.029	0.002	0.024	0.034
β	0.001	0.000	0.000	0.001

This version of Model 3 produced a mean daily productivity of 169.9 Kg C /lake/day (5.8E-06 Kg C / m^2 /day) with a minimum of 6.4 Kg C /lake /day (2.2E-07 Kg C / m^2 /day) and maximum of 224.5 Kg C /lake/day (7.6E-06 Kg C / m^2 /day). The spring of 1996 displayed the highest mean daily productivity results (224.3 Kg C/ lake /day), while the lowest (19.5 Kg C/ lake /day) was in the winter of 1996. The overall trend was similar to the trend produced by smoothed and corrected PAR data (Figures 4.9 and 4.10). Figure 5.40 illustrates the trend developed from the single equation with chlorophyll normalization. Daily PAR, which was smoothed and corrected for ice and snow, produced a smooth curve. No difference was seen between the years. Productivity values were, however, increased on average by a factor of 7.196 with a minimum factor of 0.522 and a maximum factor of 27.726. This type of whole lake modelling was simple to compile (both collection of productivity parameters and calculations) but again it appeared to severely overestimate the productivity occurring within the lake by losing daily variability and seasonality dynamics. Overestimation was not, however, as severe as with the use of P_{max}, which had not been normalized for chlorophyll-a.

5.5 Analysis

The data are presented in the Appendix: Table A.5.2 for Station 1 variables and parameters compiled and Table A.5.4 for Station 2 variables and parameters compiled.

5.5.1 Thermal Gradient

The mean thermal gradient was 0.795 °/m with a minimum of 0 °/m and maximum of 2.267 °/m. The summer of 1997 displayed the highest thermal gradient results (1.363 °/m), while the lowest (0 °/m) was in the spring, fall, and winter of both 1996 and 1997. Yearly and seasonal differences were found due to the lake being dimictic. In the spring and fall, the lake mixed to homothermal conditions (i.e. gradient was 0 °/m). During the winter season, temperatures were relatively constant and the gradient was 0 °/m. The thermal gradient steepened through the summer with peaks being reached on June 30, 1996 and August 13, 1997. Figure 5.41 illustrates these trends.

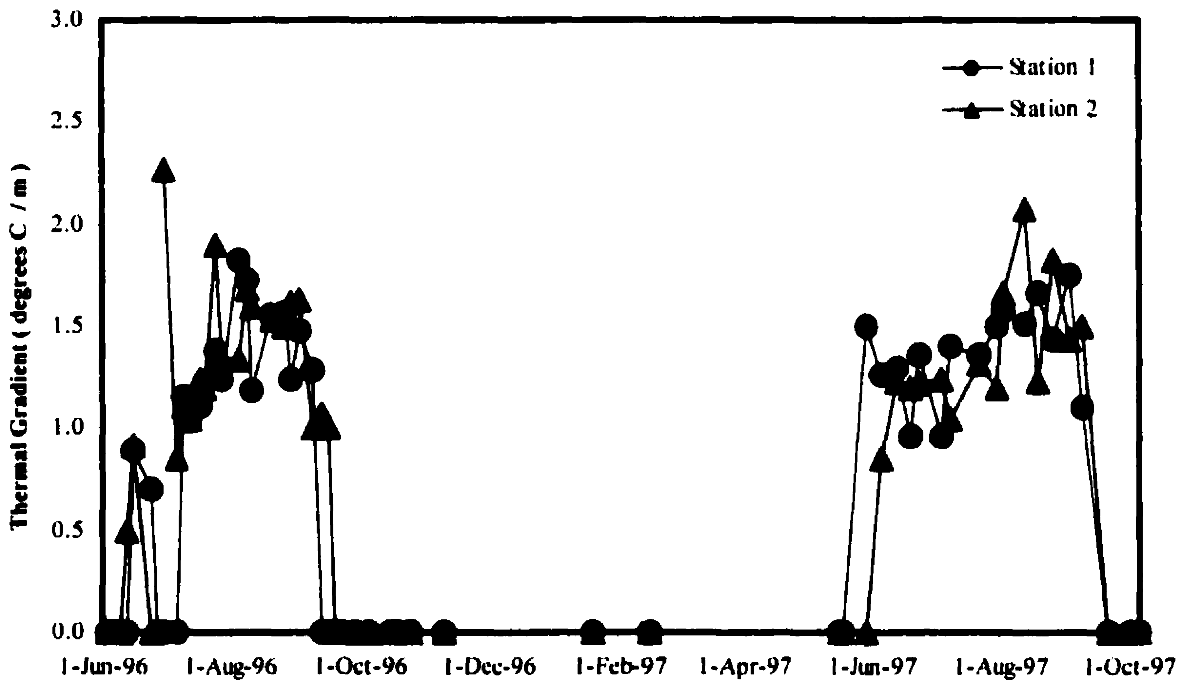


Figure 5.41 - A time series plot comparison of the thermal gradient at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997. Homothermal conditions are indicated by the thermal gradient slope equalling 0.

5.5.2 Thermocline depth

The mean thermocline depth was 15.15 m with a minimum of 2.00 m and maximum of 33.00 m. The winter of 1996 displayed the highest thermocline depth (25 m), while the lowest (10.75 m) was in the summer 1997. Like thermal gradients, seasonal differences were found due to the lake being dimictic. As the season progressed from spring to fall, the thermocline depth deepened. The deepest points were seen when the lake was demonstrating homothermal conditions. Station 1 and Station 2 were different at this point due the difference in station depths. In the fall of 1996 (late September), the depth gradually decreased as the lake began to mix, pushing the thermocline deeper. Figure 5.42 illustrates these trends.

5.5.3 Surface Temperature

The mean surface temperature was 15.11 °C with a minimum of 0°C and maximum of 21.9°C. The summer of 1997 displayed the highest surface temperature, while the lowest was in the winter 1996.Yearly and seasonal differences were found. The surface temperature increased through the summer with peaks being reached August 11, 1996 and August 2, 1997. These peaks were followed by decreases to a low point in January / February 1997. Figure 5.43 illustrates these trends.

5.5.4 Mean Light Extinction

The mean light extinction was 25.08% per metre with a minimum of 12.01% per metre and maximum of 46.03% per metre. The fall of 1997 displayed the highest light

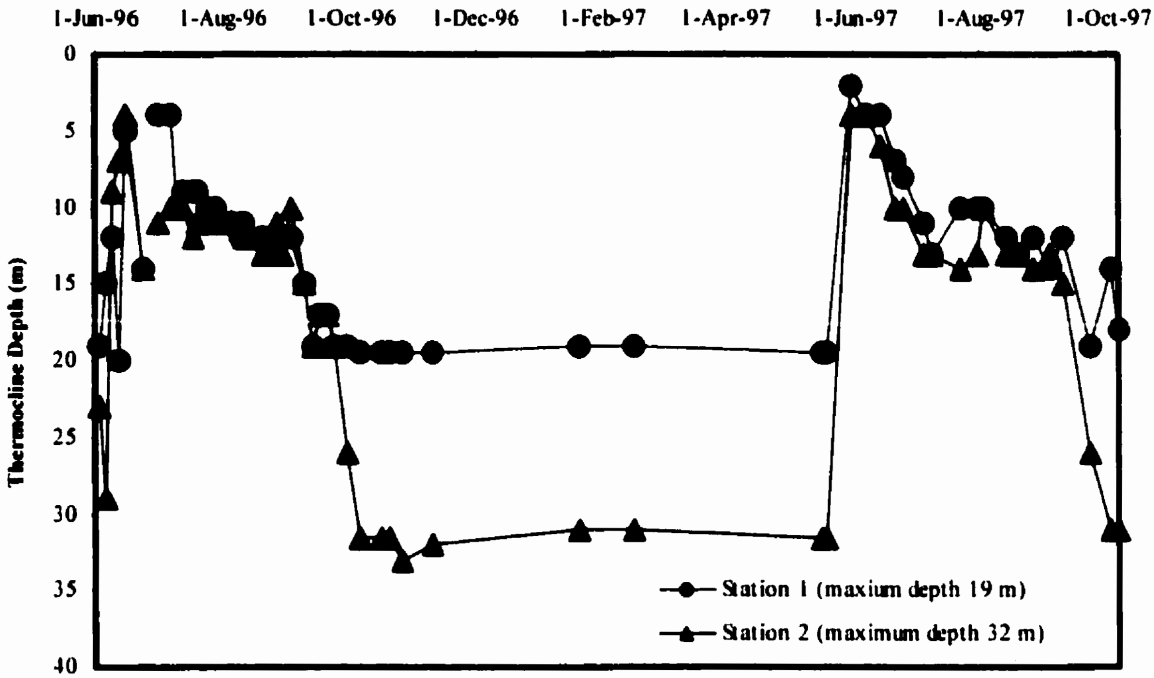


Figure 5.42 - A time series plot comparison of the thermocline at depth at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

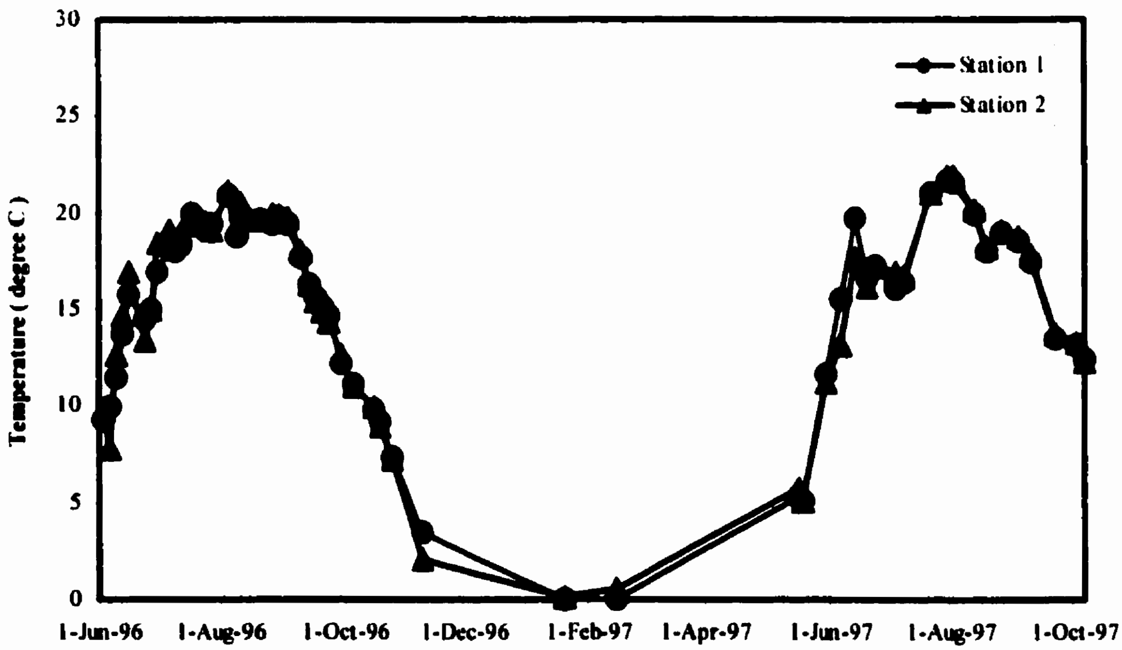


Figure 5.43 - A time series plot comparison of the surface temperature at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

extinction (46.03% per metre), while the lowest (12.01% per metre) was in the spring 1997. Yearly and seasonal differences were found. In 1997, mean light extinctions were higher (approximately 1%) when compared with 1996. As the season progressed from spring to fall, the mean light extinction increased reaching peaks at September 16, 1996 and August 26, 1997. Mean light extinction through the ice and snow was 22.89% per metre. This value was high but the euphotic zone was indeed very shallow. Wetzel (1983) states that ice and snow cover are rarely uniformly distributed over lake surfaces, which can lead to patchiness in reflectance and attenuation of light through this cover. Variable light distribution below ice and snow may affect algal photosynthesis horizontally across a lake. Figure 5.44 illustrates these trends.

5.5.5 Compensation Point

The mean light compensation point was 13.54 m with a minimum of 2 m and maximum of 20 m. The spring of 1997 displayed the deepest seasonal mean compensation point (16 m), while the lowest (2 m) was in the winter 1996. Yearly and seasonal differences were found. In 1997, the compensation point seemed to fluctuate. Whereas, in 1996, the values were more consistent and higher. As the season progressed from spring to fall, the compensation point decreased from peaks reached on June 26, 1996 and May 18, 1997. Low points were reached during January and February 1997. The deeper the compensation points, the wider that area was for phytoplankton productivity, which should result in elevated rates, provided incident PAR was not reduced. Figure 5.45 illustrates these trends.

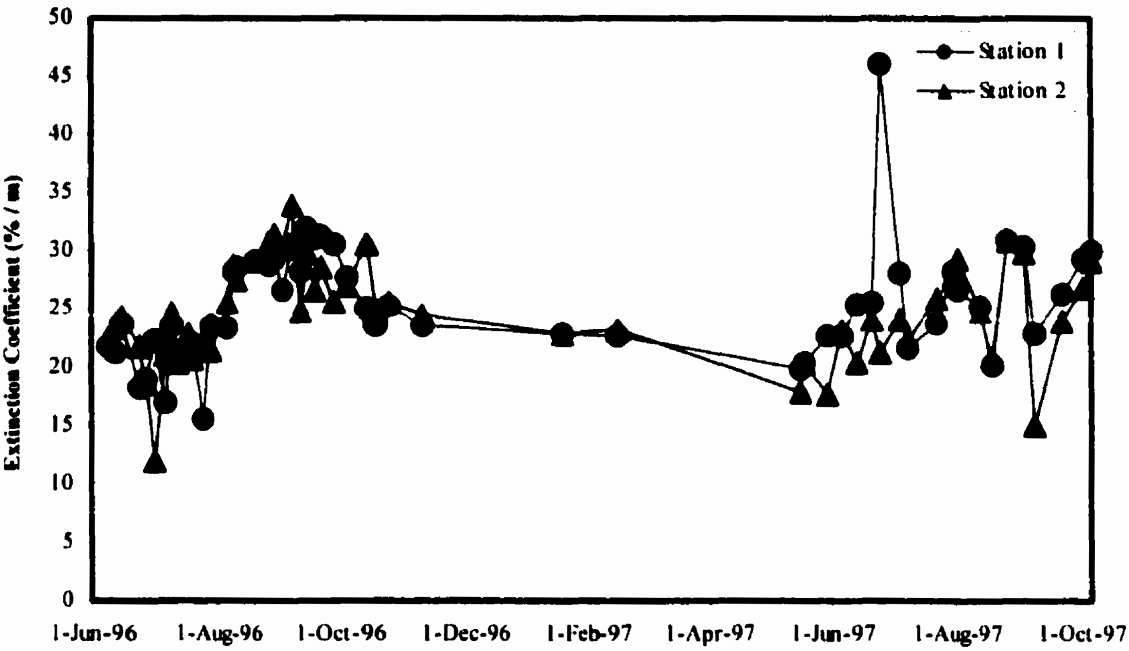


Figure 5.44 - A time series plot comparison of the light extinction through the water column at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

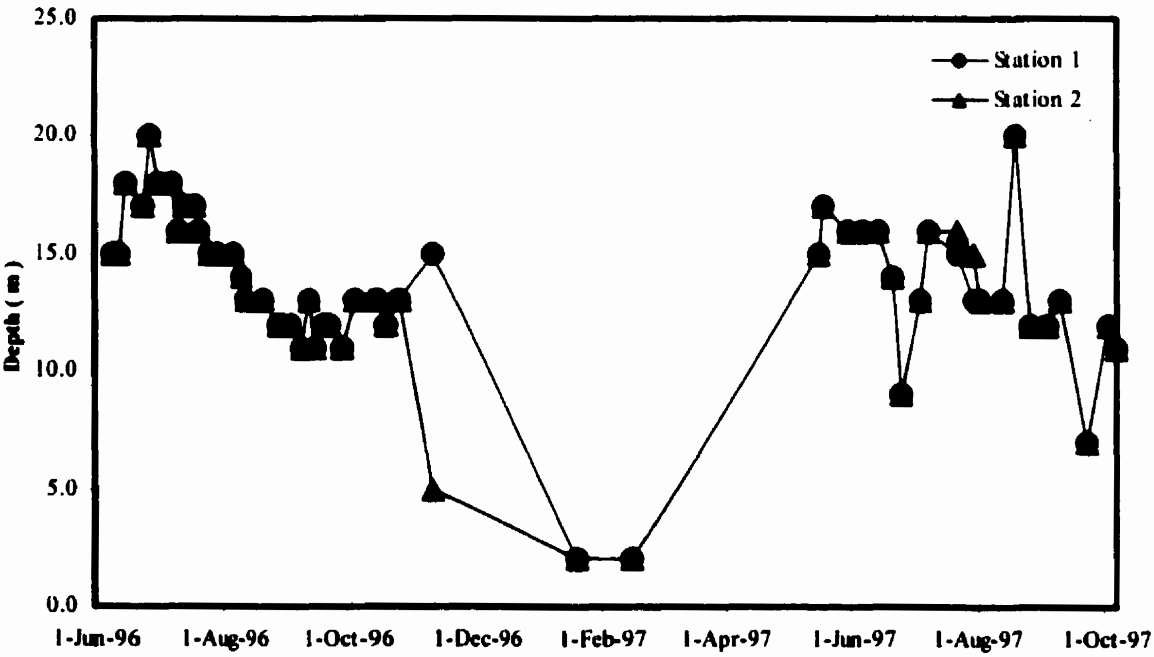


Figure 5.45 - A time series plot comparison of the light compensation point in the water column at Station 1 and Station 2 in Clear Lake, Manitoba from June 1996 to October 1997.

5.5.6 Total Light

The mean daily light was determined to be 31.169 μmoles /m^2/day with a minimum value of 1.160 μmoles /m^2 /day and maximum value of 40.729 μmoles /m^2 /day. The spring of 1996 displayed the highest mean seasonal daily light results (40.614 μmoles /m^2 /day), while the lowest (3.532 μmoles /m^2 /day) were in the winter 1996. Seasonal trends were seen and described in Chapter 4 (Figures 4.9 and 4.11).

5.5.7 Light History

Measurements of the light history involved recording the total incident daily light and adding the total daily light for the six previous days. The mean light history was 203.946 μmoles /m^2/ 6 days with a minimum of 1.160 μmoles /m^2/ 6 days and maximum of 284.671 μmoles /m^2/ 6 days. The spring of 1996 displayed the highest mean seasonal light history (282.519 μmoles /m^2/ 6 days), while the lowest (5.325 μmoles /m^2/ 6 days) was in the winter 1996. Seasonal trends were seen and described in Chapter 4 (Figures 4.9 and 4.11).

5.6 Lake Level and Wind Speed

Daily lake levels were recorded (Stevenson Gauge) at the Main Pier in Wasagaming by Riding Mountain National Park Staff (Rousseau, 1997 pers comm.) (Table 5.19). Hourly speeds were recorded by an anemometer at Warden Stores in Wasagaming by Environment Canada (Svistovski, 1999 pers comm.) (Table 5.20).

Table 5.19 - Summary of Productivity Model 1 and Lake Level (m) in Clear Lake, Manitoba from June 1996 to October 1997.

Date	Productivity kg C / lake/ day	Water Level m
09-Jun-96	32.9	615.526
12-Jun-96	26.4	615.518
15-Jun-96	14.6	615.507
23-Jun-96	11.6	615.462
26-Jun-96	16.3	615.459
30-Jun-96	28.3	615.472
06-Jul-96	31.5	615.465
09-Jul-96	30.9	615.460
12-Jul-96	26.8	615.457
17-Jul-96	29.9	615.447
19-Jul-96	24.9	615.445
24-Jul-96	37.1	615.425
28-Jul-96	40.6	615.411
05-Aug-96	54.2	615.393
09-Aug-96	61.4	615.385
11-Aug-96	46.2	615.383
20-Aug-96	62.1	615.350
27-Aug-96	42.7	615.328
30-Aug-96	46.5	615.317
03-Sep-96	51.2	615.303
09-Sep-96	56.6	615.338
13-Sep-96	62.3	615.310
16-Sep-96	21.6	615.294
20-Sep-96	25.2	615.283
23-Sep-96	47.0	615.291
29-Sep-96	45.0	615.257
05-Oct-96	33.7	615.239
15-Oct-96	31.7	615.229
19-Oct-96	29.8	615.214
25-Oct-96	8.7	615.231
09-Nov-96	19.5	615.215
16-May-97	54.9	615.351
18-May-97	17.7	615.354
30-May-97	19.7	615.361
06-Jun-97	8.1	615.357
13-Jun-97	8.4	615.329
20-Jun-97	25.7	615.350
24-Jun-97	18.1	615.346
04-Jul-97	20.3	615.326
08-Jul-97	26.1	615.323
22-Jul-97	30.5	615.319
30-Jul-97	31.0	615.278
02-Aug-97	18.9	615.261
13-Aug-97	31.2	615.218
19-Aug-97	10.2	615.227
26-Aug-97	30.9	615.210
03-Sep-97	34.8	615.187
09-Sep-97	37.6	615.173
22-Sep-97	33.4	615.133
02-Oct-97	37.1	615.108
06-Oct-97	33.8	615.097
mean	31.0	615.328
min	6.6	615.097
max	62.3	615.526

Table 5.20 - Summary of Productivity Model 1 and Wind Speed (Km/hour) in Clear Lake, Manitoba from June 1996 to October 1997.

Date	Productivity kg C / lake/ day	Wind Speed Km / hour
09-Jun-96	32.9	8.00
12-Jun-96	26.4	10.13
15-Jun-96	14.6	8.67
23-Jun-96	11.6	5.50
26-Jun-96	16.3	6.33
30-Jun-96	28.3	10.56
06-Jul-96	31.5	11.40
09-Jul-96	30.9	2.77
12-Jul-96	26.8	8.36
17-Jul-96	29.9	7.90
19-Jul-96	24.9	8.00
24-Jul-96	37.1	7.00
28-Jul-96	40.6	4.76
05-Aug-96	54.2	9.21
09-Aug-96	61.4	6.50
11-Aug-96	46.2	8.07
20-Aug-96	62.1	7.56
27-Aug-96	42.7	7.95
30-Aug-96	46.5	5.17
03-Sep-96	51.2	9.92
09-Sep-96	56.6	8.04
13-Sep-96	62.3	5.40
16-Sep-96	21.6	5.58
20-Sep-96	25.2	3.83
23-Sep-96	47.0	11.83
29-Sep-96	45.0	5.54
05-Oct-96	33.7	9.13
15-Oct-96	31.7	18.42
19-Oct-96	29.8	6.08
25-Oct-96	8.7	20.17
09-Nov-96	19.5	12.88
20-Jan-97	6.6	2.79
15-Feb-97	12.2	6.00
16-May-97	54.9	10.54
18-May-97	17.7	8.18
30-May-97	19.7	12.29
06-Jun-97	8.1	9.96
13-Jun-97	8.4	7.70
20-Jun-97	25.7	6.75
24-Jun-97	18.1	21.55
04-Jul-97	20.3	7.05
08-Jul-97	26.1	2.00
22-Jul-97	30.5	8.71
30-Jul-97	31.0	6.78
02-Aug-97	18.9	12.46
13-Aug-97	31.2	8.26
19-Aug-97	10.2	7.79
26-Aug-97	30.9	6.88
03-Sep-97	34.8	4.63
09-Sep-97	37.6	9.92
22-Sep-97	33.4	8.92
02-Oct-97	37.1	12.29
06-Oct-97	33.8	8.42
mean	31.0	8.50
min	6.6	2.00
max	62.3	21.55

5.7 Summary

1. Phytoplankton displayed a diurnal rhythm. Productivity was the highest in the morning and gradually decreased throughout the day. Biomass peaked during the noon period. It was decided that sampling was to occur 7:00 cst to 9:00 cst.

2. Phytoplankton displayed uniform horizontal distribution across Clear Lake. Wind was determined not to affect the horizontal distribution of phytoplankton assemblages at least during the times that this was tested.

3. Chlorophyll-a (Phytoplankton biomass) displayed yearly and seasonal differences. Three major peaks were illustrated in Figure 5.1. Two of these peaks occurred in October of 1996 and 1997. The third peak occurred in the spring of 1997. Phytoplankton biomass was higher in 1997 than in 1996.

4. Phytoplankton species found fall within the following classes: Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cryptophyceae, Cyanobacteria, and Dinophyceae. The common species were *Dinobryon sociale, Fragilaria crotonensis, Pediastrium duplex, Stephanodiscus niagarae, Cyclotella bodanica, Tabellaria fenestrata, and Peridinium sp.*

5. At Station 1, *Peridinium* sp. dominated during the ice season and summer of 1997;

Fragilaria sp. dominated during the summer of 1996; and *Synedra* sp. dominated during the spring of 1996 and 1997.

6. At Station 2, *Peridinium* sp. dominated during the ice season and summer of 1997; *Fragilaria* sp. and *Peridinium* sp dominated during the spring and summer of 1996; *Peridinium* sp. dominated during the summer of 1997; and *Fragilaria* sp. dominated during the spring of 1997.

7. Combining Station 1 and 2, *Peridinium* sp. dominated during the ice season and summer of 1997; *Fragilaria* sp. dominated during the spring and summer of 1996; *Tabellaria* sp. dominated during the spring of 1996; and *Synedra* sp. dominated during the spring of 1997.

8. Average total particulate volumes (Station 1 and Station 2) were higher in the 1997 season with the Dinophyceae dominating. Bacillariophyceae shifted to dominance in June 1997. In 1996, the Bacillariophyceae dominated especially during July / August and November to January.

9. Species Diversity (Shannon-Weiner diversity index) was the lowest during the winter ice season, while in the late summer early fall the values increased. The Bacillariophyceae displayed the highest proportion of species diversity throughout the study.

10. Total particulate biovolume and diversity displayed seasonal differences. In 1996, total particulate volume was lower but diversity was higher, while in 1997, diversity was low and total particulate volume was higher from May to July then diversity was high as total particulate volume was low.

11. Chlorophyll-a and total particulate biovolume displayed similarities but some seasonal differences. In 1996, chlorophyll-a increased with species richness following suit with a major peak in both was observed just before ice in. In 1997, chlorophyll-a decreased, while species richness increased, especially during May to June and mid August to October. July showed that as chlorophyll-a increased, species richness increased.

12. P_{max} and SP_{max} were higher in 1997 than in 1996. Generally, the 1996 trend displayed a gradual increase until late August early / September followed by a decrease. Low levels were seen throughout the ice season. This trend was mirrored in 1997 but no decrease was seen.

13. α and chlorophyll normalized α were higher 1996 than in 1997. The 1996 trend displayed a gradual increase until late August / early September followed by a decrease. Low levels were seen throughout the ice season and were followed by a spring peak. This trend was mirrored in 1997 but again no decrease was seen.

14. I_k was higher in 1996 than in 1997. The 1996 trend displayed a gradual increase until late August / early September followed by a decrease. Low levels were seen throughout the ice season but followed by a spring increase especially in Station 2 in 1997. In 1997, no clear trend was observed.

15. Total alkalinity and dissolved inorganic carbon (DIC) levels were generally lower in 1996 than in with 1997. In 1996, levels gradually increased until August, being followed by a slight decrease in September. In 1997, a major peak in DIC occurred in January, followed by a gradual decrease until June. Levels then gradually increased until July but were followed by a slight decrease in September. The last few samples of the study showed a gradual increase.

16. Total alkalinity was well within the Manitoba Surface Water Quality Objective for domestic consumption is 30 mg/L - 500 mg/L based on aesthetic consideration.

17. pH levels was similar in 1996 and 1997 with very slight variations.

18. Nitrogen Debt displayed no trend throughout the study. The values obtained in 1997 were higher than in 1996. Severe nitrogen deficiency (according to this indicator) was indicated on 51% of the sampling occasions.

19. Phosphorous Debt displayed no trend throughout the study. The values obtained in

1997 were higher as compared with 1996. Severe phosphorous deficiency (according to this indicator) was indicated 5% of the time.

20. Alkaline phosphatase activity also displayed no trend throughout the study. The values obtained in 1996 were higher than in 1997. Severe phosphorous deficiency (according to this indicator) was indicated on 85% of sampling occasions.

21. Mean total Kjeldahl Nitrogen in the lake was 0.484 mg/L, mean Nitrate-Nitrite-N was 0.264 mg/L, and mean particulate nitrogen was 0.220 mg/L.

22. Mean total phosphorous in the lake was 0.054 mg/L, mean dissolved phosphorous was 0.026 mg/L, and mean particulate phosphorous was 0.028 mg/L.

23. Mean total organic carbon in the lake was 5.327 mg/L, mean dissolved organic carbon was 5.060 mg/L, and mean particulate organic carbon was 0.266 mg/L.

24. The mean Si / P atomic ratio was determined to be 1442.65 with a minimum value of 31.51 and maximum value of 7250.00.

25. Elemental particulate ratios displayed a variety of deficiencies: N/P indicated severe phosphorous deficiency 72% of the time; C/P indicated severe phosphorous deficiency 8% of the time; C/N indicated severe nitrogen deficiency was not experienced at all; and C/Chl-a indicated severe carbon deficiency 44% of the time

26. Whole Lake Productivity Modelling - In late spring 1996 / early summer 1996, the productivity within the lake was low but increased as the summer progressed. A peak in productivity was seen late August 1996 / early September 1996 (August 16, 1996) when conditions were apparently optimal. This was followed by a decline up to and through the ice season reaching the lowest point just before ice break up (March 23, 1997). In 1997, productivity increased to a spring peak (May 5, 1997). This was followed by a gradual decrease before the occurrence of two consecutive peaks (August 13, 1997 and September 20, 1997).

27. Productivity Model 1 produced 6 distinctive stages. Two main differences occurred between 1996 and 1997. In 1996 (Stage 1 Summer), productivity was higher (about 5 Kg C /lake /day) as compared to values in 1997 (Stage 5 Summer). The end point difference between these two stages was a 2 week period, which in 1997 (August 1, 1997) ended two weeks early than in 1996 (August 17, 1996), therefore making the slope steeper in 1997. In 1996 (Stage 2 Fall), a decrease was seen after August 17, 1996, whereas in 1997 (Stage 6 Fall) an increase was seen after August 1, 1997.Mean productivity was higher in 1996 than is 1997.

28. The trend produced by Model 2 was similar to that of Model 1. During the ice season, the curve resembled the pattern of light data corrected for ice and snow. It is

suggested that this type of whole lake modelling maybe easier to compile (both collection of productivity parameters and calculations) but that it overestimates (by a factor of 2) the productivity occurring within the lake.

29. The productivity trend produced by Model 3 using P_{max} was similar to the trend produced by smoothed and corrected PAR data. No difference was seen between the years. This type of whole lake modelling was again simple to compile (both collection of productivity parameters and calculations) but it likely overestimates (by a factor of 114) the productivity occurring within the lake by not accounting for daily variability and seasonal dynamics.

30. Model 3 (using SP_{max}) displayed an overall trend similar to the trend produced by smoothed and corrected PAR data and no difference was seen between years. This type of whole lake modelling was again simple to compile (both collection of productivity parameters and calculations) but it overestimates (by a factor of 7) productivity by losing daily variability and seasonal dynamics.

31. The thermal gradient displayed yearly and seasonal differences due to the lake being dimictic. The gradient steepened through the summer with peaks being reached on June 30, 1996 and August 13, 1997.

32. Thermocline depth displayed seasonal differences, again due to the lake being dimictic. As the season progressed from spring to fall, the thermocline depth deepened.

33. Surface temperature displayed yearly and seasonal differences. The surface temperature increased through the summer with peaks being reached on August 11, 1996 and on August 2, 1997. These peaks were followed by decreases to a low point in January / February 1997.

34. Light extinction displayed yearly and seasonal differences. In 1997, mean light extinction was higher by approximately 1% when compared with 1996. As the season progressed from spring to fall, the light extinction increased reaching peaks at September 16, 1996 and August 26, 1997.

35. The compensation point displayed yearly and seasonal differences As the season progressed from spring to fall, the compensation point decreased from maxima reached on June 26, 1996 and May 18, 1997. Low points were reached during January and February 1997. In 1997, the compensation point seemed to fluctuate more than in 1996.

Chapter 6 Discussion

6.1 Introduction

The purpose of this study was to quantify phytoplankton primary production (one of the main primary sources of organic carbon) in Clear Lake, Manitoba, and to determine, where possible, sources of variability. This represents a first, and an essential stage in the development of a quantitative understanding of the Clear Lake Basin Aquatic Ecosystem and, ultimately, in management strategies and stewardship for the benefit of all stakeholders. This information will in part make it possible to assess and put forth ecologically based management decisions for the benefit of the Clear Lake Basin and its stakeholders. In addition, the information will aid in education and the stewardship of the aquatic ecosystem within Riding Mountain National Park.

6.2 Estimation of Phytoplankton Primary Productivity

6.2.1 Productivity Parameters

Assessment of phytoplankton productivity parameters was conducted through the use of experimentally determined Photosynthesis - Irradiance (P vs I) relationships. Any response of such relationships to changing environmental conditions has the potential to greatly influence the outcome. The parameters of photosynthesis / irradiance relationships that were examined were α, P_{max}, and I_k. Each of these parameters was examined for response to light and temperature. The temperature variables examined were surface water temperature, gradient slope of the thermocline, and depth of thermocline. Light variables examined were light extinction, compensation point, daily hourly light (PAR) incidence (total light), and light history (exposure to PAR for 6 days prior to determination). Note correlation was determined by Pearson Product-Moment Correlation.

P_{max} increased with temperature (surface temperature (r^2 = 0.0961 and Correlation = 0.310) and thermocline depth (r^2 = 0.0195)). Such an effect was to be expected because P_{max} is an expression of enzymatic dominated CO_2 - fixation, and as such is temperature dependent. α increased as the thermocline depth increased (r^2 = 0.2556 and Correlation = -0.520). As surface temperature (r^2 = 0.0245) and thermal gradient (r^2 = 0.0717) increased, α decreased. Photosynthetic efficiency (α) represents a photochemical process, which is not likely to be directly temperature dependent. I_k decreased as the thermocline depth decreased (r^2 = 0.3676). Surface temperature (r^2 = 0.2352) and thermal gradient (r^2 = 0.0773) increased when compared with I_k. It should be remembered that I_k was derived arithmetically from α and P_{max}.

Because of the connection between cellular metabolism and light saturation, photosynthesis and cell growth are dependent on both light and temperature. Generally when temperature increases by 10°C, enzymatic activity rates increase by a factor of 2-3 (Neilson and Hansen, 1959 and Darley, 1982). In a single species experiment, P_{max} has shown to be significantly affected by temperature, whereas α was not affected (Fee *et al.*, 1987). In P-I curves, α responds to increasing light because of the physiological photochemical reactions of pigments. On the other hand, P_{max}, as the enzymatic portion of the photosynthetic - irradiance relationship (the 'dark reactions' of photosynthesis), is dependent on active enzyme concentrations and temperature. Enzymatic activity can influence carbon dioxide fixation and the electron transport chain. More specifically, RUBISCO is affected by changing temperature that ultimately influences both carboxylase and oxygenase activity (Geider and Osborne, 1992).

Light affect on the above parameters vary. Darley (1982) states that algal cells maximize their growth with varying light intensities by modifying the dark reaction (P_{max}) and/or light reactions (α). Cells take full use of their environment and assemble light capturing systems that are proficient. As daily light (r^2 = 0.2124 and Correlation = -0.318) and light history (r^2 = 0.1703 and Correlation = -0.350) increased, P_{max} decreased. The decrease in P_{max} is attributed to the fact that cells increased production of chlorophyll instead of producing dark reaction enzymes (Darley, 1982). P_{max} increased with increased light extinction (r^2 = 0.1919 and Correlation = 0.438). Clear Lake is not light limited, therefore lower amounts of chlorophyll (characteristic of sun cells) may occur throughout the water column. Darley (1982) suggests that when P_{max} is high the cells are less susceptible to photoinhibition at high light intensities. The same affect was seen with α. As daily light (r^2 = 0.4814 and Correlation = -0.649), light history (r^2 = 0.4311 and Correlation = -0.682), and compensation point (r^2 = 0.1169 and Correlation = -0.342) increased, α decreased. Low amounts of chlorophyll are characteristic of sun cells. Sun adapted cells show low α, high I_k, and high P_{max} (Darley, 1982). α increased with increased light extinction (r^2 = 0.1702 and Correlation = 0.412). Shade adapted cells show higher photosynthetic efficiency (α) because pigment levels increase allowing the photosystems to take advantage of higher proportions of available energy. I_k showed the opposite response of α and P_{max}. As daily light (r^2 = 0.2348 and Correlation = 0.563), light history (r^2 = 0.2130 and Correlation = 0.571), and compensation point (r^2 =

0.2050 and Correlation = 0.453) increased, I_k increased.

6.2.2 Productivity Modelling

Three models (including 2 versions of Model 3) of increasing simplicity were developed. As discussed in Chapter 5 (section 5), the models displayed similarities but were very different in absolute terms (Table 6.1).

Table 6.1 - A summary of the factors by which Model 2 and the two versions of Model 3 differ from the output of Model 1 in Clear Lake, Manitoba.

Productivity Model	Multiplication Factor
Productivity Model 2	2.108
Productivity Model 3 using P_{max}	113.98
Productivity Model 3 using chlorophyll normalized P_{max} (SP_{max})	7.196

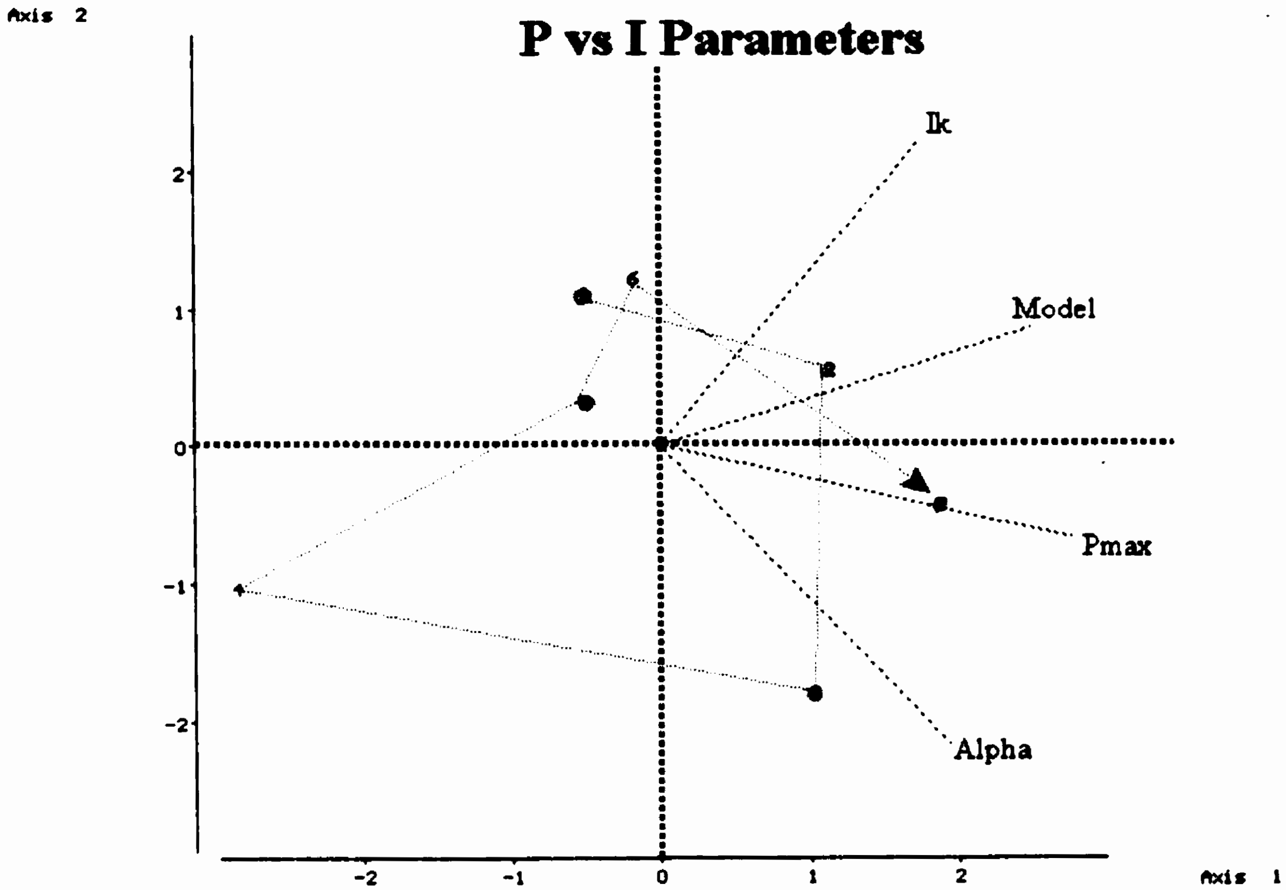
'*In situ*' phytoplankton productivity in Clear Lake will be best estimated by using photosynthesis parameters ('alpha' (α), Pmax, and 'beta' (β)) derived from *in vitro* experiments (incubator), euphotic depth, the extinction of PAR within the lake, and hourly integrations of PAR. Productivity Model 1 was developed to provide the best estimates to model productivity in Clear Lake, Manitoba. This model accounts for hourly changes in light as a opposed to Model 2, which uses total daily light. Weather patterns, environmental conditions and cloud cover patterns undoubtedly resulted in varying light intensities throughout the day. Model 3 was developed using a single equation that would not allow for daily or seasonal changes, peaks / lows in productivity parameters, environmental conditions, and weather patterns that would affect *in vitro* experiments.

Upon relating the output of Productivity Model 1 to measured variables, a variety of trends were observed. This was done through Principal Components Analysis (PCA.) in SYN-TAX (version 5).

Productivity parameters (P_{max}, α, and, and I_k) and chlorophyll normalized parameters (SP_{max}, and α/chl-a,) are displayed in Figures 6.1 and 6.2 respectively. Both figures display a seasonal trend. As modelled productivity (in all cases) increased, so did I_k. P_{max}, α, SP_{max}, and α/chl-a were high in the fall of 1996 and 1997 and low in the spring of 1996 and 1997. Productivity and I_k were highest in the summer of 1997 and lowest in the winter in 1996.

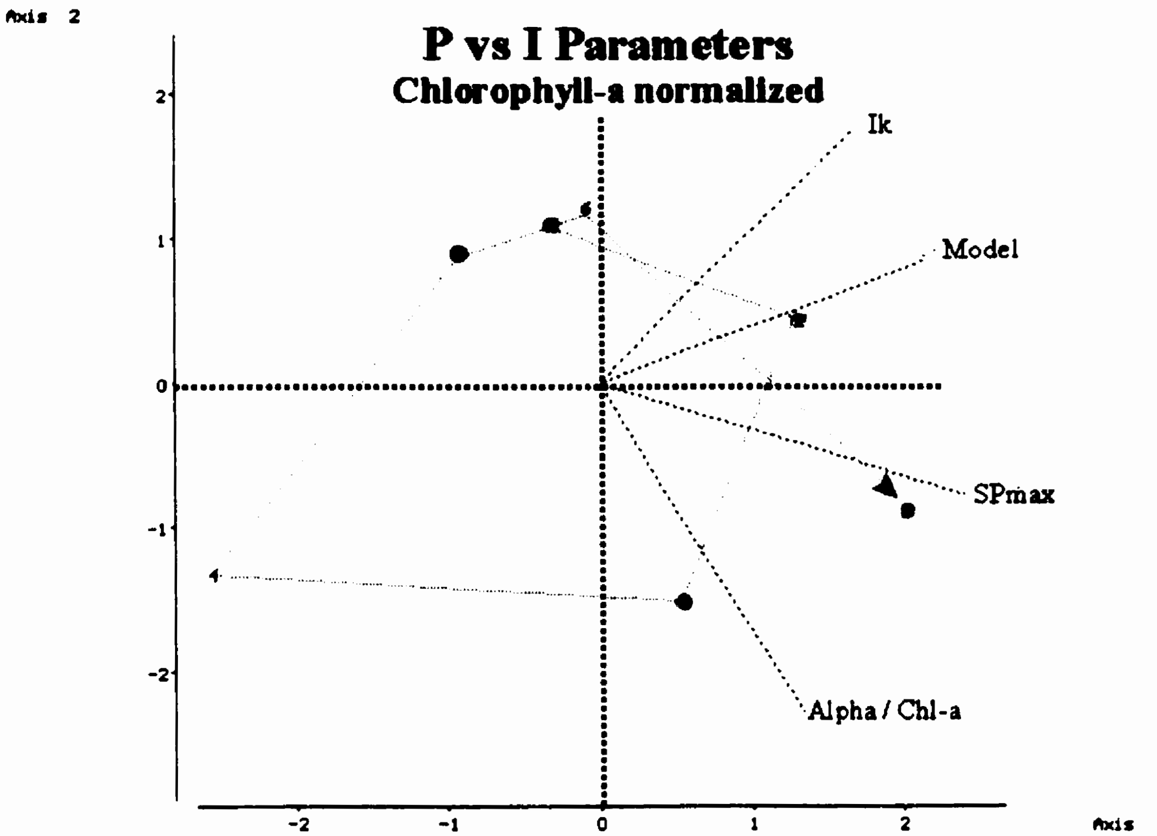
A comparison of these models is illustrated in Figure 6.3. Productivity according to Model 1 and 2 was highest in the summer of 1996 and lowest in the winter of 1996. These two models were driven by the productivity parameters calculated from individual sampling occasions. Productivity according to Model 3 was high in the spring of 1996 and 1997 and summer of 1997. This model was driven by a single equation derived from all sampling occasions, a mean photic zone, and an overall mean chlorophyll (used for chlorophyll-a normalization). The light data used were smoothed and corrected. Since the productivity parameters were consistent, the available light (PAR) would dictate highs and lows of productivity. Light was highest in the summer and productivity followed suit.

The influence of light and temperature variables (Figure 6.4) examines any influence of light history (PAR for that day and preceding 6 days), daily light (PAR) readings(total light), extinction coefficients, compensation point, surface water temperature, gradient slope of the thermocline, and depth of thermocline on the output of Productivity Model 1. As



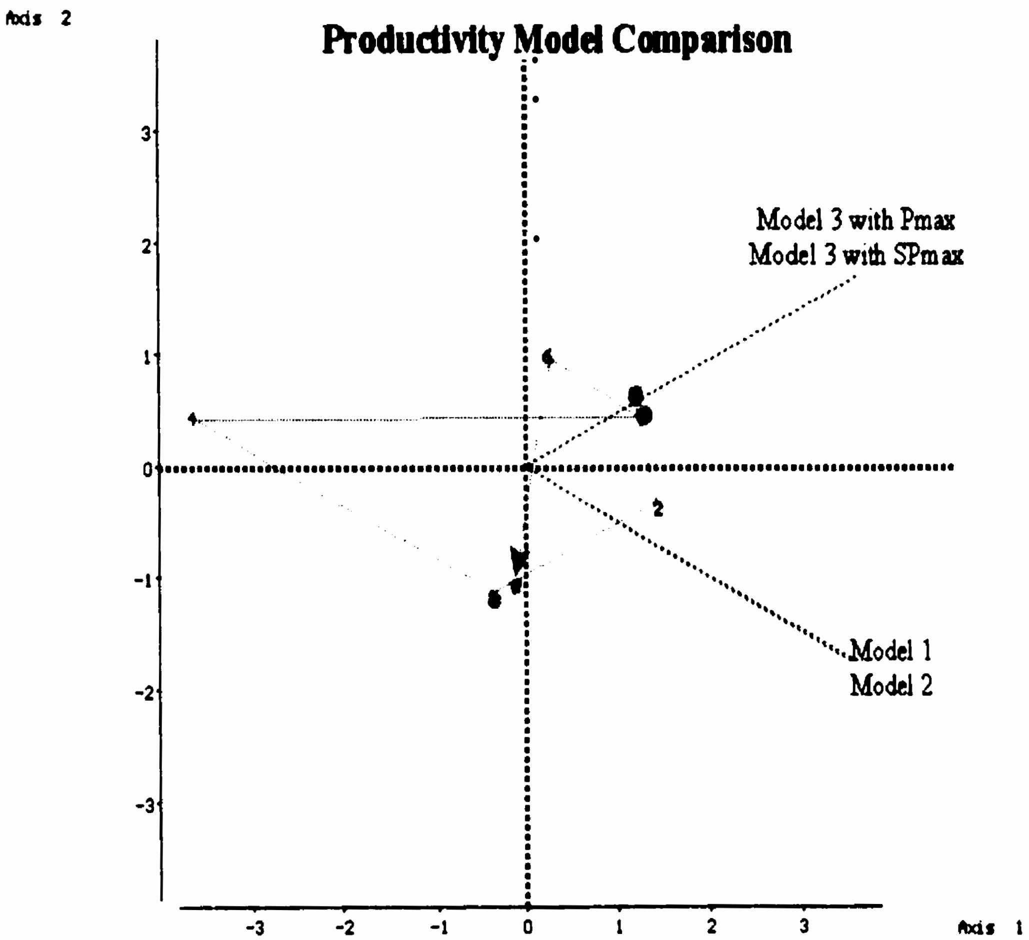
1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997
7 - Fall 1997

Figure 6.1 - **Principle Components Analysis comparing P vs I parameters used to calculate the output of Productivity Model 1 for Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 62.3% of the data. Axis 2 comprises of 24.4% of the data.**



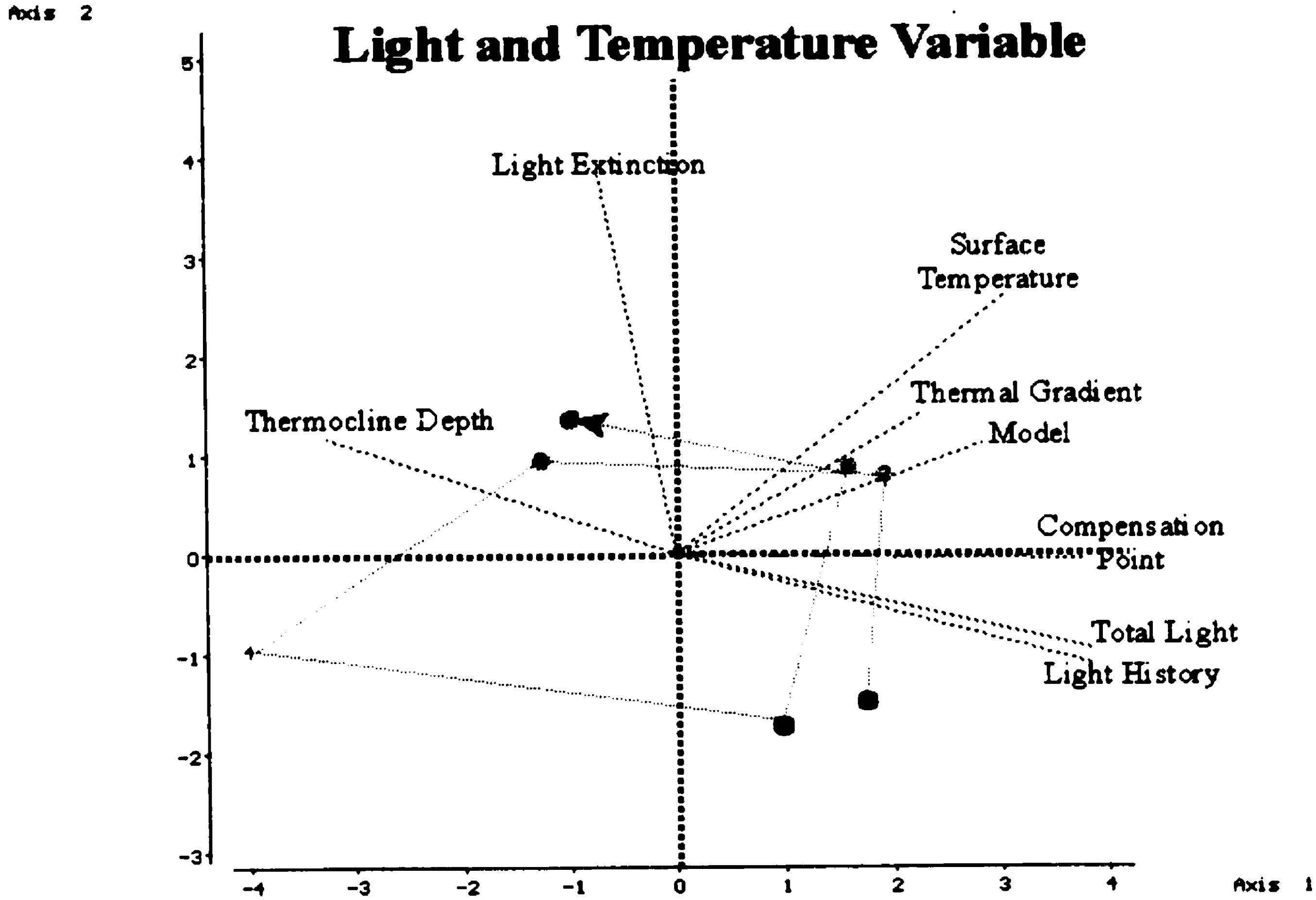
1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997
7 - Fall 1997

Figure 6.2 - Principle Components Analysis comparing the output of Productivity Model 1 with P vs I parameters Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 57.8% of the data. Axis 2 comprises of 25.0% of the data.



1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997
7 - Fall 1997

Figure 6.3 - **Principle Components Analysis comparing the output of the different Productivity Models Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 50.1% of the data. Axis 2 comprises of 44.8% of the data.**



1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997
7 - Fall 1997

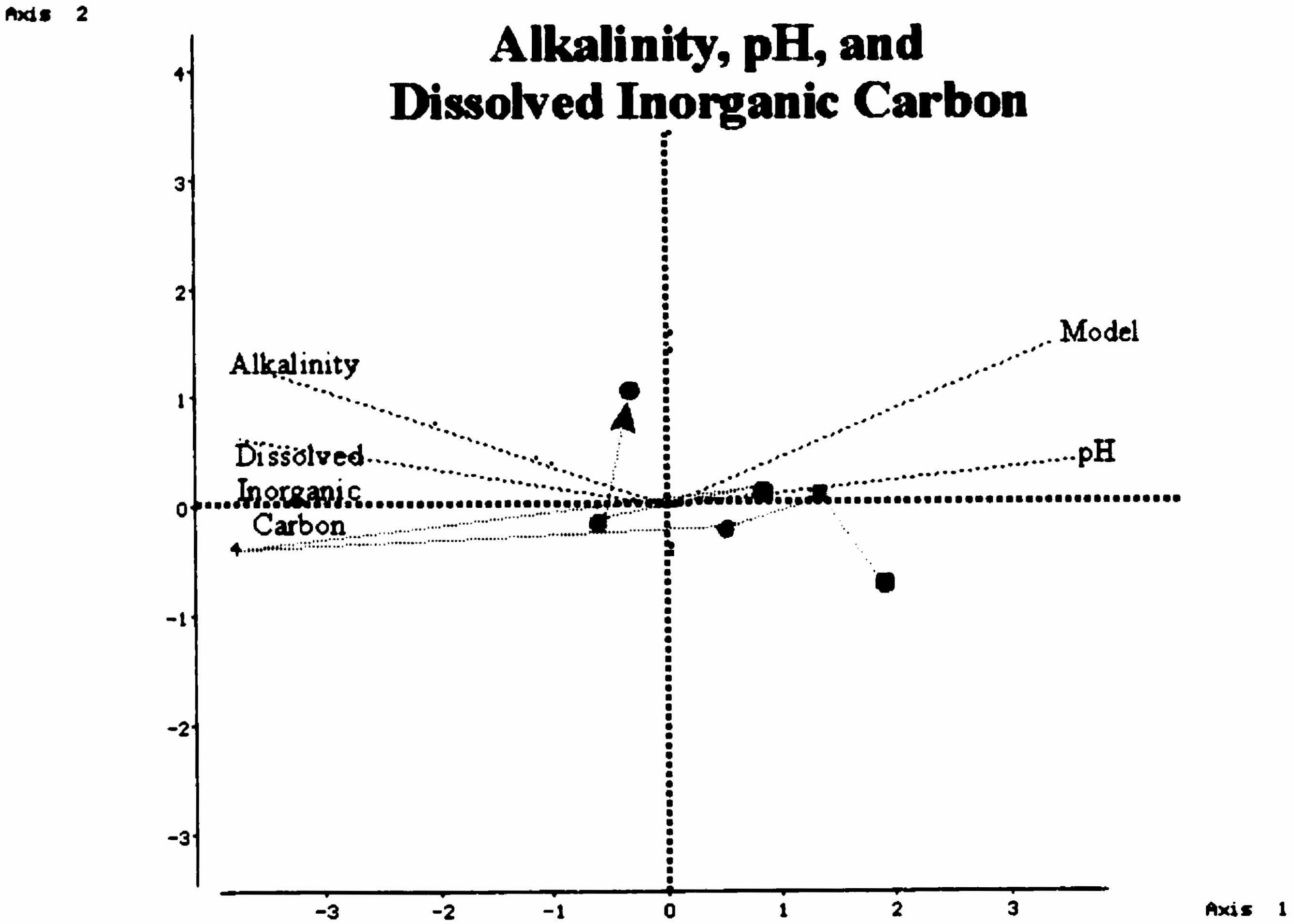
Figure 6.4 - **Principle Components Analysis comparing the output of Productivity Model 1 with light and temperature variables for Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 54.5% of the data. Axis 2 comprises of 19.4% of the data.**

surface temperature and the thermal gradient increased, productivity according to Model 1 increased. When total light and light history were high, thermocline depth and light extinction decreased. In the summer of 1996 and 1997, Productivity according to Model 1, thermal gradient, and surface temperature were highest. Total Light and light history were the highest in the spring of 1996 and 1997. Light extinction and thermocline depth were the highest in the fall of 1996 and 1997.

When the output of Productivity Model 1 was compared with alkalinity, pH, and dissolved inorganic carbon (Figure 6.5) no real seasonal trend was seen. As productivity and pH were high, alkalinity and dissolved inorganic carbon were low. Dissolved inorganic carbon and alkalinity were highest in the winter of 1996. Productivity and pH were the highest in the summer 1996, fall 1996, and spring 1997.

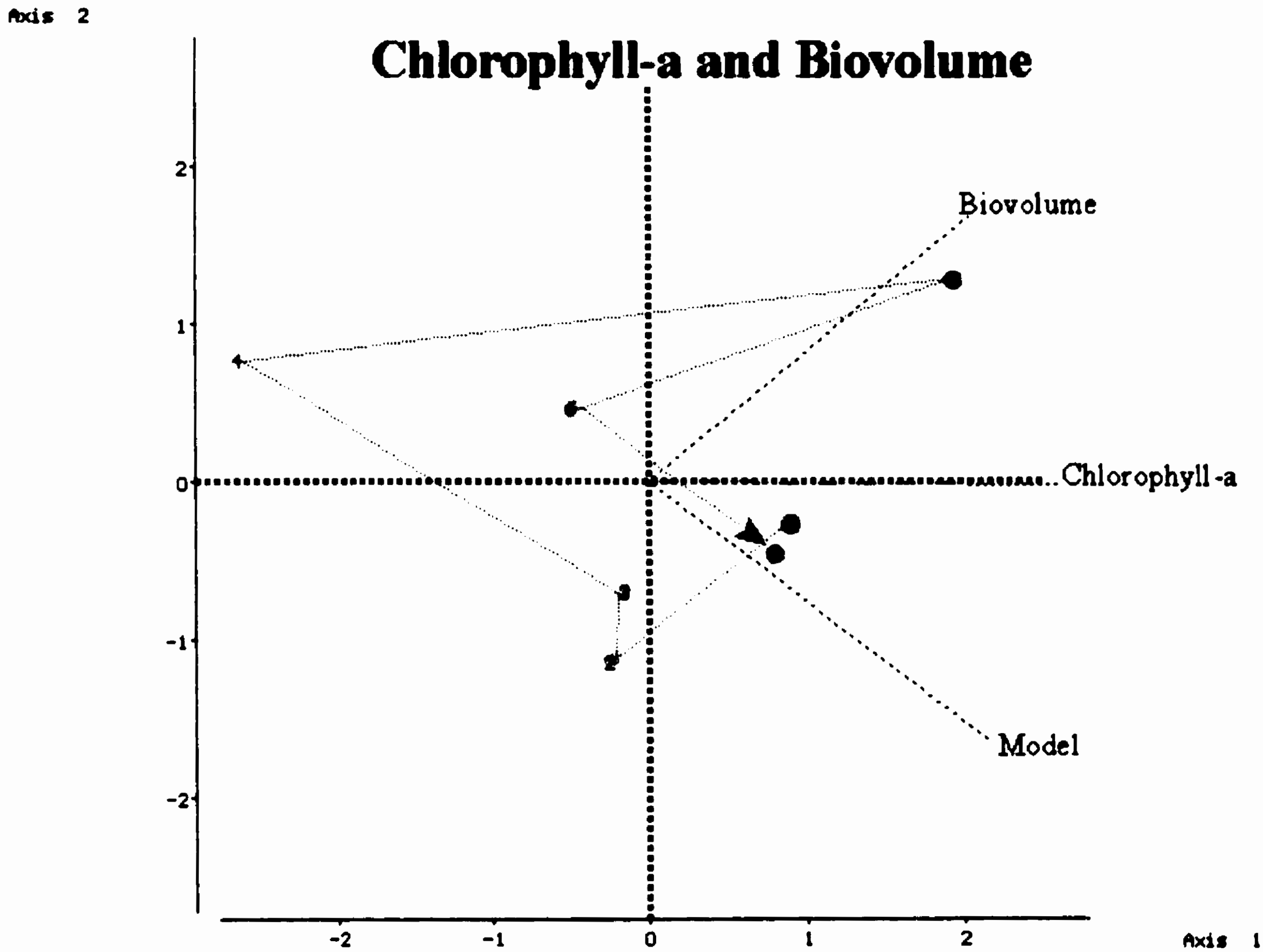
Figure 6.6 compares chlorophyll-a and total particulate biovolume with the output of Productivity Model 1. When productivity was high so were chlorophyll-a and total particulate biovolume. Winter of 1996 showed all three to be low. Biovolume was highest in the spring of 1997, and productivity was the highest in the spring of 1996 and fall of 1997.

The relationship between water chemistry (nitrogen, phosphorous, carbon, and silicon) and the output of Productivity Model 1 are displayed in Figure 6.7. When productivity and nitrate-nitrite were high, particulate organic carbon, particulate nitrogen, dissolved phosphorous, and total kjeldahl nitrogen were low. Total organic carbon and dissolved organic carbon were high when total phosphorous, silica, and particulate phosphorous were low. Spring and summer of 1996 displayed the highest levels of total organic carbon and dissolved organic carbon. Productivity and nitrate-nitrite were highest in



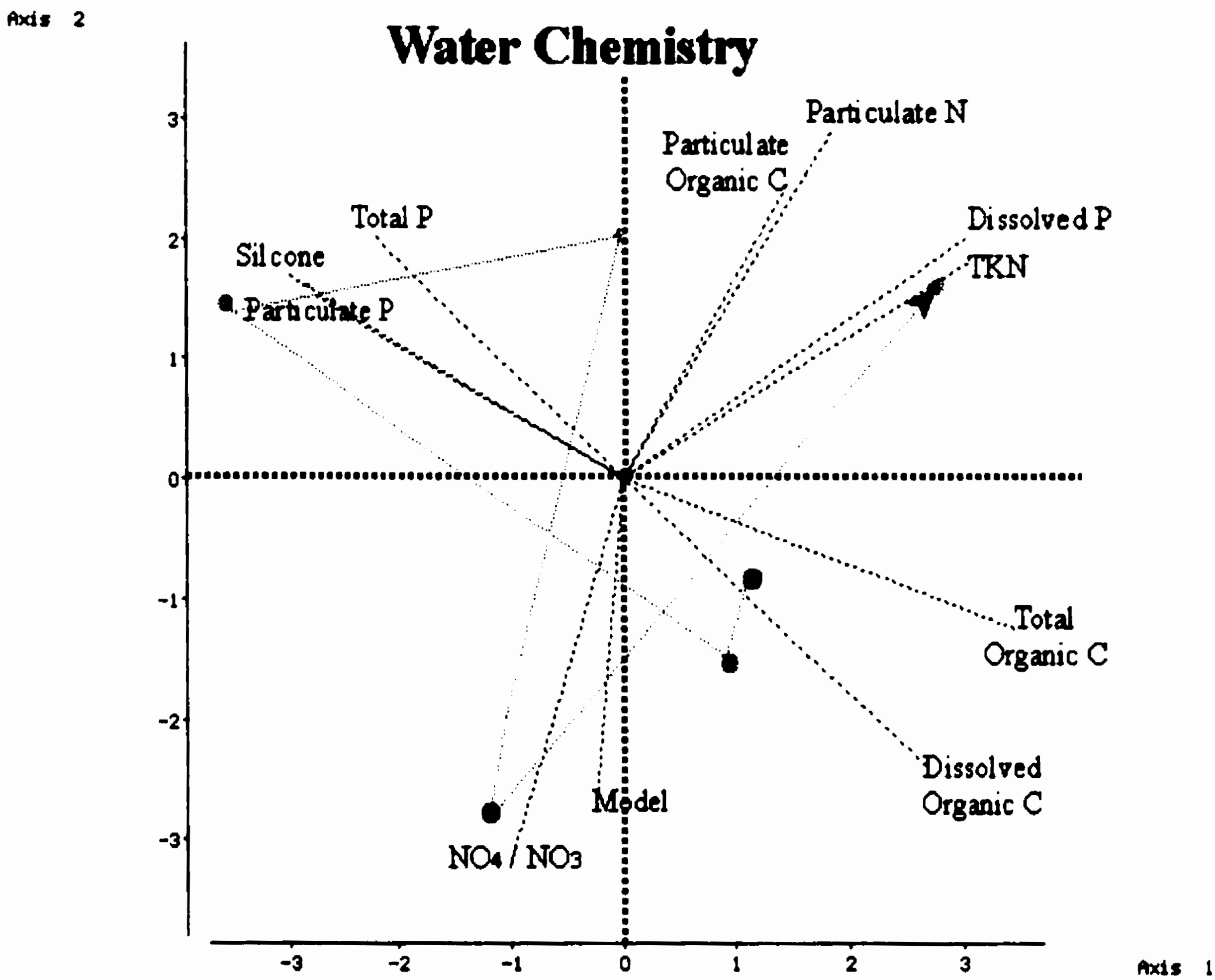
1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997
7 - Fall 1997

Figure 6.5 - Principle Components Analysis comparing the output Productivity Model 1 with Alkalinity, pH, and Dissolved Inorganic Carbon for Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 52.5% of the data. Axis 2 comprises of 29.0% of the data.



1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997
7 - Fall 1997

Figure 6.6 - **Principle Components Analysis comparing the output Productivity Model 1 with Chlorophyll-a and Phytoplankton Biovolume for Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 42.6% of the data. Axis 2 comprises of 32.6% of the data.**



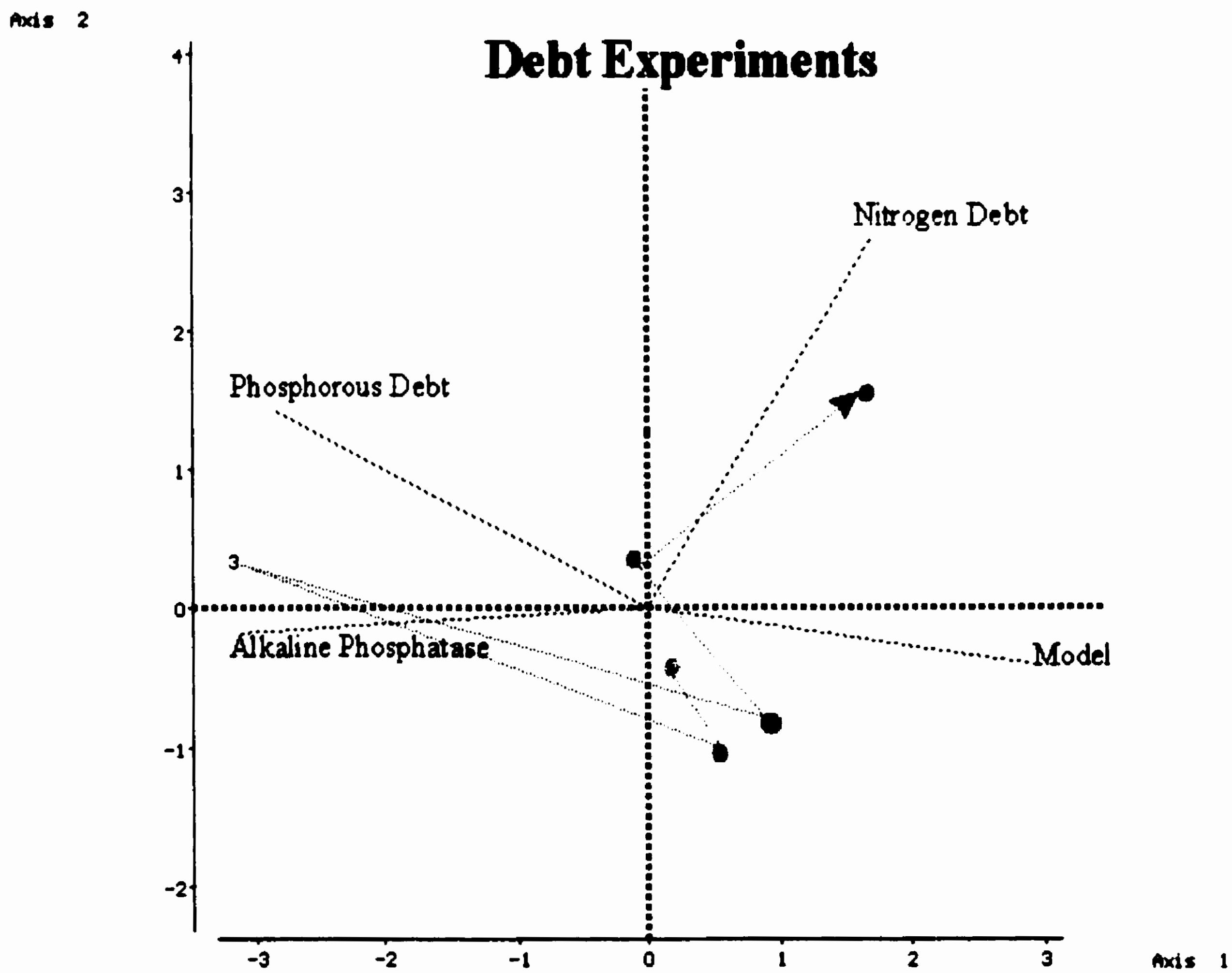
1 - Spring 1996
2 - Summer 1996
3 - Fall 1996
4 - Winter - 1996
5 - Spring 1997
6 - Summer 1997

Figure 6.7 - **Principle Components Analysis comparing the output of Productivity Model 1 with Water Chemistry for Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 41.9% of the data. Axis 2 comprises of 25.4% of the data.**

the spring of 1997. Fall of 1996 produced the highest levels of total phosphorous, silica, and particulate phosphorous. Particulate organic carbon, particulate nitrogen, dissolved phosphorous, and total kjeldahl nitrogen were highest in the summer of 1997.

The final comparison examines Nutrient Debt Assays (nitrogen debt, phosphorous debt, and alkaline phosphatase) and the output of Productivity Model 1 (Figure 6.8). When productivity was the highest, the phosphorous debt assay was the lowest. In other words, when phosphorous deficiency was experienced, productivity was the lowest. As nitrogen deficiency increased, productivity increased. Nitrogen deficiency was the highest in the fall of 1997. Winter of 1996 displayed the highest phosphorous deficiency through both phosphorous debt and alkaline phosphatase activity.

A second multivariate approach was taken to determine any control mechanisms of the output of Productivity Model 1. A stepwise multiple regression was utilized to examine correlations of light and temperature with productivity and other variables.This method is mathematically based not biologically. It does not determine controlling mechanisms but simply examines the highest correlations. The variables compared with modelled productivity were surface temperature, daily light, light history, chlorophyll-a, nitrogen debt, phosphorous debt, and alkaline phosphatase. Stations 1 and 2 were examined separately.



1 - Summer 1996
2 - Fall 1996
3 - Winter - 1996
4 - Spring 1997
5 - Summer 1997
6 - Fall 1997

Figure 6.8 - Principle Components Analysis comparing Productivity Model 1 with Debt Experiments for Clear Lake, Manitoba for the period of June 1996 to October 1997. Axis 1 comprises of 31.2% of the data. Axis 2 comprises of 30.2% of the data.

Table 6.2 - Results from the Stepwise Multiple Regression analysis of temperature and light history against productivity for Clear Lake, Manitoba for the period of June 1996 to October 1997.

		r^2	correlation	F-ratio
Surface temperature and light history				
Station 1	1996	86.4 %	0.93	94.9
Station 1	1997	30.7 %	0.554	3.76
Station 2	1996	87.0 %	0.917	100
Station 2	1997	10.6 %	0.326	1.01
Light History				
Station 1	1997	30.4 %	0.551	7.85
Station 2	1997	8.5 %	0.292	1.68

The above results (Table 6.2) display that in 1996, the productivity output of Model 1 was strongly correlated to temperature and light history. In 1997, however, this was not the case. Nutrient Status had no apparent effect on productivity. It appeared that the obvious control of primary productivity was different in each year, so further investigation of control mechanisms was needed.

Weather patterns were different between years. In 1997, stronger winds prevailed, which brought storms, shifting wind patterns, and air mass instability. Riding Mountain National Park and surrounding area was experiencing drought like conditions from extremely little rainfall and snow cover (winter 1996). Clear Lake had experienced extremely high water levels in 1995. In fact, the main pier in Wasagaming was about 30 cm under water due to high amounts of rainfall causing most of the inlets to overflow their banks. Spruces became a raging river that flooded out Highway #10. Clear Creek, the only outlet, was flowing at peak levels and continued to flow through the winter months. The flow in Clear Creek had dropped drastically in 1996 and by the end of the season very little flow occurred at all. Lake level began to decrease. In 1997, Clear Creek did not flow at all and the lake level continued to decrease. The main pier was by then about 60 cm out of the water. The next section will discuss the possibility that these changed conditions may have accounted for the apparent difference in the control of phytoplankton primary productivity in 1996 and 1997.

6.3 Control Mechanisms

6.3.1 Nutrient Regulations

Although nutrient status was ruled out as a control mechanism because none of the nutrient variables were selected by stepwise regression, nutrient limitations were indeed experienced. The assays employed to decide limitation displayed varying results. For algal growth and reproduction to occur a variety of nutrients are needed in varying concentrations. Most of these are found in sufficient quantities so as not to affect growth but phosphorous, nitrogen, and sometimes silicon maybe limiting. Phosphorous can be limiting in lakes whereas nitrogen is often the limiting nutrient in the sea. Silicon can limit diatom growth in both freshwater and marine systems (Darley, 1982). Deficiency or limitation can cause stress that can result in inefficient photosynthesis.

A composition of elemental ratios displayed that phosphorous deficiency occurred on 72% (N/P ratio) of sampling occasions and 8% using the C/P ratio. Carbon deficiency was determined from the C:Chl-a ratio (44% of the samples). These results were based on 25 sample points as compared with the debt experiments, which were based on 100 sampling occasions.

Nitrogen debt suggested severe nitrogen deficiency on 51% of sampling occasions and was higher in 1997 than in 1996. Phosphorous debt suggested severe phosphorous deficiency on 5% of sampling occasions with 1997, results again being higher. Alkaline phosphatase activity (for which here were 82 assays) displayed severe phosphorous deficiency on 85% of sampling occasions but the 1996 values were higher. Nutrient deficiency did vary with seasons as displayed in Figure 6.8. When phosphorous deficiency was experienced, productivity output of Model 1 was the lowest. As nitrogen deficiency increased, productivity output of Model 1 increased. Undoubtedly, both phosphorous and nitrogen deficiency did, in fact, impact productivity, but likely this impact was not as pronounced as the influence of light and temperature in 1996, and did not correlated with productivity in each year.

6.3.2 Lake Temperature

Circulation of the water body is dependent on temperature and wind stress. Williams (1978) showed that in one situation after stratification the concentration of nitrate decreased to be limiting and thus reduced α. Harris *et al.* (1980) found that in Hamilton Harbour, P_{max} and I_k increased with an index of water column stability. The lag time was about one week. Nanoplankton in the Bedford Basin showed an opposing relationship between stratification and biological activity (Cote and Platt, 1983).

The temperature profiles for Clear Lake varied between the two years. Figures 6.9 and 6.10 display these differences. As the isopleth graphs illustrate, there was somewhat less thermal stability in 1997. The thermal gradient was steeper and the thermocline was deeper

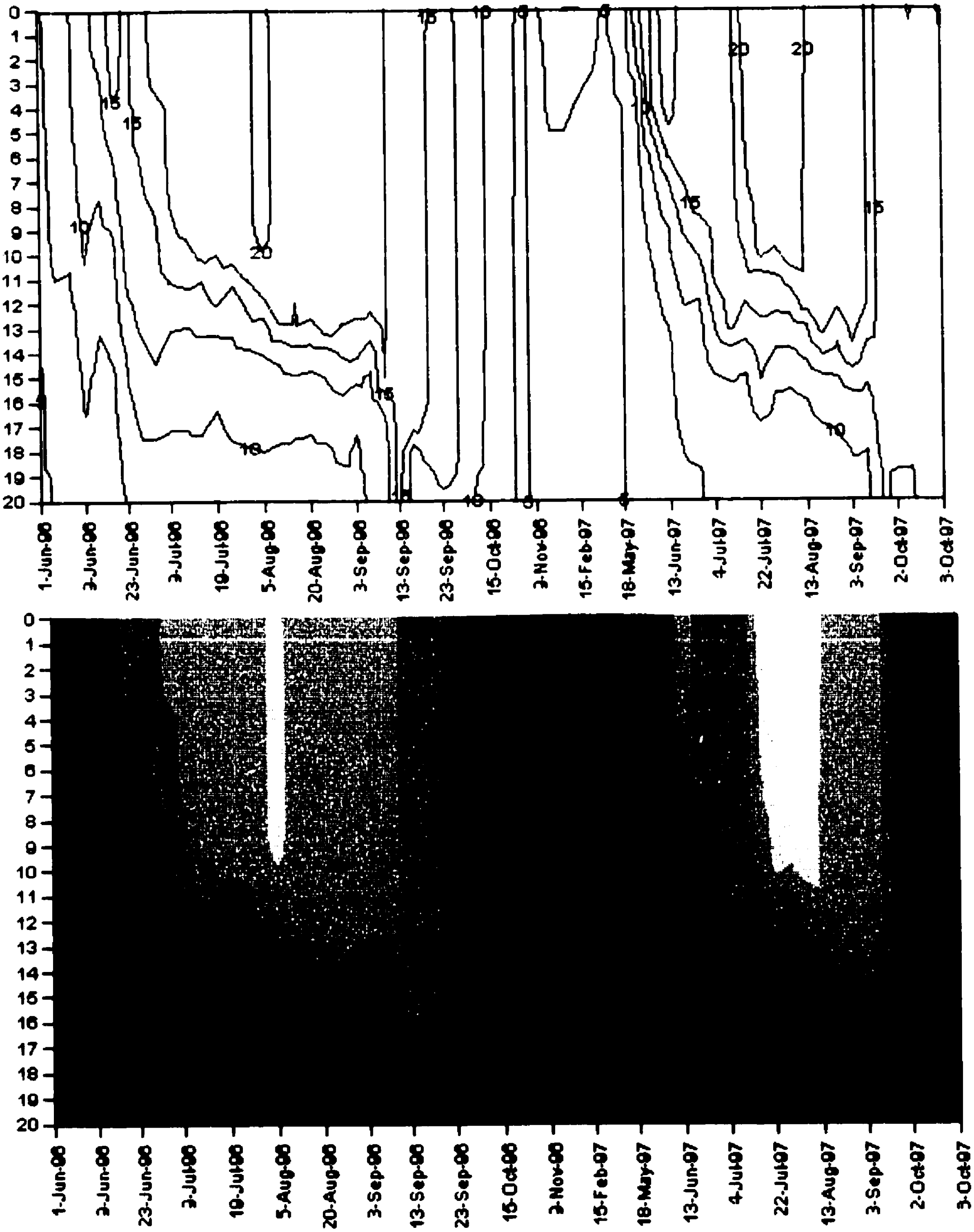
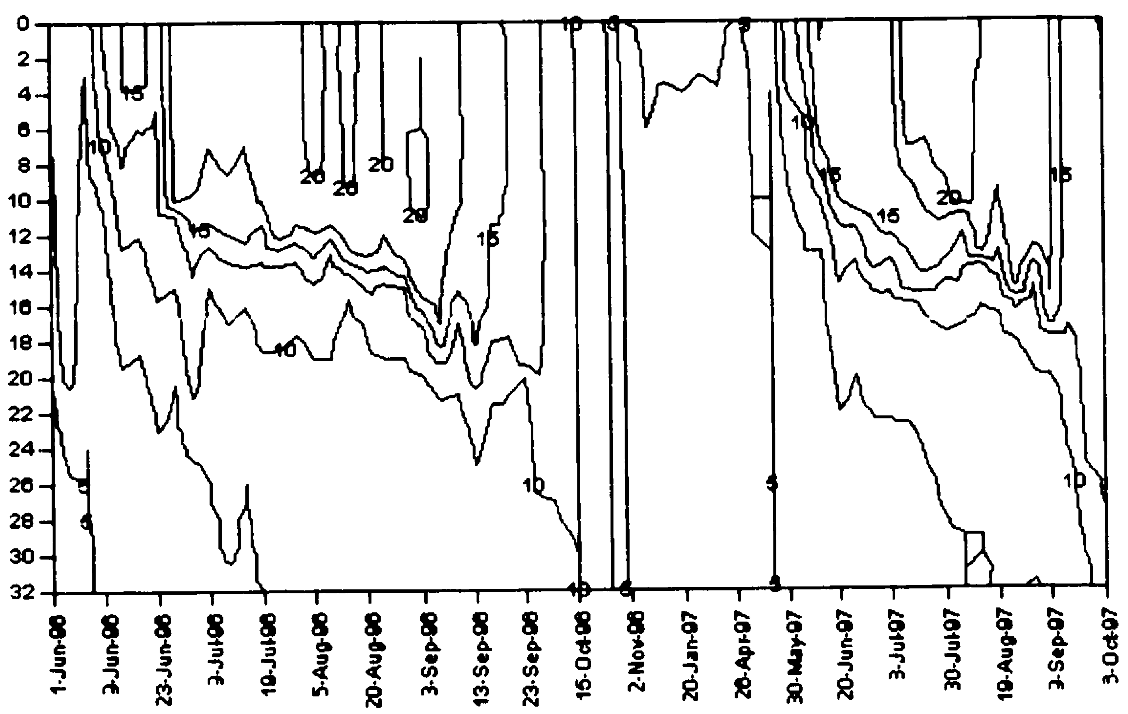


Figure 6.9 - Isopleth graph and diagram of water temperature in the water column for Station 1 in Clear Lake, Manitoba for the period of June 1996 to October 1997. Each isopleth is in 5°C increments.



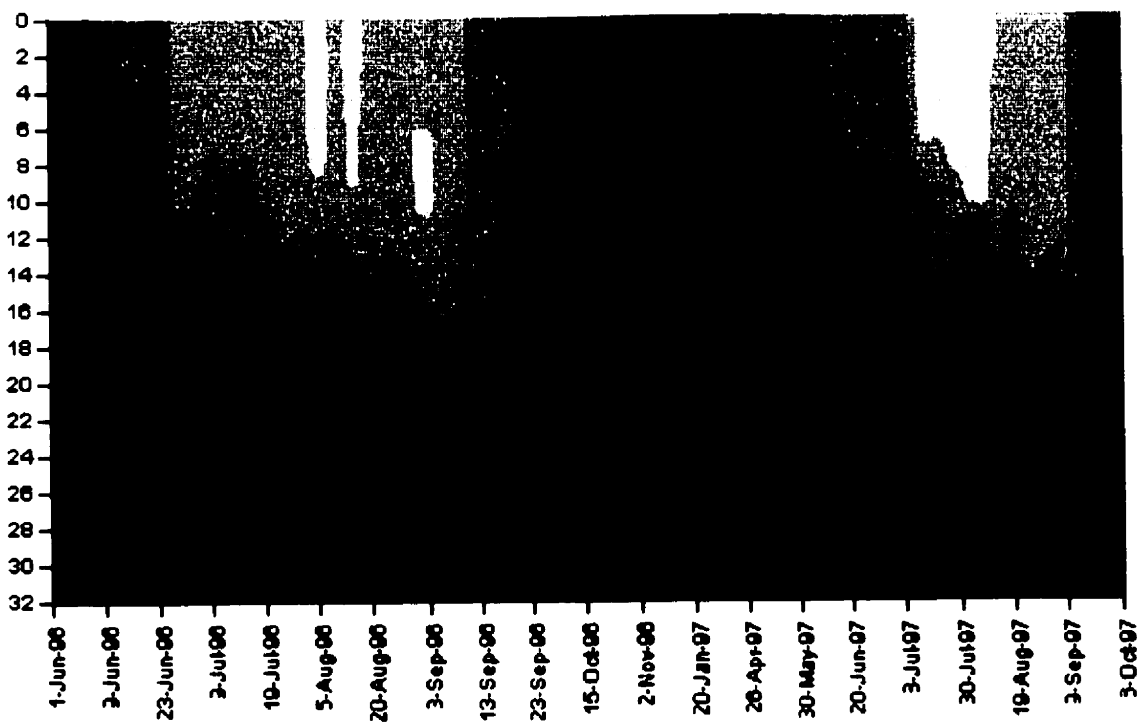


Figure 6.10 - Isopleth graph and diagram of water temperature in the water column for Station 2 in Clear Lake, Manitoba for the period of June 1996 to October 1997. Each isopleth is in 5°C increments.

in 1997. Wind may have been a significant contributing factor.

6.3.3 Wind

Phytoplankton is sensitive to turbulence because resulting rapid light fluctuations influence the impact of light history on species survival (Harris *et al.*, 1980). Deep water mixing, caused by transient physical phenomena (storms and upwellings) may well influence any normal seasonal progression of phytoplankton community structure and growth conditions (Cote and Platt, 1983).

Wind can cause the breakdown of the thermocline, which can mix the phytoplankton out of the photic zone, ultimately decreasing productivity within the lake. Wind speed (average speed per day in km / hour) had no obvious affect on phytoplankton productivity in 1996 (Figure 6.11). Principle Coordinates Analysis (Figure 6.17) confirms that wind speed had no direct influence on productivity Model 1 output. The wind, although variable, appeared to be consistently low throughout the summer months of 1996. As fall approached, wind speed increased and fall turnover occurred as productivity decreased. Figure 6.12

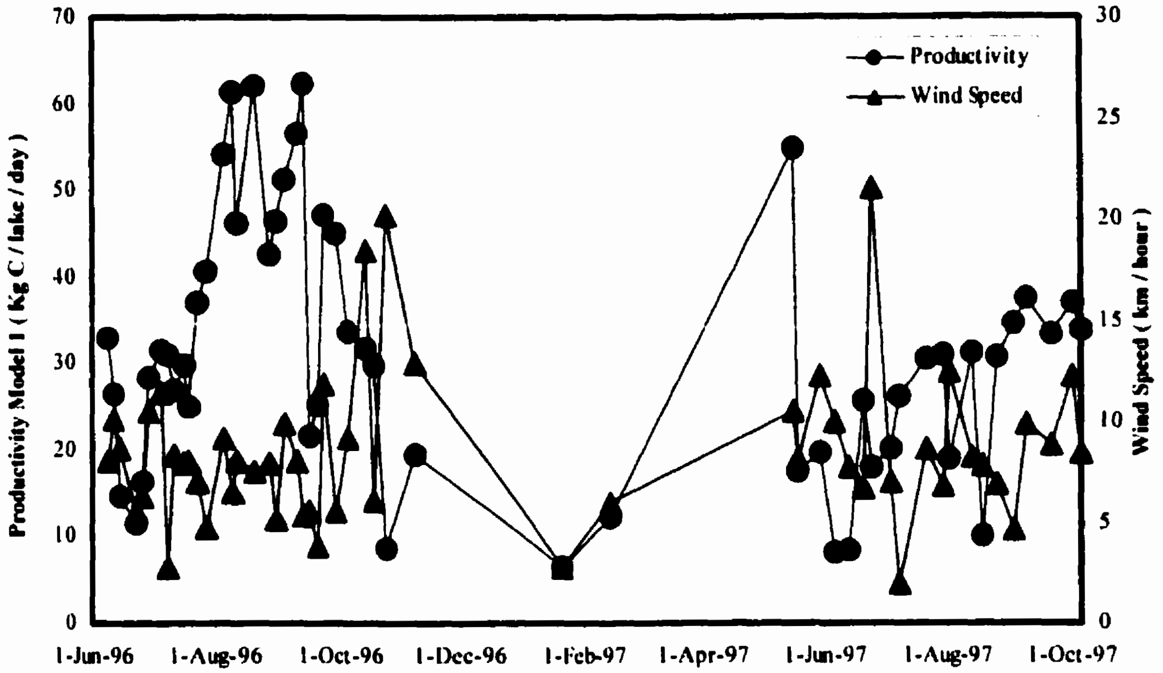


Figure 6.11 - A time series plot of productivity output from Model 1 and average wind speed (calculated for each week) in Clear Lake, Manitoba from June 1996 to October 1997.

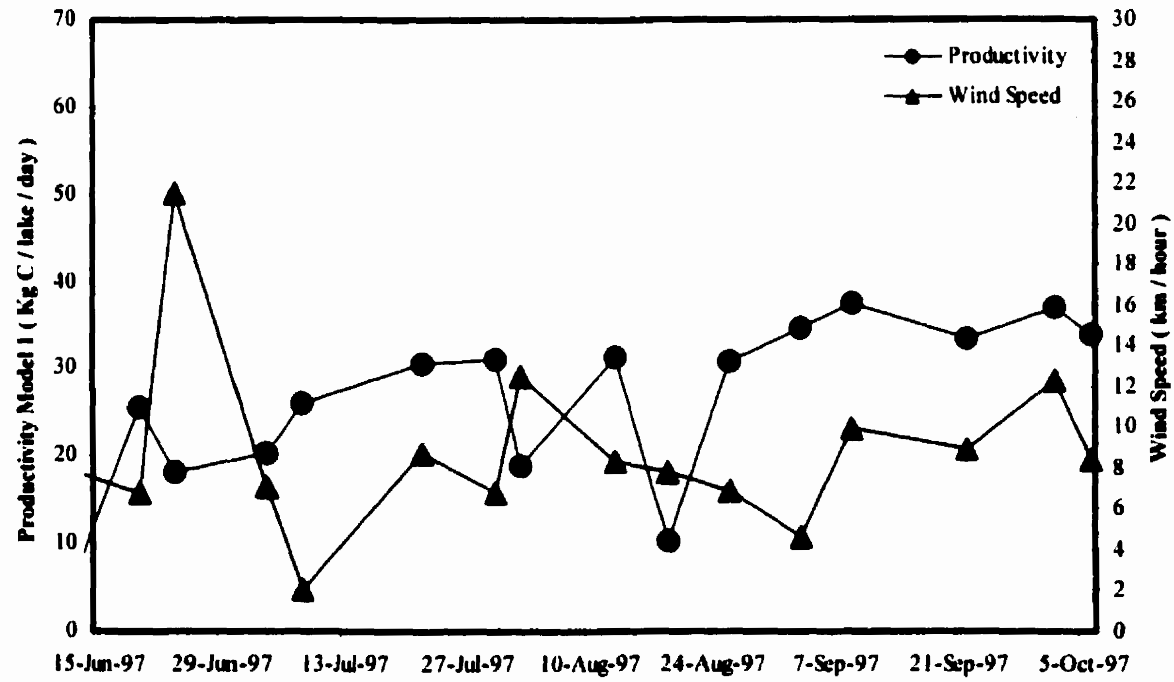


Figure 6.12 - A time series plot of productivity output from Model 1 and average wind speed (calculated) in the latter portion of 1997in Clear Lake, Manitoba.

illustrates that the trend that was seen in 1997. The winds in 1997 were more variable and stronger. June maximum wind speed (21.55 km/hour) was almost double of 1996 (10.56 km/hour). During July and August, the wind speeds were slightly higher then compared with 1996, however, September and October were somewhat lesser. Higher wind speed in 1997 did relate to decreased productivity. Further investigations showed when wind speed was higher than 8 to 9 km/hour, productivity decreased (Figure 6.15). This trend was not experienced in 1996 because wind speed was generally lower than this possible 'critical' value. It is speculated that wind in 1997 may have caused deeper mixing of phytoplankton during the summer months thus reducing productivity, although total particulate biovolume was higher in 1997 and does not directly support this speculation. It should be noted, however, that productivity and phytoplankton biomass need not be expected to be related to each other.

6.3.4 Lake Level

As discussed earlier, Clear Lake experiences a distinct hydrological cycle. In 1996, the lake level dropped a total of 0.297 m and no relationship between lake level and productivity was evident. Figures 6.13 and 6.14 illustrate that a small trend was seen in 1997, during which the lake level dropped a total of 0.200 m. As lake level decreased, productivity increased (Figure 6.16). Over the study the lake dropped 0.415 m. Principle Coordinates Analysis (Figure 6.17) illustrates that as Model 1 productivity increased, lake level decreased. Productivity was highest in September / October, whereas lake levels were highest in June. This relationship suggests that as the lake level decreased, volume decreased causing an

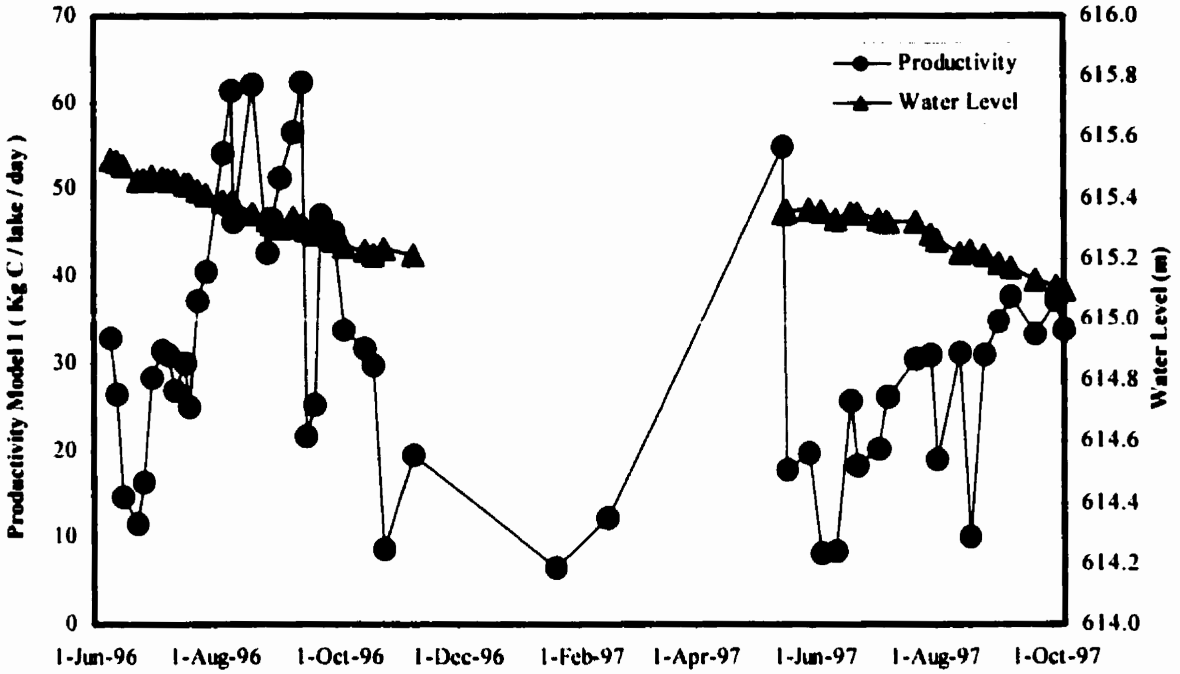


Figure 6.13 - A time series plot of productivity output from Model 1 and lake level in Clear Lake, Manitoba from June 1996 to October 1997.

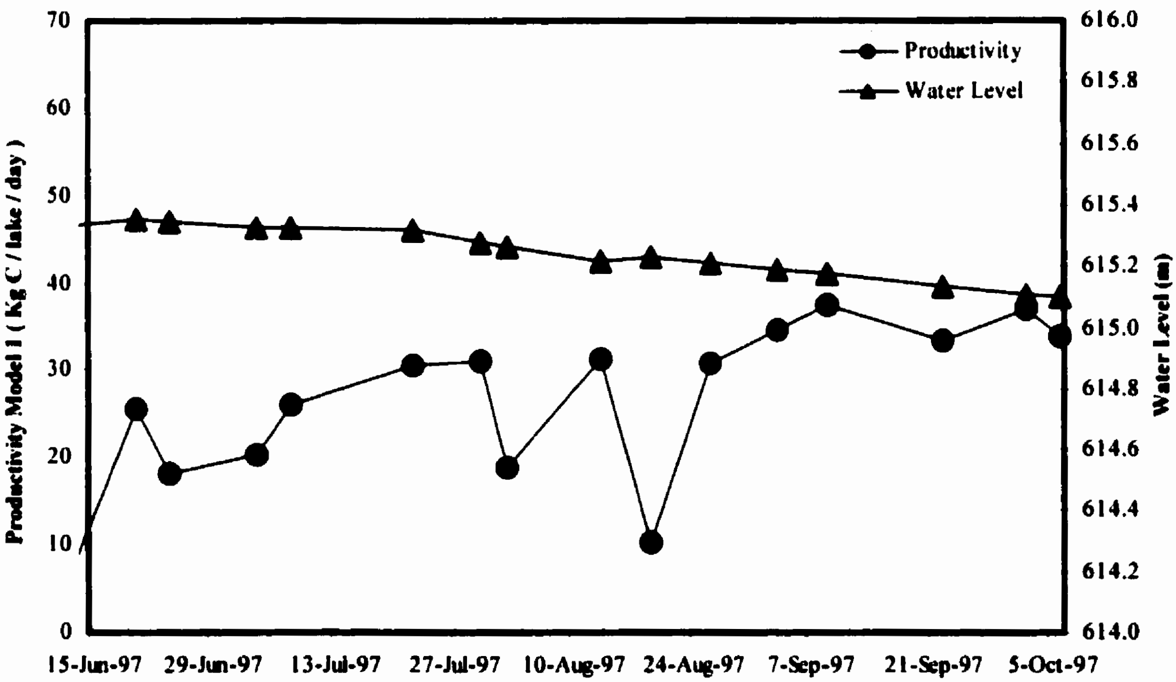


Figure 6.14 - A time series plot of productivity output from Model 1 and lake level in the latter portion of 1997in Clear Lake, Manitoba.

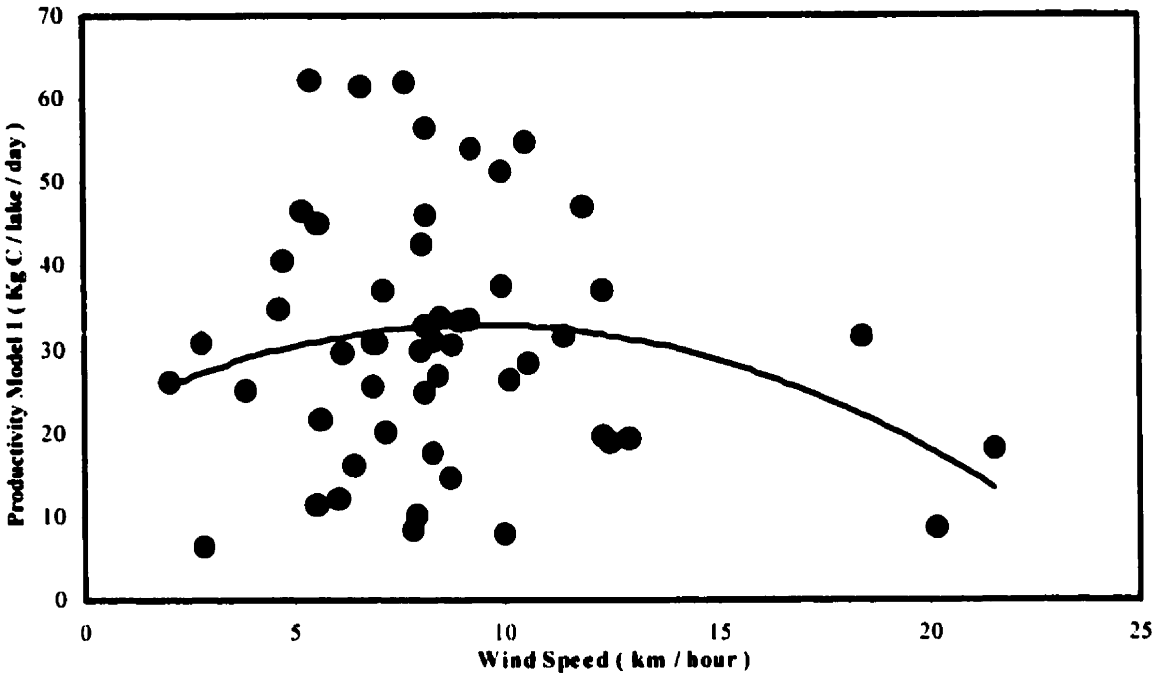


Figure 6.15 - A comparison of productivity output from Model 1 and average wind speed (calculated for each week) in Clear Lake, Manitoba from June 1996 to October 1997. Trend line is calculated polynomial (y = -131.76x2 + 2471.4x + 21397)line .

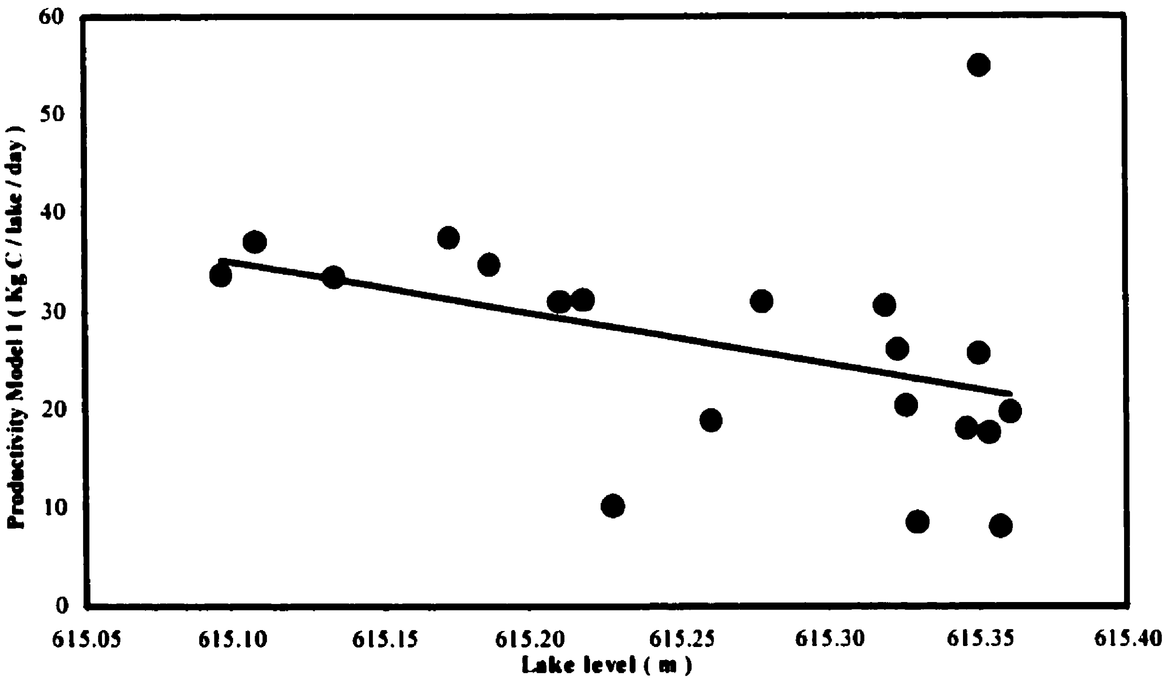


Figure 6.16 - A comparison of productivity output from Model 1 and lake level in Clear Lake, Manitoba from June 1996 to October 1997. Trend line is calculated as linear (y = -52498x + 3E+07).

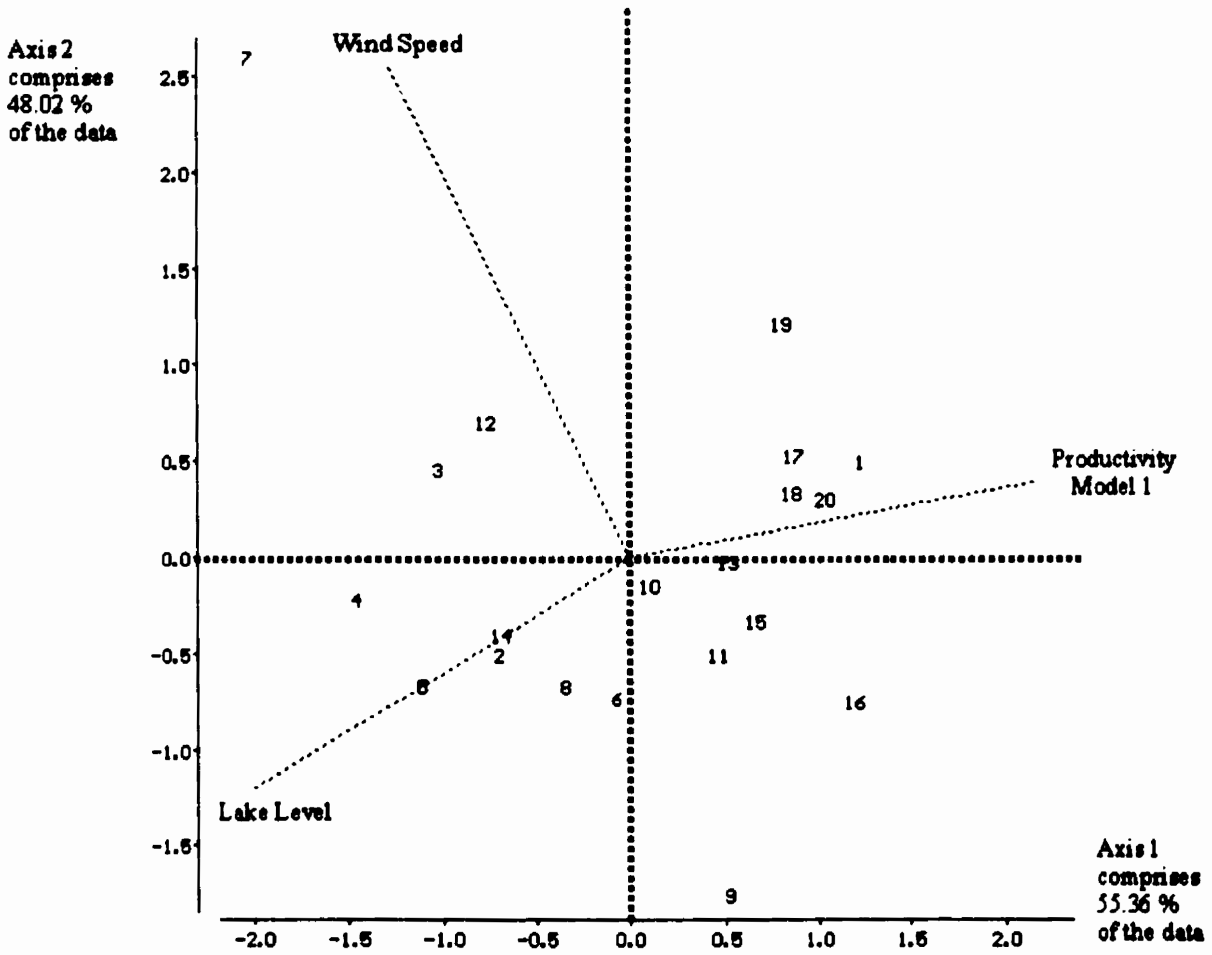


Figure 6.17 - Principle Coordinates Analysis (PCA) of Productivity Model 1 (g C / m^3 / day), Lake Level (m), and Wind Speed (km / hour) for Clear Lake, Manitoba for 1997. The sampling points are indicated by the numbers.

increase in nutrient concentration, which increased density of cells, as demonstrated by the total particulate biovolume. The result was an increase in phytoplankton production.

6.4 Summary

1. Temperature affected phytoplankton primary productivity: P_{max} increased as surface temperature and thermocline depth increased because P_{max} is enzymatic and is temperature dependent; α increased as the thermocline depth increased but as surface temperature and thermal gradient decreased; and I_k increased as surface temperature and thermal gradient increased but thermocline depth decreased.

2. Light affected the productivity parameters: P_{max} increased with increased light extinction but decreased as daily light, light history and compensation point increased; α increases with increased light extinction but decreased as daily light, light history and compensation point increased.This is expected because α is a photochemical phase; and I_k increased as daily light, light history, and compensation point increased but light extinction decreased.

3. Productivity Models 2 and 3 overestimated the productivity occurring within the lake. Productivity Model 2 produced a curve that resembled the curve produced by the light data corrected for ice and snow Productivity Model 3 displayed an overall trend similar to the trend produced by smoothed and corrected PAR data. No difference

was seen between the years and daily variability and seasonality dynamics were lost.

4. Output of Productivity Models 1 and 2 were highest in the summer of 1996 and lowest in the winter of 1996. These two models were driven by the productivity parameters calculated from individual sampling points.

5. Productivity Model 3 was high in the spring of 1996 and 1997 and summer of 1997. This model was driven by a single equation derived from all sampling occasions, a mean photic zone, and an overall mean chlorophyll (used for chlorophyll-a normalization). The light data used was smoothed and corrected. Since the productivity parameters were consistent, the available light (PAR) would dictate highs and lows of productivity.

6. In the summer of 1996 and 1997, Productivity Model 1 output, thermal gradient, and surface temperature were highest. Total Light and light history were the highest in the spring of 1996 and 1997. Light extinction and thermocline depth were the highest in the fall of 1996 and 1997.

7. As Productivity Model 1 output and pH were high, alkalinity and dissolved inorganic carbon were low. Dissolved inorganic carbon and alkalinity were highest in the winter of 1996. Productivity Model 1 output and ph were the highest in the summer 1996, fall 1996, and spring 1997.

8. Biovolume was highest in the spring of 1997. Productivity Model 2 output was the highest in the spring of 1996 and fall of 1997.

9. Spring and summer of 1996 displayed the highest levels of total organic carbon and dissolved organic carbon. Productivity Model 1 and nitrate-nitrite were highest in spring of 1997. Fall of 1996 produced the highest levels of total phosphorous, silica, and particulate phosphorous. Particulate organic carbon, particulate nitrogen, dissolved phosphorous, and total kjeldahl nitrogen were highest in the summer of 1997.

10. As nitrogen deficiency increased, Productivity Model 1 output increased. Nitrogen deficiency was the highest in the fall of 1997. Winter of 1996 displayed the highest phosphorous deficiency as indicated by phosphorous debt and alkaline phosphatase activity.

11. Stepwise multiple regression displayed that in 1996, Productivity Model 1 output was correlated with temperature and light (r^2 = 86.4% - 87%) and F-ratio (94.9 - 100). In 1997, light and temperature were not correlated with Productivity Model 1 output. Nutrient Status had no affect on Productivity Model 1 output.

12. Elemental ratio comparison displayed that phosphorous deficiency occurred on 72% (N/P ratio) and 8% using the C/P ratio of the sampling occasions. Carbon

deficiency (determined from the C:Chl-a ratio) occurred on 44% of samples occasions. These results were based on 25 sample points as compared with the debt experiments, which were based on 100 sampling points.

13. The nutrient debt experiments provided physiological indicators that suggest deficiency. Severe nitrogen deficiency was experienced 51% of the time and severe phosphorous deficiency was experienced 5% of the time using phosphorus debt determinations. In both assays, 1997 results were higher than in 1996. When phosphorous deficiency was experienced through both phosphorous debt and alkaline phosphatase, Productivity Model 1 output was the lowest and nitrogen deficiency increased, Productivity Model 1 output increased.

14. The temperature profiles for Clear Lake varied between the two years by the thermal gradient being steeper and the thermocline deeper in 1997. Wind may have been the factor responsible for the thermal instability in 1997.

15. Higher wind speed appeared to decrease productivity in 1997. Further investigations showed when wind speed was higher than 8 to 9 km/hour, productivity decreased. This trend was not experienced in 1996 when wind speeds were lower. Wind speed affect seemed to phytoplankton productivity in 1997 by increased winds cause deeper mixing to occur. An expected consequence would be decreased density of phytoplankton cells because the cells were being mixed

into deeper waters, although phytoplankton biovolumes did not support this.

16. Principle Coordinates Analysis indicates that as Productivity Model 1 output increased, lake level decreased. Productivity was highest in September / October, whereas lake levels were highest in June. This relationship suggests that as the lake level decreases, volume decreased causing an increase in nutrient concentration, which increases density of cells. The result was an increase in phytoplankton production.

6.5 Conclusions

1. Clear Lake Productivity

Yearly and seasonal differences occurred (Figures 5.33 and 5.34) with 1996 being more productive than 1997. The mean daily productivity for the entire period sampled was 31.0 Kg C / lake/day (1.1E-06 Kg C / m^2/day) with a minimum of 0.9 Kg C / lake/day (3.1E-08 Kg C / m^2/day) and maximum of 71.1 Kg C / lake/day (2.4E-06 Kg C / m^2/day). The summer of 1996 displayed the highest daily productivity (37.4 Kg C / m^3/day), while the lowest daily productivity (9.4 Kg C /m^3/ day) was in the winter of 1996. Major peaks in productivity were seen late August / early September when conditions were likely optimal. In 1997, a spring peak was achieved. Six distinctive stages or lines were determined:

Stage 1 - June 9, 1996 - August 16, 1996 - gradual increase in summer productivity

Stage 2 - August 17, 1996 - November 9, 1996 - a decrease occurred

Stage 3 - November 11, 1996 - May 9, 1997 - ice season with low productivity and very little change

Stage 4 - May 10, 1997 - June 9, 1997 - represents decrease in productivity from the spring bloom

Stage 5 - June 10, 1997 - July 31, 1997 - gradual increase in summer productivity

Stage 6 - August 1, 1997 - October 6, 1997 - an increase was seen after August 1, 1997

2. Productivity Modelling

As discussed in Chapter 5 (section 5), the models displayed similarities but were very different (Table 6.1). *In situ* phytoplankton productivity in Clear Lake was best estimated by using photosynthesis parameters ('alpha' (α), Pmax, and 'beta' (β)) derived from *in vitro* experiments (incubator), euphotic depth, the extinction of PAR within the lake, and hourly integrations of PAR as in Productivity Model 1.

3. Control Mechanisms

A stepwise multiple regression examined correlations of light and temperature with productivity and other variables. It was determined that the obvious control of primary productivity was different in each year, so further investigation into control mechanisms was needed.

4. Year 1 - 1996 - Light and Temperature

Stepwise multiple regression displayed that Productivity Model 1 output was correlated with temperature and light (r^2 = 86.4% - 87%) and F-ratio (94.9 - 100).

5. Year 2 - 1997 - Wind and Water depth

Stepwise multiple regression displayed that light and temperature were not correlated with Productivity Model 1 output. Nutrient Status had no affect on Productivity Model 1 output. Clear Lake temperature profiles varied between the two years by the thermal gradient being steeper and the thermocline deeper in 1997. Wind may have been the factor responsible for the thermal instability in 1997. Two other factors were examined closer:

A. Wind speed - The winds in 1997 were more variable and stronger. June maximum wind speed (21.55 km/hour) was almost double that of 1996 (10.56 km/hour). Further examinations displayed when wind speeds were higher than 8 to 9 km/hour, productivity decreased It is speculated that wind in 1997 may have caused deeper mixing of phytoplankton during the summer months thus reducing productivity, although total particulate biovolume was higher in 1997 and does not support this speculation.

B. Water Depth - Clear Lake experiences a unique hydrological cycle. Over the study the lake dropped 0.415 m. Principle Coordinates Analysis illustrated that as Model 1 productivity increased, lake level decreased. This relationship suggests that as the lake level decreases, volume decrease causing an increase in nutrient concentration, which increased density of cells, as demonstrated by the total particulate biovolume. The result was an increase in phytoplankton production.

6. Nitrogen and Phosphorous Deficiency

Phosphorous deficiency, with phosphorous debt and alkaline phosphatase, was experienced when Model 1 productivity output was the lowest, whereas when nitrogen deficiency increased, Model 1 productivity output increased.

7. Phytoplankton Domination

Phytoplankton species found fall within the following classes: Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cryptophyceae, Cyanobacteria, and Dinophyceae. Average total particulate volumes (Station 1 and Station 2 combined) were higher in the 1997 season with the Dinophyceae dominating. Bacillariophyceae shifted to dominance in June 1997. In 1996, the Bacillariophyceae dominated especially during July / August and November to January. The common species were *Dinobryon sociale, Fragilaria crotonensis, Pediastrium duplex, Stephanodiscus niagarae, Cyclotella bodanica, Tabellaria fenestrata, and Peridinium sp.* Dominating phytoplankton species depended upon season:

- Ice season and Summer of 1997 - *Peridinium* sp.
- Spring and Summer of 1996 - *Fragilaria* sp.
- Spring of 1996 - *Tabellaria* sp.
- Spring of 1997 *Synedra* sp.

REFERENCES

Ahlgren, Gunnel. 1980. Effects on algal growth rates by multiple nutrient limitations. Arch. Hydrobiol. 89:43-53.

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1992. Standard Methods for the examination of Water and Wastewater - 13ed. pp 52-56.

Baird and Associates. 1994. Riding Mountain National Park - Clear Lake Beach Waterfront Study. Baird and Associates. Ottawa, Ontario.

Banse, K. 1976. Rates of growth, respiration, and photosynthesis of unicellular algae as related to cell size - A review. J. Phycol. 12:135-140.

Bazillion, Helen, and Braun, Connie. 1992. Human Intervention in the Clear Lake Basin in Riding Mountain National Park - Visitor Services. The Rural Development Institute. Brandon University. Brandon, Manitoba.

Canadian Heritage Parks Canada. 1989. National Parks Act. Minister of Supply and Services Canada. Ottawa, Canada. 147p.

Canadian Heritage Parks Canada. 1994. The Guiding Principles and Operational Policies. Minister of Supply and Services Canada. Ottawa, Canada. 125p.

Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian Water Quality Guidelines.. Ottawa, Ontario.

Cole, Gerald A. 1983. The textbook of Limnology. Waveland Press. Prospect Heights, Illinois. 401p.

Cote, B., and Platt, T. 1983. Day to day variations in the spring-summer photosynthetic parameters of coastal marine phytoplankton. Limnol. Oceanogr. 2(28):320-344.

Darley, W.M. 1982. Algal biology: a physiological approach. Blackwell Scientific Publications.

Data Descriptions, Inc. 1988. DataDesk (version 6).

DeLCan Consulting Engineers and Planner. 1982. Clear Lake Beach Study - Riding Mountain National Park, Manitoba.

Dodds, Walter K., and Priscu, John C. 1990. A comparison of methods for assessment of nutrient deficiency of phytoplankton in a large oligotrophic lake. Can. J. Fish. Aquat. Sci. 47:2328-2338.

Droop, M.R. 1973. Some thoughts on nutrient limitation in algae. J. Phycol. 9:264-272.

Droop, M.R. 1974. The nutrient status of algal cells in continuous culture. J. mar. biol. 54:825-855.

Ecosystem Conservation Plan Team. 1997. Riding Mountain National Park - Ecosystem Conservation Plan. Canadian Heritage Parks Canada.

Dunstan, W.M. 1973. A comparison of the photosynthesis - light intensity relationship in phylogenetically different marine microalgae. J. Exp. Mar. Biol. Ecol. 13:181-187.

Ecosystem Conservation Plan Team. 1997. Riding Mountain National Park - Ecosystem Conservation Plan. Canadian Heritage Parks Canada.

Falkowski, Paul G., and Owens, Thomas G. 1980. Light-Shade Adaptations: two strategies in marine phytoplankton. Plant Physiol. 66:592-595.

Fee, E.J., Hecky, R.E., and Welch, H.A. 1987. Phytoplankton photosynthesis parameters in central Canadian lakes. J. Plank. Res. 9(2):305-316.

Fee, E.J., Shearer, J.A., DeBruyn, E.R., and Schindler, E.U. 1992. Effects of Lake size on Phytoplankton Productivity. Can. J. Fish. Aquat. Sci. 49:2445-2459.

Feuillade J.B and Feuillade M. G. 1975. Etude des besoins en azote et en phosphore d'Oscillatoria rubescens. D.C. a l'aide de cultures en chemostats. Verh. Internat. Verein. Limnol. 19:2698-2708.

Fleet, R.J., Schindler, D.W, Hamilton, R.D., and Campbell, N.E.R. 1980. Nitrogen Fixation in Canadian Precambrian Shield Lakes. Can. J. Fish. Aquat. Sci. 37:493-505.

Fitzgerald, George P. 1969. Field and Laboratory evaluations of bioassays for nitrogen and phosphorus with algae and aquatic weed. Limnol. Oceanogr. 14:206- 212.

Forti, Giorgio. 1966. Light energy utilization in photosynthesis. In CR. Goldman (ed.), Primary Productivity in Aquatic Environments. (pp 19-35).University of California Press.

Frey, Sean. 1997. Bathymetric map. Personal Communication.

Gallegos, L.G., Platt, T., Harrison, W.G., and Irwin, B. 1983. Photosynthetic parameters of arctic marine phytoplankton: Vertical variations and time scales of adaptation. Limnol. Oceanogr. 4(28):698-708.

Geider, R.J., and Osborne, B.A. 1992. Algal photosynthesis. Chapman and Hall.

George, V. A. 1917. Water Resources Paper #19. Department of the Interior.

Glufka, Roger. 1992. Water Quality in the Clear Lake Basin in Riding Mountain National Park. The Rural Development Institute. Brandon University. Brandon, Manitoba.

Glover, H.E., Keller, M.D., and Spinard, R.W. 1987. The effects of light quality and intensity on photosynthesis and growth of marine eukaryotic and prokaryotic phytoplankton clones. J. Exp. Mar. Biol. Ecol. 105:137-159.

Goldman, J.C. 1980. Physiological processes, nutrient availability, and the concept of relative growth rate in marine phytoplankton ecology. In Primary Productivity in the sea (ed. P.G. Falkowski). Plenum Press. New York, New York. 179-194.

Guillard and Lorenzen. 1972. Yellow - green algae with Chlorophyllide C. J. Phycol. 8:10-14.

Halldal, P. 1970. The photosynthetic apparatus of microalgae and its adaptation to environmental factors. In P. Halldal (ed.), Photobiology of micro-organisms. (pp.17-55). Wiley Interscience.

Harding, L.W., Prezelin, B.B., Sweeney, B.M., and Cox, J.L. 1982. Diel Oscillations of the Photosynthesis - Irradiance (P-I) relationships in Natural Assemblages of Phytoplankton. Marine Biology. 67:167-178.

Harris, G.P. 1978. Photosynthesis, productivity, and growth: The physiological ecology of the phytoplankton. Arch. Hydrobiol. Beih. Ergeb. Limnol. 10:1-171.

Harris, Graham P., Haffner, G. Douglas, and Piccinin, B. Beryl. 1980. Physical variability and phytoplankton communities: II. Primary productivity by phytoplankton in a physically variable environment. Arch. Hydrobiol. 88(4):393-425.

Harrison, W.G., and Platt, T. 1980. Variations in assimilation number of coastal marine phytoplankton: Effects of environmental co-variates. J. Plank. Res. 2(4)249-260.

Healey, F.P. 1973. Characteristics of phosphorous deficiency in Anabaena. J. Phycol. 9:383-394.

Healey, F.P. 1975.Physiological indicators of nutrient deficiency in algae. Fish. Mar. Serv. Res. Dev. Tech. Rep. 585: 30p.

Healey, F.P. 1977. Ammonium and urea uptake by some freshwater algae. Can. J. Bot. 55:61-69.

Healey, F.P., and Hendzel, L.L. 1979. Indicators of phosphorous and nitrogen deficiency in five algae culture. J. Fish. Res. Board Can. 36:1364-1369.

Healey, F.P., and Hendzel, L.L. 1979b. Fluorometric measurement of alkaline phosphatase activity in algae. Freshwater Biology. 9:429-439.

Healey, F.P., and Hendzel, L.L. 1980. Physiological indicators of nutrient deficiency in lake phytoplankton. Can. J. Fish. Aquat. Sci. 37:442-453.

Hecky, R.E. Campbell, P., and Hendzel, L.L. 1993.The stoichiometry of carbon, nitrogen, and phosphorous in particulate matter of lakes and oceans. Limnol. Oceanogr. 38:709-724.

Hecky, R.E. and Kilham, P. 1988. Nutrient limitation of phytoplankton in freshwater and marine environments: A review of recent evidence on the effects of enrichment. Limnol. Oceanogr. 33:796-822.

Hutchinson, G. E. 1975. A Treatise on Limnology, Volume 1, Part 1. Geography and Physics of Lakes. John Wiley and Sons. New York, New York.

Hysop, Debbie. 1994. "High copper levels in Lake". The Guide. Killarney, Manitoba. 31 May 1994, volume 99 number 35, page 1.

Jorgensen, E.G. 1968. The adaptation of plankton algae. II. Aspects of the temperature adaptation of *Skeletonema costatum*. Physiol. Plant. 21:423-427.

Kirk, J.T.O. 1983. Light and photosynthesis in aquatic ecosystems. Cambridge University Press.

Kilham P. 1981. Pelagic bacteria: extreme abundances in African saline lakes. Naturwissenschaften. 67:S 380-381.

Kooyman, A.H, and Hutchison, R.C. 1979. The Aquatic Resources of Riding Mountain National Park - Volume I - General Summary. Canadian Wildlife Services, Winnipeg, Manitoba.

Kooyman, A.H. 1980a. The Aquatic Resources of Riding Mountain National Park - Volume III - Data on Lakes. Canadian Wildlife Services, Winnipeg, Manitoba.

Kooyman, A.H. 1980b. The Aquatic Resources of Riding Mountain National Park - Volume V - Data on Streams. Canadian Wildlife Services, Winnipeg, Manitoba.

Lean, D.R.S. 1987. Overview of studies on the Nutrient Status of Lake Ontario. Can. J. Fish. Aquat. Sc. 44:2042-2046.

Lockhart, W.L., Hunt, R.V., and Murray, D.A.J. 1986. Mercury in fish from Riding Mountain National Park. a report for Park's Canada. Unpublished.

Lund, J.W.G., Kipling, C., and LeCren, E.D. 1958. The Inverted Microscope Method of estimation algal numbers and the statistical basis of estimations by counting. Freshwater Biological Association, The Ferry House, Ambleide Westmorland, England. Hydrobiologia 11: 143-170.

MacLaren. 1977. Engineering study of sewage treatment and disposal requirements for Riding Mountain National Park, Manitoba. James F. MacLaren Limited. Winnipeg, Manitoba.

Marker, A.F.H., Crowther, C.A., and Gunn, R.J.M. 1980. Methanol and acetone for estimating chlorophyll-a and phaeopigments by spectrophotometry. Archiv für Hydrobiologie Beihefte. 14: 52:69.

Marra, John. 1980. Vertical mixing and primary production. Brookhaven Symp. Biol. 31. 121-137 Plenum.

Marra, John, and Heinemann, Kristina. 1982. Photosynthesis response by phytoplankton to sunlight variability. Limnol. Oceanogr. 27(6)1141-1153.

Moore, K.L., McGinn, R.A., and Rousseau, P. 1997. Spring Freshet Nutrient Loading in the Octopus Creek Watershed. Unpublished.

Neilson, E.S, and Hansen, V.K. 1959. Light adaptation in marine phytoplankton and its interrelation with temperature. Physiologia Plantarum. 12:353-370.

Perry, M.S. 1972. Marine Biol. 15:113-119

Pettersson, Kurt. 1980. Alkaline phosphatase activity and algal surplus phosphorous as phosphorous-deficiency indicators in Lake Erken. Arch Hydrobiol. 89:54-87.

Platt, T.C., Gallegos, L, and Harrison, W.G. 1980. Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. Journal of Marine Research. 38:687-701.

Pick, F.R. 1987. Interpretations of Alkaline Phosphatase Activity in Lake Ontario. Can. J. Fish. Aquat. Sci. 44:2087-2094.

Platt, T., Gallegos, C.L., and Harrison, W.G. 1980. Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. Journal of Marine Research. 38: 678-703.

Prairie Farm Rehabilitation Administration (PFRA). 1997. Water Quality Matters - Prairie Water Quality Problems. December 1997.

Pratt. 1991. Riding Mountain National Park Wasagaming townsite utilities capacity study. GA Pratt and Associates Engineering Consultants. Draft Report. Winnipeg, Manitoba.

Prezelin, B.B. 1981.Light Recreations in Photosynthesis. In T. Platt (ed.). Physiological Bases of Phytoplankton Ecolgy (pp 1-43). Department of Fisheries and Oceans.

Reynolds, C.S. 1984. Ecology of freshwater phytoplankton. Cambridge.

Rhee, G-Yull, 1978. Effects of N:P atomic ratios and nitrate limitation on algal growth, cell, composition, and nitrate uptake. Limnol. Oceanogr. 23:10-25.

Rhee, G-Yull, and Gotham, Ivan J. 1980. Optimum N:P ratios and coexistence of planktonic algae. J. Phycol. 16:486-489.

Riding Mountain National Park Round Table. 1996. Management Plan - Riding Mountain National Park - A Partnership Approach for Managing the Park and Its Resources. Canadian Heritage Parks Canada. 38p.

Round, F.E. 1981. The Ecology of Algae. Cambridge Press. New York, New York. 653p.

Rounds, Richard C., Bazillion, Helen, and Braun, Connie. 1992. Human Intervention in the Fishery of the Clear Lake Basin in Riding Mountain National Park. The Rural Development Institute. Brandon University. Brandon, Manitoba.

Rousseau, Pat. 1997. Clear Lake Lake Level Data. Personal Communication.

Rousseau, Pat. 1986. Water quality monitoring plan - Clear Lake and Katherine Lake, Riding Mountain National Park. Canadian Parks Services, Riding Mountain National Park. Wasagaming, Manitoba.

Rousseau, Pat. 1990. Water quality monitoring plan - Clear Lake and Katherine Lake, Riding Mountain National Park. Canadian Parks Services, Riding Mountain National Park. Wasagaming, Manitoba E.A.R.P. Report 90-5/RMN.

Rousseau, Pat. 1992. Water quality monitoring plan - Clear Lake, Riding Mountain National Park. Canadian Parks Services, Riding Mountain National Park. Wasagaming, Manitoba E.A.R.P. Report 92/RMN.

Schelske, C.L. 1975. Silica and nitrate depletion as related to rate of eutrophication in Lake Michigan, Huron, and Superior. In A.D. Hunter ed. Coupling of land and water systems. Springer - Verlag New York Inc, New York. pg 277-298.

Schindler, D.W. 1971.Carbon, Nitrogen, and Phosphorous and the eutrophication of Freshwater Lake. J. Phycol. 7:321-329.

Schlesinger, William H. 1991 Biogeochemistry An analysis of global change. Academic Press, Inc New York, New York. 443p.

Shearer, J.A., DeBruyn, E.R, DeClerq, D.R.,Schindler, D.W., and Fee, E.J. 1985. Manual of phytoplankton primary production methodology. Canadian Technical Report of Fisheries and Aquatic Sciences 1341. iv + 58 p.

Shearer, J.A., and Fee, E.J. 1973. Phytoplankton Primary Production in the Experimental Lakes Area using an Incubator Technique - 1973 Data. Environment Canada. Fisheries and Marine Service Technical Report 474.

Smith, Robert Leo. 1980. Ecology and Field Biology. Harper and Row Publishers. New York, New York. 835p.

Sournia, Alain. 1974. Circadian periodicities in natural populations of marine phytoplankton. Adv. Mar. Biol. 12:325-389.

South, G. Robin, and Whittick, Alan. 1987. Introduction to Phycology. Blackwell Scientific Publication. Boston, Massachusetts.341p.

Stainton, M.P., Capel, M.J., and Armstrong, F.A.J. 1977. The Chemical Analysis of Freshwater. 2nd ed. Can. Fish. Serv. Misc. Spec. Publ. 25: 180p.

Svistovski, Frank, 1999. Wasagaming Wind Speed Data. Personal Communication.

Tabulenas, D.T. 1983. A Narrative Human History of Riding Mountain National Park and Area: Prehistory to 1980.

Taguchi, Satoru. 1976. Relationship between photosynthesis and cell size of Marine Diatoms. J. Phycol. 12:185-189.

Terrestrial and Aquatic Environment Managers Manitoba Inc. 1993. A Vision for Water Quality in the Clear Lake Basin - Workshop Proceedings. 85p.

Tett, P., Heaney, S.I., and Droop, M.R. 1985. The Redfield ratio and phytoplankton growth rate. J. mar. biol. 65:487-504.

Wallen, D.G., and Geen, G.H. 1971. Light quality in relationship to growth, photosynthetic rates and carbon metabolism in two species of marine plankton algae. Marine Biology. 10:34-43.

Wetzel, Robert G. 1983. Limnology. Saunders College Publishing, Harcourt Brace College Publishers. Toronto, Ontario. 767p.

Williams, N.J. 1978. Annual variation of photosynthetic parameters in Lake Tahoe. Verh.Internat. Verein. Limnol. 20:419-425.

Williamson, D.A. 1988. Manitoba Surface Water Quality Objective. A Water Standards and Studies Report. Department of Environment and Workplace Safety and Health.

Wood, R.D. 1975. Hydrobotanical Methods. University Park Press. Baltimore / London / Tokyo. 173pp.

APPENDICES

Table A.4.1 - Transect Field Data collected and used in the determination of Station 1 and Station 2 for the study on Clear Lake, Manitoba in 1996 and 1997

Station	Date	Time	Altitude	N	W	Sample Depth	Total Depth	Notes	0 m	1 m	2 m	3 m
A1	1-Jun-96	08:00 cst	2189 ft	50'4 1.62'	99'5 9.78'	1 m	1.5	Trans. A - North Shore (Ma-ee-gun) to west of South Lake	5.9	5.6		
A2	1-Jun-96	08:10 cst	2292 ft	50'4 1.71'	99'5 9.81'	2 m	7		6.2	5.3	5.1	5.0
A3	1-Jun-96	08:25 cst	2119 ft	50'4 1.63'	99'5 9.84'	2 m	13		6.1	5.5	5.4	5.0
A4	1-Jun-96	08:40 cst	2080 ft	50'4 1.38'	99'5 9.96'	2 m	19		7.1	6.9	6.6	6.5
mean												
B1	1-Jun-96	09:00 cst	2075 FT	50'3 9.65'	99'5 8.39'	1 m	1.75	Trans. B - Wasagaming (west of pier) to North Shore	10.0	9.9	9.4	
B2	1-Jun-96	09:15 cst	2206 ft	50'3 9.65'	99'5 8.39'	2 m	6.5		9.7	9.6	9.5	9.4
B3	1-Jun-96	09:25 cst	1948 ft	50'3 9.99'	99'5 8.45'	2 m	23		9.4	9.3	8.8	8.1
B4	1-Jun-96	09:44 cst	1973 ft	50'4 0.19'	99'5 8.42'	2 m	31		8.8	8.1	7.8	7.6
mean												
C1	1-Jun-96	10:05 cst	1996 ft	50'4 0.18'	99'5 6.56'	1 m	10	Trans. C - swim area in deep bay to deep hole off of tip	8.7	8.3	8.1	7.8
C2	1-Jun-96	10:15 cst	1868 ft	50'4 0.22'	99'5 6.55'	2 m	20		9.7	8.4	8.1	7.9
C3	1-Jun-96	10:30 cst	2094 ft	50'4 0.34'	99'5 6.39'	2 m	28		9.1	8.4	7.9	7.7
mean												

Table A.4.1 cont. - Transect Field Data collected and used in the determination of Station 1 and Station 2 for the study on Clear Lake, Manitoba in 1996 and 1997

Station	Date	4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	13 m	14 m	15 m	16 m	17 m	18 m	19 m	20 m	21 m	22 m	23 m	24 m	25 m	26 m	27 m	28 m	29 m	30 m	31 m	32 m	Chl-a	SD
A1	1-Jun-96																														3.64	0.43
A2	1-Jun-96	4.8	4.7	4.6	4.6																										3.37	0.22
A3	1-Jun-96	5.0	4.9	4.9	4.8	4.7	4.7	4.6	4.6	4.5	4.5																				3.34	0.17
A4	1-Jun-96	6.5	6.4	6.3	6.1	5.9	5.9	5.4	5.1	4.9	4.8	4.8	4.6	4.4	4.4	4.4	4.2														2.83	0.36
mean																															3.29	0.30
B1	1-Jun-96																														1.90	0.30
B2	1-Jun-96	8.8	8.5	8.4																											1.47	0.57
B3	1-Jun-96	7.8	7.7	7.6	7.6	7.6	7.1	7.1	6.8	6.7	6.6	6.4	6.3	6.3	6.2	5.9	5.6	5.2	5.2	5.0	4.8										1.61	0.17
B4	1-Jun-96	7.4	7.1	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.1	6.0	5.9	5.7	5.5	5.1	4.6	4.4	4.3	4.2	4.2	4.1	3.9	3.8	3.8	3.8	3.8		1.95	0.16
mean																															2.26	0.30
C1	1-Jun-96	7.7	7.6	7.6	7.5	7.3	7.2	7.0																							2.00	0.15
C2	1-Jun-96	7.7	7.6	7.6	7.4	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.6	6.5	6.4	5.9	5.1													1.96	0.14
C3	1-Jun-96	7.7	7.6	7.6	7.5	7.2	7.0	6.9	6.8	6.8	6.6	6.4	6.3	6.3	6.1	5.8	5.7	5.5	4.6	4.3	4.2	4.1	4.1	4.1	4.1	4.1					0.50	0.50
mean																															2.32	0.29

Table A.4.2 - Daily Cycle Field Data collected in Clear Lake, Manitoba (Station 2) on September 3, 1996.

Time	Altitude	N	W	Sample Depth	Total Depth	Notes	0 m	1 m	2 m	3 m
07:00cst	1976 ft	50'4 0.27'	99'5 6.40'	0 - 10 m	34 m	NW samples taken 2 m choppy waves windy alot of drift	19.8	19.9	20.0	20.0
09:10 cst	1970 ft	50'4 0.26'	99'5 6.41'	0 - 15 m	31 m	no NW choppy waves windy alot of drift	20.1	20.1	20.1	20.1
11:45 cst	1932 ft	50'4 0.36'	99'5 6.26'	0 - 14 m	31 m	no NW choppy waves windy alot of drift	20.2	20.2	20.2	20.2
14:45 cst	2159 ft	50'4 0.33'	99'5 6.41'	0 - 14 m	30 m	no NW choppy waves windy alot of drift extreme waves	20.0	20.0	20.0	20.0
16:45 cst	1897 ft	50'4 0.39'	99'5 6.47'	0 - 18 m	33.5 m	no NW choppy waves windy alot of drift extreme waves	20.0	20.0	20.0	20.0

Table A.4.2 cont.- Daily Cycle Field Data collected in Clear Lake, Manitoba (Station 2) on September 3, 1996.

Time	4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	13 m	14 m	15 m	16 m	17 m	18 m	19 m	20 m	21 m	22 m	23 m	24 m	25 m	26 m	27 m	28 m	29 m	30 m	31 m
07:00cst	20.0	20.0	20.0	21.1	21.1	21.1	21.1	20.0	19.9	19.8	19.8	19.4	16.4	12.9	11.1	10.5	10.0	9.6	9.5	9.2	9.1	9.0	8.8	8.7	8.7	8.6	8.6	8.6
09:10 cst	20.1	20.1	20.1	20.1	20.1	20.1	20.0	20.0	20.0	19.9	19.1	18.5	14.2	11.6	11.1	10.3	9.9	9.6	9.2	9.1	8.9	8.8	8.7	8.6	8.6	8.6	8.6	8.5
11:45 cst	20.2	20.1	20.1	20.1	20.1	20.1	20.1	20.0	20.0	20.0	19.8	17.1	15.1	12.8	11.2	10.8	10.1	9.8	9.5	9.2	9.0	8.9	8.8	8.7	8.7	8.6	8.6	8.4
14:45 cst	20.0	20.0	20.0	20.0	19.9	19.8	19.8	19.8	19.8	19.8	19.2	18.8	18.5	14.1	11.5	10.6	10.4	9.3	9.2	9.0	8.9	8.8	8.8	8.6	8.6	8.4	8.3	
16:45 cst	20.0	20.0	20.0	20.0	20.0	19.9	19.6	19.6	19.5	19.5	19.5	19.4	19.4	19.4	19.4	13.8	13.8	10.8	10.4	9.7	9.5	9.4	9.1	9.0	8.9	8.9	8.8	8.7

Table A.4.2 cont.- Daily Cycle Field Data collected in Clear Lake, Manitoba (Station 2) on September 3, 1996.

Time	32 m	33 m	34 m	light ext.	Alk	ph	DIC	Chl-a	Pmax	error bar (ase)	upper 95%	lower 95%	Alpha	error bar (ase)	upper 95%	lower 95%	Ik	Spmax	error bar (ase)	upper 95%	lower 95%
07:00cst	8.6	8.5	8.4	30.18	193.2	8.35	46.368	1.72	10.246	0.825	12.196	8.296	0.074	0.009	0.095	0.053	136.459	5.957	0.428	6.968	4.946
09:10 cst				26.45	193.2	8.35	46.368	2.11	7.501	0.825	9.452	5.549	0.067	0.013	0.099	0.036	111.955	3.555	0.333	4.341	2.768
11:45 cst				30.28	193.2	8.35	46.368	2.28	7.500	1.797	11.750	3.250	0.034	0.009	0.055	0.013	220.588	3.290	0.493	4.454	2.125
14:45 cst				29.79	193.2	8.35	46.368	1.95	6.622	0.936	8.837	4.408	0.052	0.012	0.080	0.025	127.346	3.396	0.372	4.275	2.517
16:45 cst	8.6	8.5	8.5	29.47	193.2	8.35	46.368	1.84	2.682	0.390	3.606	1.759	0.036	0.013	0.065	0.006	74.500	1.454	0.182	1.884	1.024

Table A.4.2 cont.-

Time	Alpha/Chla	error bar (ase)	upper 95%	lower 95%	Ik
07:00cst	0.043	0.005	0.055	0.031	138.535
09:10 cst	0.032	0.006	0.047	0.017	111.094
11:45 cst	0.015	0.004	0.023	0.008	219.333
14:45 cst	0.027	0.006	0.041	0.013	125.778
16:45 cst	0.019	0.007	0.035	0.003	76.526

Table A.4.3 - Horizontal Distribution Field Data collected in Clear Lake, Manitoba on August 7, 1996 and August 29, 1996.

Date	Time	Altitude	N	W	Total Depth	Notes	0 m	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m	9 m
August 7 - 1	09:00 cst	2204 ft	50°4 2.61'	100°0 3.24'	2.5	wind rain overcast huge waves 2m sample	19.5	19.6	19.6	19.6						
August 7 - 2	09:05 cst	1923 ft	50°4 2.06'	100°0 2.58'	4.5	wind rain overcast huge waves 2m sample	19.2	19.2	19.2	19.2	19.2	19.2				
August 7 - 3	09:15 cst	2194 ft	50°4 1.49'	100°0 1.95'	6.5	wind rain overcast huge waves 2m sample	19.8	19.8	19.8	19.9	19.9	19.9	19.9	19.9		
August 7 - 4	09:20 cst	2156 ft	50°4 0.08'	100°0 1.20'	17	wind rain overcast huge waves 2m sample	19.9	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.7
August 7 - 5	09:35 cst	2410 ft	50°4 0.44'	100°0 0.11'	24	wind rain overcast huge waves 2m sample	19.9	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
August 7 - 6	09:45 cst	2337 ft	50°4 0.19'	100°0 8.50'	29	wind rain overcast huge waves 2m sample	20.0	20.0	20.0	20.1	20.1	20.1	20.2	20.2	20.2	20.2
August 7 - 7	10:00 cst	2071 ft	50°4 0.40'	99°9 7.09'	30	wind rain overcast huge waves 2m sample	20.1	20.1	20.1	20.1	20.1	20.2	20.2	20.2	20.2	20.2
August 7 - 7	10:15 cst	1994 ft	50°4 0.33'	99°9 5.85'	27	wind rain overcast huge waves 2m sample	20.2	20.3	20.2	20.3	20.3	20.3	20.3	20.3	20.3	20.3
August 7 - 9	10:22 cst	1742 ft	50°4 0.39'	99°9 5.21'	23	wind rain overcast huge waves 2m sample	20.4	20.4	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
August 7 - 10	10:30 cst	1986 ft	50°4 0.33'	99°9 4.74'	21	wind rain overcast huge waves 2m sample	20.4	20.4	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
August 29 - 1	08:45 cst	2184 ft	50°4 2.73'	100°0 3.20'	2.5	some drift rel calm 1m sample	19.9	19.9	19.8	19.4						
August 29 - 2	08:50 cst	1903 ft	50°4 2.13'	100°0 2.79'	3.5	some drift rel calm 2m sample	19.5	19.5	19.5	19.6						
August 29 - 3	09:00 cst	1978 ft	50°4 1.42'	100°0 2.06'	6.5	some drift rel calm 2m sample	19.4	19.5	19.5	19.5	19.5	19.5	19.5	19.4		
August 29 - 4	09:15 cst	2145 ft	50°4 0.89'	100°0 1.51'	15.5	some drift rel calm 2m sample	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.4	19.4
August 29 - 5	09:30 cst	2020 ft	50°4 0.40'	100°0 0.14'	24	some drift rel calm 2m sample	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.4
August 29 - 6	09:45 cst	1977 ft	50°4 0.16'	100°0 9.15'	26	some drift rel calm 2m sample	19.6	19.6	19.6	19.6	19.6	19.5	19.5	19.5	19.5	19.5
August 29 - 7	10:15 cst	2117 ft	50°4 0.33'	99°9 7.63'	33	some drift rel calm 2m sample	20.0	20.0	19.9	19.8	19.8	19.7	19.7	19.6	19.5	19.2
August 29 - 8	10:30 cst	2000 ft	50°4 0.36'	99°9 6.54'	29	some drift rel calm 2m sample	19.9	19.8	19.8	19.7	19.6	19.6	19.3	19.2	19.0	18.9
August 29 - 9	10:35 cst	2111 ft	50°4 0.37'	99°9 5.60'	26	some drift rel calm 2m sample	19.9	19.9	19.6	19.5	19.4	19.4	19.4	19.3	19.0	18.9
August 29 - 10	10:45 cst	2170 ft	50°4 0.36'	99°9 4.96'	22	some drift rel calm 2m sample	19.5	19.5	19.4	19.4	19.3	19.3	19.2	19.2	19.1	19.0

Table A.4.3 cont. - Horizontal Distribution Field Data collected in Clear Lake, Manitoba on August 7, 1996 and August 29, 1996.

Date	Time	10 m	11 m	12 m	13 m	14 m	15 m	16 m	17 m	18 m	19 m	20 m	21 m	22 m	23 m	24 m	25 m	26 m	27 m	28 m	29 m	30 m	31 m	32 m	33 m	Chl-a	SD
August 7 - 1	09:00 cst																									1.89	0.22
August 7 - 2	09:05 cst																									1.30	0.29
August 7 - 3	09:15 cst																									1.83	0.28
August 7 - 4	09:20 cst	18.2	17.4	16.1	12.6	12.6	11.1	10.8	10.5																	1.65	0.20
August 7 - 5	09:35 cst	20.0	20.0	16.9	15.4	12.1	11.1	10.7	10.2	10.1	9.8	9.5	9.5	9.2	8.9	8.8										1.65	0.20
August 7 - 6	09:45 cst	20.2	20.2	20.1	14.4	13.0	12.2	11.4	11.0	10.6	10.0	9.6	9.4	9.2	9.1	8.8	8.5	8.3	8.1	8.0						1.53	0.20
August 7 - 7	10:00 cst	20.2	20.1	20.0	16.1	12.4	11.7	10.8	10.5	10.3	10.1	9.8	9.6	9.5	9.4	9.3	9.2	8.8	8.4	8.2	8.1	8.1				2.24	1.43
August 7 - 7	10:15 cst	20.4	20.4	20.4	19.7	11.6	11.0	10.5	10.2	9.8	9.5	9.3	9.1	8.9	8.6	8.4	8.2	8.2	8.1							1.18	0.20
August 7 - 9	10:22 cst	20.5	20.5	20.1	19.7	12.9	11.1	10.6	9.9	9.6	9.4	9.2	9.0	8.8	8.4											1.62	0.35
August 7 - 10	10:30 cst	20.5	20.5	20.5	20.5	11.4	10.8	10.3	10.0	9.8	9.6	9.4	9.1													1.40	0.38
August 29 - 1	08:45 cst																									1.18	0.46
August 29 - 2	08:50 cst																									1.28	0.11
August 29 - 3	09:00 cst																									1.54	0.20
August 29 - 4	09:15 cst	19.4	19.4	19.3	19.2	18.5	14.6	14.5																		1.86	0.24
August 29 - 5	09:30 cst	19.4	19.4	19.4	19.1	15.6	13.5	12.1	11.5	10.8	10.3	10.0	9.7	9.2	9.0	8.9										2.01	0.83
August 29 - 6	09:45 cst	19.5	19.1	19.0	18.7	14.2	12.2	11.4	10.8	10.5	10.1	9.8	9.5	9.2	8.9	8.8	8.6	8.6								1.63	0.01
August 29 - 7	10:15 cst	19.0	18.6	18.4	18.4	16.3	11.9	11.1	10.5	10.1	9.8	9.5	9.3	9.0	8.9	8.7	8.6	8.5	8.5	8.4	8.3	8.2	8.2	8.2	8.0	2.11	0.11
August 29 - 8	10:30 cst	18.6	18.5	18.2	16.8	15.7	13.4	10.7	10.3	10.0	9.9	9.6	9.4	9.3	9.1	8.9	8.7	8.6	8.4	8.3	8.2					2.09	0.64
August 29 - 9	10:35 cst	18.5	18.2	17.9	17.1	15.2	12.7	11.6	11.1	10.3	10.0	9.7	9.3	9.1	8.9	8.6	8.6	8.6								2.22	0.19
August 29 - 10	10:45 cst	18.9	18.7	17.8	15.3	13.3	11.8	10.4	10.2	10.0	9.9	9.7	9.6	9.2												2.09	0.06

Table A.4.4

WC' Algal Growth Medium for phosphate limited algal cultures.
Modified from Guillard and Lorenzen (1972).

Major Elements

Compound	Molecular Weight	Stock (100mM) g/100 mL	[Final] mg/L	[Final] µM	Add ml/L
$NaNO_3$	85.0	0.850	17.0	500	5.0
KH_2PO_4	236.5	1.361	1.4	10	0.1
KCl	74.6	0.746	3.0	40	0.4
$MgSO_4.7H_2O$	246.5	2.465	37.0	150	1.5
$CaCl_2$.2H2O	147.0	1.471	36.8	250	2.5
$NaHCO_3$	84.0	0.840	12.6	150	1.5
$Na_2SiO_3.9H_2O$	284.2	2.842	56.8	200	2.0

Note - KH_2PO_4 was removed to make a phosphorous limited medium.

Trace Elements - Combine the following compounds, in the order listed, to 1 L of glass distilled water. Add 2.5 mL of this stock to 1 L of medium.

Na_2EDTA	874.0 mg
$FeCl_3.6H_2O$	630.0 mg
H_3 Bo_3	200.0 mg
$MnCl_2.4H_2O$	36.0 mg
Na_2 $MoO_4.2H_2O$	1.2 mg
$ZnSO_4.7H_2O$	4.4 mg
$CoCl_2.6H_2O$	2.0 mg
$CuSO_4.5H_2O$	2.0 mg

Buffer - Prepare stock bicine buffer by adding 16.32 g og bicone (M.W. 163.2) to 1 L of distilled water. Adjust the pH of the stock to 7.0. Add 10 mL/L to medium. Adjust the pH of the medium to 7.6 using HCL or NaOH.

Vitamins - Prepare the three separate solution. Add 1.0 mL of solution C to 1 L of media
A: cyanocobolamine (B_{12}) 10.0 mg / 100 mL H_2O
B: biotin 10.0 mg / 100 mL H_2O
C: thiamine 10.0 mg + 0.5 mL solution A + 0.5 mL solution B + 99.0 mL distilled water

Table A.5.1 - Station 1 Field Data in Clear Lake, Manitoba for the period of June 1996 to October 1997.

Date	Time	Altitude	N	W	Sample Depth	Total Depth	Notes	
1-Jun-96	08:40 cst	2080 ft	50'4 1.38'	99'5 9.96'	2 m	19 m	only 3 chl-a.	1 phyto. and drag
3-Jun-96	10:30 cst	2153 ft	50'4 1.38'	99'5 9.97'	2 m	19 m	no drag net	strong winds
6-Jun-96	07:30 cst	2141 ft	50'4 1.30'	100'0 0.05'	2 m	19.5 m		
9-Jun-96	08:30 cst	2156 ft	50'4 1.24'	100'0 0.12'	2m	20 m	no NW taken	rain just before
12-Jun-96	06:30 cst	2152 ft	50'4 1.39	100'0 0.18'	2m & 5m	20 m	alot of drift	was occuring
15-Jun-96	08:00 cst	2004 ft	50'4 1.25	100'0 0.03'	2m & 4m	20.5 m	some drift	was occuring
23-Jun-96	08:00 cst	2150 ft	50'4 1.27	100'0 0.03'	2m & 14m	20.5 m	NW samples	taken
26-Jun-96	07:35 cst	2148 ft	50'4 1.25	100'0 0.07'	2m & 10m	20 m	no NW	samples
30-Jun-96	09:00 cst	2020 ft	50'4 1.31'	100'0 0.23'	2m & 3m	19 m	no NW	samples
6-Jul-96	07:40 cst	2017ft	50'4 1.27'	100'0 0.13'	0m - 4m	19 m	no NW	samples
9-Jul-96	08:00 cst	2017ft	50'4 1.27'	100'0 0.13'	0m - 10m	19.5 m	NW sample	2m mark
12-Jul-96	10:45 cst	2115 ft	50'4 1.30'	100'0 0.09'	0m - 9m	20 m	no NW	samples
17-Jul-96	10:45 cst	2010 ft	50'4 1.26	100'0 0.16'	0m - 9m	19.5 m	no NW	samples
19-Jul-96	07:50 cst	2000 ft	50'4 1.27'	100'0 0.15'	0m - 9m	19.5 m	no NW	samples
24-Jul-96	10:00 cst	1732 ft	50'4 1.24'	100'0 0.15'	0m - 10m	19.5 m	NW sample	2m mark
28-Jul-96	09:30 cst	1919 ft	50'4 1.28'	100'0 0.15'	0m - 10m	19.5 m	no NW	samples
5-Aug-96	08:30 cst	2014 ft	50'4 1.27'	100'0 0.19'	0m - 11m	19.5 m	no NW	samples
9-Aug-96	07:55 cst	1994 ft	50'4 1.26'	100'0 0.16'	0m - 12m	19.5 m	no NW	samples
11-Aug-96	01:30 cst	2072 ft	50'4 1.27'	100'0 0.16'	0m - 11m	19.5 m	NW sample	2m mark
20-Aug-96	09:15 cst	2070 ft	50'4 1.27'	100'0 0.16'	0m - 12m	19.5 m	no NW	samples
27-Aug-96	08:00 cst	2316 ft	50'4 1.21'	100'0 0.18'	0m - 13m	19.5 m	no NW	samples
30-Aug-96	08:00 cst	2214 ft	50'4 1.25'	100'0 0.17'	0m - 12m	19.5 m	no NW	samples
3-Sep-96	06:30 cst	2074 ft	50'4 1.27'	100'0 0.15'	0 - 12 m	19 m	NW samples	taken 2 m
6-Sep-96	08:00 cst	2086 ft	50'4 1.30'	100'0 0.17'	0m - 12m	19.5 m	no NW	choppy waves
9-Sep-96	07:00 cst	2310 ft	50'4 1.26'	100'0 0.14'	0m - 15m	19.5 m	no NW	rel. calm
13-Sep-96	09:00 cst	2316 ft	50'4 1.26'	100'0 0.18'	0m - 19m	19.5 m	no NW	choppy waves
16-Sep-96	09:15 cst	2107 ft	50'4 1.30'	100'0 0.17'	0m - 17m	19 m	NW sample 2m	rel. calm
20-Sep-96	07:50 cst	1982 ft	50'4 1.24'	100'0 0.18'	0m - 17m	19.5 m	no NW	rel. calm
23-Sep-96	08:30 cst	1938 ft	50'4 1.25'	100'0 0.14'	0m - 19m	19.5 m	no NW	choppy waves
29-Sep-96	08:15 cst	2170 ft	50'4 1.23'	100'0 0.16'	0m - 19m	19.5 m	no NW	choppy waves
5-Oct-96	08:00 cst	1779 ft	50'4 1.25'	100'0 0.13'	0m - 19.5m	19.5 m	NW sample 2m	rel. calm
15-Oct-96	08:30 cst	1993 ft	50'4 1.26'	100'0 0.13'	0m - 19.5m	19.5 m	no NW	choppy waves
19-Oct-96	08:55 cst	1802 ft	50'4 1.30'	100'0 0.13'	0m - 19.5m	19.5 m	no NW	calm overcast
25-Oct-96	08:40 cst	1955 ft	50'4 1.27'	100'0 0.15'	0m - 19.5m	19.5 m	no NW	foggy & no
9-Nov-96	09:30 cst	1954 ft	50'4 1.31'	100'0 0.15'	0m - 19.5m	19.5 m	no NW	snowing
1-Jan-97	14:15 cst	1954 ft	50'4 1.33'	100'0 0.13'	0m - 19m	19 m	no NW	snow 27cm
20-Jan-97	11:00 cst	2017 ft	50'4 1.32'	100'0 0.16'	0m - 19m	19 m	NW sample 2m	snow 11cm
15-Feb-97	13:30 cst	2033 ft	50'4 1.30'	100'0 0.13'	0m - 19m	19 m	NW sample 2m	snow 8-16cm
17-Mar-97	12:00 cst	1849 ft	50'4 1.31'	100'0 0.09'	0m - 19m	19 m	NW sample 2m	snow 17-22cm
16-May-97	09:45 cst	1890 ft	50'4 1.28'	100'0 0.20'	0m - 19.5m	19.5 m	NW sample 2m	calm
18-May-97	02:30 cst	1890 ft	50'4 1.28'	100'0 0.20'	0m - 19.5m	19.5 m	NW sample 2m	snowy
30-May-97	09:00 cst	1903 ft	50'4 1.30'	100'0 0.14'	0m - 2m	18.5 m	no NW	sunny
6-Jun-97	09:20 cst	1951 ft	50'4 1.34'	100'0 0.18'	0m - 4m	18.5 m	no NW	sunny
13-Jun-97	03:00 cst	1915 ft	50'4 1.29'	100'0 0.20'	0m - 4m	19.5 m	no NW	sunny
20-Jun-97	09:20 cst	1915 ft	50'4 1.30'	100'0 0.13'	0m - 7m	19 m	no NW	sunny
24-Jun-97	09:45 cst	2185 ft	50'4 1.26'	100'0 0.13'	0m - 8m	19 m	NW	sunny
4-Jul-97	09:15 cst	2072 ft	50'4 1.33'	100'0 0.14'	0m - 11m	19 m	no NW	sunny
8-Jul-97	10:10 cst	2264 ft	50'4 1.30'	100'0 0.14'	0m - 13m	19 m	no NW	cloudy
15-Jul-97	11:45 cst	2060 ft	50'4 1.31'	100'0 0.16'	0m - 11m	19.5 m	no NW	sunny
22-Jul-97	09:15 cst	2267 ft	50'4 1.36'	100'0 0.14'	0m - 10m	19.5 m	no NW	sunny
30-Jul-97	09:30 cst	1971 ft	50'4 1.33'	100'0 0.20'	0m - 10m	18.5 m	no NW	sunny
2-Aug-97	09:20 cst	1964 ft	50'4 1.32'	100'0 0.17'	0m - 10m	18.5 m	no NW	sunny
13-Aug-97	02:20 cst	2105 ft	50'4 1.32'	100'0 0.12'	0m - 12m	19 m	no NW	sunny
19-Aug-97	09:55 cst	1992 ft	50'4 1.24'	100'0 0.20'	0m - 13m	19 m	no NW	no sun
26-Aug-97	09:15 cst	2072 ft	50'4 1.29'	100'0 0.16'	0m - 12m	18.5 m	no NW	sunny
3-Sep-97	10:00 cst	1969 ft	50'4 1.31'	100'0 0.15'	0m - 14m	18.5 m	no NW	sunny
9-Sep-97	9:00 cst	1996 ft	50'4 1.28'	100'0 0.15'	0m - 12m	18.5 m	no NW	sunny
22-Sep-97	8:35 cst	1996 ft	50'4 1.30'	100'0 0.15'	0m - 19m	19 m	no NW	sunny
2-Oct-97	10:00 cst	2406 ft	50'4 1.26'	100'0 0.14'	0m - 14m	19 m	no NW	sunny
6-Oct-97	9:20 cst	1983 ft	50'4 1.32'	100'0 0.14'	0m - 18m	18.5 m	no NW	sunny

Table A.5.1 cont.- Station 1 Field Data in Clear Lake, Manitoba for the period of June 1996 to October 1997

Date				0 m	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m
1-Jun-96	net			7.1	6.9	6.6	6.5	6.5	6.4	6.3	6.1	5.9	5.9	5.4	5.1
3-Jun-96	and weather	may have mixed	lake	9.3	9.1	9.1	8.8	8.6	8.6	8.5	8.4	8.3	8.2	7.9	7.5
6-Jun-96				9.9	9.8	9.8	9.8	9.7	9.7	9.5	9.3	8.8	8.3	7.7	7.4
9-Jun-96	and overcast			11.4	11.3	11.2	11.2	11.0	10.9	10.7	10.5	10.6	10.3	10.1	9.8
12-Jun-96	no NW taken			13.7	13.6	12.9	12.1	11.6	11.3	10.6	10.6	9.8	9.4	8.9	8.3
15-Jun-96	no NW taken			15.8	15.7	15.6	15.4	14.8	13.7	12.5	11.8	11.4	10.1	9.6	9.3
23-Jun-96	alot of wind	action days	before	14.5	14.5	14.5	14.5	14.4	14.4	14.3	14.2	14.1	13.9	13.3	12.9
26-Jun-96	taken	thermometer	forgotten												
30-Jun-96	taken	alot of drift	HUGE waves	16.9	16.9	16.8	16.7	15.7	15.6	15.1	14.9	14.7	14.5	14.2	13.5
6-Jul-96	taken	alot of drift	HUGE waves	18.1	18.1	18.0	17.9	16.5	16.3	15.9	15.6	15.1	14.9	14.5	14.2
9-Jul-96	no wind	smooth/calm	1L at 2m depths	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.9	17.5	17.2	16.4	15.2
12-Jul-96				18.3	18.3	18.2	18.2	18.1	18.0	18.0	18.0	17.9	17.9	16.8	15.5
17-Jul-96				20.0	19.7	19.3	19.3	19.2	19.2	19.2	19.2	19.1	19.1	17.9	15.1
19-Jul-96	rel. calm	dark	overcast	19.7	19.7	19.8	19.8	19.8	19.8	19.8	19.8	19.7	19.5	17.5	16.5
24-Jul-96	alot of drift	HUGE waves		19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.0	18.9	18.6	15.6
28-Jul-96	rel. calm	dark	overcast	19.4	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.3	17.6
5-Aug-96	rel. calm	some	drift	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.5	19.9	19.1
9-Aug-96	rel. calm	some	drift	18.8	18.9	18.9	18.9	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
11-Aug-96	rel. calm	some	drift	19.8	19.8	19.8	19.8	19.8	19.7	19.5	19.4	19.4	19.3	19.3	19.1
20-Aug-96	rel. calm	some	drift	19.6	19.6	19.6	19.6	19.6	19.6	19.5	19.5	19.5	19.5	19.4	19.4
27-Aug-96	taken	alot of drift		19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4
30-Aug-96	calm			19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.0
3-Sep-96	choppy waves	windy	alot of drift	19.4	19.5	19.5	19.5	19.5	19.5	19.0	19.6	19.6	19.6	19.6	19.0
6-Sep-96	windy couple days	alot of drift	ppt before dark	18.1	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
9-Sep-96	some drift			17.7	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
13-Sep-96	alot of drift			16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
16-Sep-96	some drift			15.7	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
20-Sep-96	some drift			15.1	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
23-Sep-96	alot of drift			14.7	14.7	14.7	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
29-Sep-96	alot of drift			12.2	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.4	12.4	12.4	12.4
5-Oct-96	some drift			11.1	11.1	11.1	10.9	10.8	10.8	10.8	10.8	10.7	10.7	10.7	10.7
15-Oct-96	alot of drift			9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
19-Oct-96	huge N winds	previous days	no drag net	9.2	9.1	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
25-Oct-96	visibility	some wind	& drift	7.3	7.2	7.2	7.1	7.1	7.1	7.1	7.0	6.9	6.9	6.9	6.9
9-Nov-96	overcast foggy	extreme cold	no drag net	3.4	3.4	3.4	3.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
1-Jan-97	ice 33 cm	overcast	no sun	0.4	1.5	2.0	2.2	2.3	2.5	2.6	2.7	2.8	2.9	3.0	3.1
20-Jan-97	ice 59 cm	some cloud	sunny	0.0	1.2	1.7	2.0	2.3	2.5	2.7	2.8	2.9	2.9	2.9	3.0
15-Feb-97	ice 73 cm	some cloud	sunny	0.0	1.2	2.2	2.4	2.6	2.7	2.8	2.8	2.8	2.9	3.0	3.1
17-Mar-97	ice 74 cm	some wind	sunny	0.4	1.3	2.4	2.6	2.6	2.7	2.8	2.8	2.9	2.9	3.0	3.0
16-May-97	no clouds	some wind	sunny	5.3	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8
18-May-97	some wind	cloudy	cold	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
30-May-97	some wind	some cloud		11.7	11.4	10.6	8.2	7.6	7.4	7.1	6.9	6.7	6.6	6.4	6.4
6-Jun-97	some wind	no clouds		15.5	15.3	15.2	15.2	15.2	13.0	10.9	9.7	8.9	8.2	7.8	7.4
13-Jun-97	some wind	some clouds	no drag net	19.7	19.5	19.1	18.9	18.6	17.2	15.3	12.6	11.5	10.0	9.8	8.9
20-Jun-97	calm	no wind		16.6	16.4	16.3	16.3	16.1	16.0	15.7	15.2	13.6	12.8	11.6	10.9
24-Jun-97	calm	little wind	cloud cover	17.3	17.3	17.2	17.2	17.2	17.0	16.9	16.7	16.3	13.5	12.7	10.8
4-Jul-97	wavy	wind		16.1	16.1	16.0	15.9	15.8	15.6	15.6	15.5	15.4	15.4	15.3	15.3
8-Jul-97	foggy	some wind	no sun	16.4	16.4	16.4	16.4	16.4	16.3	16.2	16.1	16.1	16.1	16.0	16.0
15-Jul-97	calm	little wind		21.0	20.7	20.4	20.3	20.1	20.0	19.9	19.7	19.0	18.3	17.6	16.6
22-Jul-97	some wind	no clouds		21.0	20.9	20.9	20.8	20.8	20.8	20.8	20.8	20.8	20.7	20.5	16.5
30-Jul-97	calm	little wind		21.7	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.3	19.6	17.1
2-Aug-97	cloudy	little wind		21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	18.6
13-Aug-97	some wind	little clouds		20.0	20.1	20.1	19.8	19.8	19.8	19.8	19.7	19.7	19.7	19.7	19.6
19-Aug-97	rel. calm	cloudy	cool	18.0	18.1	18.2	18.2	18.2	18.2	18.2	18.2	18.3	18.3	18.3	18.3
26-Aug-97	rel. calm	no clouds		19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	18.9	18.8
3-Sep-97	cool	no clouds		18.6	18.7	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
9-Sep-97	some wind	some clouds		17.5	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
22-Sep-97	some wind	some clouds	cool	13.5	13.6	13.6	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
2-Oct-97	some wind	cool		13.2	13.2	13.2	13.2	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
6-Oct-97	some wind	cool		12.4	12.6	12.6	12.6	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7

Table A.5.1 cont.-

Date	12 m	13 m	14 m	15 m	16 m	17 m	18 m	19 m	20 m
1-Jun-96	4.9	4.8	4.8	4.6	4.4	4.4	4.4	4.2	
3-Jun-96	7.3	7.2	7.0	6.9	6.8	6.5	6.4	5.4	
6-Jun-96	6.9	6.6	6.4	5.9	5.6	5.5	5.4	5.3	5.1
9-Jun-96	8.7	8.6	8.4	7.9	7.7	7.3	7.1	6.6	6.2
12-Jun-96	7.7	7.6	7.2	6.9	6.7	6.6	6.3	6.1	5.9
15-Jun-96	8.8	8.1	7.7	7.3	7.1	6.8	6.6	6.4	6.2
23-Jun-96	12.2	11.8	10.3	10.1	9.6	9.2	8.7	8.4	7.9
26-Jun-96									
30-Jun-96	13.1	12.7	12.2	10.9	10.7	10.3	9.7	9.3	
6-Jul-96	13.5	13.1	12.7	12.2	10.9	10.3	9.7	9.5	
9-Jul-96	13.2	12.6	11.8	11.3	11.0	10.1	9.4	9.2	9.1
12-Jul-96	14.1	12.4	11.7	11.1	10.5	10.1	9.3	8.9	8.9
17-Jul-96	14.0	12.8	11.7	11.3	10.5	10.1	9.8	9.3	9.1
19-Jul-96	15.2	12.8	11.7	11.1	10.1	9.8	9.4	9.2	
24-Jul-96	13.7	12.8	12.0	11.2	10.7	10.3	9.8	9.5	9.2
28-Jul-96	15.4	14.1	12.3	11.2	10.8	10.4	9.9	9.7	9.7
5-Aug-96	17.1	13.5	12.6	11.9	10.8	10.5	10.0	9.7	
9-Aug-96	19.0	17.2	12.9	12.1	11.1	10.4	9.8	9.6	9.6
11-Aug-96	17.5	17.2	14.1	12.3	11.0	10.2	9.8	9.5	9.1
20-Aug-96	19.3	16.3	14.2	11.9	10.8	10.1	9.8	9.6	9.6
27-Aug-96	19.2	18.5	14.0	12.6	11.5	10.4	9.8	9.6	9.6
30-Aug-96	18.5	17.3	15.3	13.7	12.1	11.1	10.3	9.8	9.5
3-Sep-96	19.2	16.5	15.6	13.0	10.7	10.1	9.8	9.8	
6-Sep-96	18.0	16.4	13.6	12.1	11.7	10.6	10.4	10.2	10.1
9-Sep-96	17.8	17.7	17.6	17.5	13.2	12.0	11.2	11.2	11.2
13-Sep-96	16.3	16.3	16.2	16.2	16.2	16.0	15.9	15.9	15.9
16-Sep-96	15.6	15.6	15.6	15.6	15.6	15.5	11.5	11.1	
20-Sep-96	15.0	15.0	15.0	15.0	15.0	14.5	13.4	11.8	11.2
23-Sep-96	14.6	14.6	14.6	14.6	14.6	14.5	13.7	13.2	11.9
29-Sep-96	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.3	11.4
5-Oct-96	10.7	10.7	10.6	10.6	10.6	10.5	10.4	10.1	10.0
15-Oct-96	9.8	9.8	9.8	9.7	9.7	9.7	9.7	9.7	9.7
19-Oct-96	9.0	9.0	9.0	9.0	9.0	8.9	8.9	8.9	8.9
25-Oct-96	6.9	6.9	6.9	6.9	6.8	6.8	6.8	6.8	6.8
9-Nov-96	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
1-Jan-97	3.1	3.1	3.1	3.1	3.2	3.2	3.3	3.5	
20-Jan-97	3.0	3.1	3.1	3.1	3.1	3.1	3.2	3.5	
15-Feb-97	3.1	3.1	3.1	3.2	3.3	3.4	3.5	3.5	
17-Mar-97	3.1	3.1	3.1	3.2	3.3	3.4	3.5	3.6	
16-May-97	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	
18-May-97	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
30-May-97	6.3	6.3	6.2	6.1	6.1	5.9	5.8	5.8	
6-Jun-97	7.0	6.8	6.6	6.5	6.5	6.3	6.3	6.3	
13-Jun-97	8.1	7.6	7.3	7.1	6.9	6.7	6.5	6.4	6.4
20-Jun-97	10.1	9.3	9.0	8.7	8.5	8.1	7.6	7.3	
24-Jun-97	9.9	9.3	9.0	8.6	8.3	8.1	7.8	7.4	
4-Jul-97	13.7	12.7	11.1	10.0	9.1	8.6	8.5	8.2	
8-Jul-97	15.9	15.4	11.7	10.2	9.3	8.9	8.6	8.3	
15-Jul-97	15.0	14.0	10.9	9.9	9.3	8.6	8.4	8.4	8.4
22-Jul-97	15.6	14.6	13.6	12.6	11.4	9.8	9.5	9.0	9.0
30-Jul-97	15.6	14.1	12.2	10.7	9.6	9.0	8.7	8.9	
2-Aug-97	15.8	14.2	12.2	10.7	9.3	9.0	8.5	8.5	
13-Aug-97	18.9	14.9	13.2	11.6	10.0	9.5	9.0	8.9	
19-Aug-97	18.3	18.3	15.3	12.4	10.8	10.0	9.1	8.9	
26-Aug-97	18.1	15.6	14.7	12.6	11.0	10.2	9.4	9.3	
3-Sep-97	18.8	18.1	17.2	14.0	11.8	11.1	10.1	9.8	
9-Sep-97	17.6	16.4	14.1	12.8	11.8	11.0	10.0	9.8	
22-Sep-97	13.7	13.7	13.6	13.6	13.6	13.6	13.3	12.6	
2-Oct-97	13.1	13.1	13.1	12.9	12.9	12.9	12.9	12.4	
6-Oct-97	12.7	12.7	12.7	12.7	12.7	12.8	12.8	12.4	

Table A.5.2 - Variable and parameter data compiled from Clear Lake, Manitoba (Station1) for the period of June 1996 to October 1997.

date	date #	St 1 Pmax	error bar (ase)	upper 95%	lower 95%	St 1 A	error bar (ase)	upper 95%	lower 95%	St 1 Ik
03-Jun-96	3	1.222	0.106	1.473	0.971	0.008	0.001	0.011	0.006	152.750
06-Jun-96	6	1.406	0.163	1.792	1.020	0.019	0.006	0.033	0.005	74.000
09-Jun-96	9	4.621	0.331	5.403	3.838	0.035	0.004	0.044	0.025	132.029
12-Jun-96	12	3.167	0.264	3.790	2.543	0.024	0.004	0.034	0.015	131.958
15-Jun-96	15	2.132	0.153	2.494	1.770	0.012	0.002	0.017	0.007	177.667
23-Jun-96	23	4.077	0.135	4.397	3.756	0.039	0.003	0.046	0.033	104.538
26-Jun-96	26	4.301	0.411	5.273	3.329	0.023	0.003	0.030	0.015	187.000
30-Jun-96	30	3.848	0.378	4.742	2.955	0.022	0.003	0.030	0.014	174.909
06-Jul-96	36	5.626	0.505	6.819	4.433	0.035	0.005	0.046	0.024	160.743
09-Jul-96	39	3.747	0.276	4.399	3.095	0.028	0.004	0.037	0.018	133.821
12-Jul-96	42	4.057	0.224	4.587	3.526	0.025	0.002	0.030	0.020	162.280
17-Jul-96	47	4.564	0.335	5.404	3.725	0.025	0.003	0.031	0.019	182.560
19-Jul-96	49	6.259	0.577	7.624	4.894	0.047	0.007	0.062	0.031	133.170
24-Jul-96	54	5.665	1.186	8.470	2.860	0.034	0.011	0.060	0.009	166.618
28-Jul-96	58	5.120	0.262	5.741	4.499	0.044	0.004	0.054	0.035	116.364
05-Aug-96	66	6.571	0.549	7.869	5.273	0.053	0.007	0.068	0.037	125.160
09-Aug-96	70	7.489	0.560	8.814	6.164	0.065	0.008	0.082	0.047	115.929
11-Aug-96	72	7.020	0.564	8.352	5.687	0.069	0.009	0.090	0.048	101.438
20-Aug-96	81	9.695	0.879	11.772	7.618	0.087	0.012	0.115	0.059	111.180
27-Aug-96	88	7.310	0.458	8.393	6.227	0.052	0.004	0.062	0.041	140.577
30-Aug-96	91	8.703	0.408	9.667	7.738	0.066	0.004	0.076	0.056	131.864
03-Sep-96	95	9.154	0.681	10.766	7.543	0.099	0.012	0.127	0.071	92.465
09-Sep-96	101	7.160	0.695	8.804	5.516	0.093	0.017	0.133	0.054	76.989
13-Sep-96	105	9.404	0.699	11.056	7.751	0.100	0.012	0.128	0.072	94.040
16-Sep-96	108	7.543	0.854	9.563	5.524	0.088	0.018	0.131	0.045	85.716
20-Sep-96	112	9.103	0.704	10.768	7.438	0.095	0.011	0.121	0.068	95.821
23-Sep-96	115	6.872	0.463	7.968	5.776	0.097	0.012	0.125	0.069	70.845
29-Sep-96	121	5.446	0.404	6.371	4.462	0.087	0.012	0.115	0.059	62.598
05-Oct-96	127	7.646	0.505	8.841	6.452	0.089	0.011	0.116	0.062	85.910
15-Oct-96	137	6.280	0.445	7.332	5.228	0.083	0.012	0.112	0.055	75.663
19-Oct-96	141	8.008	0.381	8.908	7.108	0.105	0.009	0.126	0.083	76.267
25-Oct-96	147	6.522	0.396	7.457	5.587	0.105	0.014	0.138	0.071	62.114
09-Nov-96	162	5.474	0.305	6.195	4.754	0.097	0.012	0.127	0.068	56.433
20-Jan-97	234	0.919	0.057	1.054	0.784	0.038	0.013	0.069	0.006	24.184
15-Feb-97	260	0.681	0.043	0.782	0.579	0.023	0.006	0.037	0.008	29.609
16-May-97	350	5.055	0.243	5.629	4.482	0.068	0.007	0.084	0.052	74.338
18-May-97	352	2.391	0.130	2.710	2.072	0.036	0.005	0.048	0.023	66.417
30-May-97	364	3.162	0.153	3.537	2.786	0.020	0.002	0.004	0.016	158.100
06-Jun-97	371	1.613	0.273	2.481	0.745	0.007	0.003	0.015	-0.001	230.429
13-Jun-97	378	1.304	0.248	0.912	0.697	0.010	0.004	0.021	0.000	130.400
20-Jun-97	385	5.046	0.393	5.980	4.113	0.027	0.003	0.033	0.021	186.889
24-Jun-97	389	2.715	0.423	3.715	1.715	0.022	0.007	0.039	0.006	123.409
04-Jul-97	399	3.431	0.773	5.419	1.443	0.019	0.007	0.037	0.000	180.579
08-Jul-97	403	3.786	0.820	5.059	2.514	0.031	0.008	0.050	0.012	122.129
22-Jul-97	417	5.510	0.698	7.610	3.860	0.050	0.011	0.075	0.024	110.200
30-Jul-97	425	3.463	0.386	4.376	2.550	0.024	0.004	0.035	0.014	144.292
02-Aug-97	428	3.491	0.221	4.014	2.967	0.023	0.002	0.028	0.017	151.783
13-Aug-97	439	3.211	0.168	3.609	2.812	0.029	0.003	0.037	0.022	110.724
19-Aug-97	445	0.259				0.002				129.500
26-Aug-97	452	6.322	0.235	6.878	5.767	0.034	0.001	0.037	0.031	185.941
03-Sep-97	460	7.983	0.621	8.952	6.015	0.053	0.005	0.064	0.041	150.623
09-Sep-97	466	6.841	0.337	7.637	6.045	0.053	0.003	0.061	0.046	129.075
22-Sep-97	479	9.686	0.688	11.312	8.059	0.062	0.004	0.072	0.053	156.226
02-Oct-97	489	11.616	0.773	13.445	9.787	0.091	0.008	0.109	0.072	127.648
06-Oct-97	493	7.226	0.303	7.942	6.510	0.071	0.004	0.082	0.061	101.775
mean		5.269	0.430	6.377	4.359	0.050	0.007	0.067	0.036	121.376
min		0.259	0.043	0.782	0.579	0.002	0.001	0.004	-0.001	24.184
max		11.616	1.186	13.445	9.787	0.105	0.018	0.138	0.083	230.429

Table A.5.2 cont. -

date	St 1 Spmax	error bar (ase)	upper 95%	lower 95%	St 1 A/Chla	error bar (ase)	upper 95%	lower 95%	St 1 Ik
03-Jun-96	0.238				0.002				119.000
06-Jun-96	1.132	0.121	1.418	0.845	0.011	0.004	0.020	0.003	102.909
09-Jun-96	3.952	0.280	4.613	3.290	0.029	0.003	0.037	0.021	136.276
12-Jun-96	2.853	0.227	3.390	2.316	0.022	0.004	0.030	0.014	129.682
15-Jun-96	1.134	0.069	1.298	0.972	0.006	0.001	0.009	0.004	189.000
23-Jun-96	1.644	0.038	1.735	1.553	0.016	0.001	0.018	0.013	102.750
26-Jun-96	2.444	0.181	2.870	2.017	0.013	0.002	0.017	0.008	188.000
30-Jun-96	2.830	0.237	3.391	2.268	0.016	0.002	0.022	0.011	176.875
06-Jul-96	3.990	0.315	4.734	3.246	0.025	0.003	0.032	0.017	159.600
09-Jul-96	3.316	0.231	3.861	2.771	0.024	0.003	0.032	0.016	138.167
12-Jul-96	4.017	0.221	4.540	3.494	0.025	0.002	0.030	0.020	160.680
17-Jul-96	1.940	0.100	2.177	1.703	0.011	0.001	0.013	0.008	176.364
19-Jul-96	3.795	0.309	4.525	3.064	0.028	0.004	0.037	0.019	135.536
24-Jul-96	5.104	1.036	7.554	2.653	0.031	0.010	0.054	0.008	164.645
28-Jul-96	2.510	0.096	2.737	2.282	0.022	0.002	0.026	0.017	114.091
05-Aug-96	4.212	0.307	4.938	3.485	0.034	0.004	0.044	0.024	124.976
09-Aug-96	4.993	0.337	5.790	4.196	0.043	0.005	0.055	0.031	115.835
11-Aug-96	4.679	0.339	5.481	3.878	0.046	0.006	0.060	0.032	101.505
20-Aug-96	6.059	0.509	7.264	4.855	0.055	0.007	0.072	0.037	111.180
27-Aug-96	4.250	0.218	4.766	3.734	0.030	0.003	0.036	0.024	141.667
30-Aug-96	4.917	0.189	5.364	4.471	0.037	0.002	0.042	0.032	132.892
03-Sep-96	5.385	0.364	6.246	4.524	0.058	0.007	0.075	0.042	92.845
09-Sep-96	3.393	0.282	4.060	2.726	0.044	0.008	0.063	0.026	77.114
13-Sep-96	2.758	0.149	3.111	2.405	0.029	0.003	0.037	0.021	95.103
16-Sep-96	3.560	0.346	4.378	2.741	0.041	0.008	0.061	0.021	86.829
20-Sep-96	6.068	0.437	7.101	5.035	0.063	0.007	0.081	0.046	96.317
23-Sep-96	4.343	0.510	5.548	3.138	0.070	0.023	0.123	0.016	62.043
29-Sep-96	3.263	0.213	3.766	2.760	0.052	0.007	0.069	0.035	62.750
05-Oct-96	4.201	0.246	4.782	3.620	0.049	0.006	0.063	0.034	85.735
15-Oct-96	2.673	0.150	3.028	2.318	0.035	0.005	0.047	0.024	76.371
19-Oct-96	3.103	0.114	3.373	2.833	0.041	0.003	0.049	0.033	75.683
25-Oct-96	2.772	0.140	3.104	2.440	0.043	0.006	0.058	0.029	64.465
09-Nov-96	1.109	0.042	1.210	1.009	0.020	0.002	0.025	0.014	55.450
20-Jan-97	0.713	0.045	0.820	0.606	0.029	0.010	0.054	0.005	24.586
15-Feb-97	0.760	0.047	0.871	0.649	0.026	0.007	0.043	0.009	29.231
16-May-97	1.509	0.047	1.619	1.399	0.020	0.002	0.025	0.016	75.450
18-May-97	0.671	0.069	0.871	0.438	0.010	0.002	0.014	0.005	67.100
30-May-97	1.411	0.047	1.525	1.297	0.009	0.001	0.001	0.007	156.778
06-Jun-97	0.823	0.209	1.487	1.158	0.004	0.001	0.008	0.000	205.750
13-Jun-97	1.572	0.296	2.296	0.848	0.012	0.005	0.025	0.000	131.000
20-Jun-97	4.125	0.284	4.797	3.452	0.022	0.002	0.027	0.017	187.500
24-Jun-97	1.156	0.152	1.515	0.796	0.010	0.003	0.016	0.003	115.600
04-Jul-97	1.378	0.209	1.914	0.841	0.007	0.003	0.014	0.001	196.857
08-Jul-97	2.176	0.235	2.752	1.601	0.018	0.004	0.028	0.007	120.889
22-Jul-97	2.722	0.267	3.359	2.086	0.025	0.005	0.037	0.012	108.880
30-Jul-97	2.706	0.274	3.354	2.057	0.019	0.003	0.027	0.011	142.368
02-Aug-97	2.706	0.151	3.063	2.349	0.017	0.002	0.022	0.013	159.176
13-Aug-97	1.560	0.061	1.704	1.416	0.015	0.002	0.018	0.011	104.000
19-Aug-97	0.168				0.001				168.000
26-Aug-97	2.851	0.065	3.005	2.697	0.015	0.000	3.017	0.014	190.067
03-Sep-97	2.834	0.351	3.663	2.004	0.026	0.006	0.040	0.013	109.000
09-Sep-97	2.119	0.061	2.262	1.976	0.017	0.001	0.019	0.014	124.647
22-Sep-97	2.503	0.095	2.729	2.277	0.016	0.001	0.018	0.014	156.438
02-Oct-97	2.522	0.091	2.736	2.308	0.019	0.001	0.023	0.016	132.737
06-Oct-97	7.666	0.310	8.399	6.932	0.077	0.005	0.088	0.066	99.558
mean	2.896	0.222	3.526	2.466	0.027	0.004	0.094	0.018	121.064
min	0.168	0.038	0.820	0.438	0.001	0.000	0.001	0.000	24.586
max	7.666	1.036	8.399	6.932	0.077	0.023	3.017	0.066	205.750

Table A.5.2 cont. -

date	Prod model 1	Prod model 2	Prod model 3 Pmax	Prod model 3 Spmax	surface temp	gradient	thermo depth
03-Jun-96					9.3	0.0	19.0
06-Jun-96					9.9	0.0	15.0
09-Jun-96	37731	64261	3551968	224252	11.4	0.0	12.0
12-Jun-96	26971	44103	3555108	224451	13.7	0.0	20.0
15-Jun-96	14022	22061	3556216	224521	15.8	0.9	5.0
23-Jun-96	9310	71526	3548398	224027	14.5	0.7	14.0
26-Jun-96	16990	42103	3541067	223564	15.0	0.0	
30-Jun-96	25408	40115	3527227	222690	16.9	0.0	4.0
06-Jul-96	37393	63272	3497109	220787	18.1	0.0	4.0
09-Jul-96	32063	50331	3477519	219550	18.0	1.2	10.0
12-Jul-96	27376	44646	3454664	218106	18.3	1.0	9.0
17-Jul-96	25349	44055	3408830	215211	20.0	1.1	9.0
19-Jul-96	24681	82299	3387629	213872	19.7	1.2	9.0
24-Jul-96	32311	58476	3327122	210051	19.1	1.4	10.0
28-Jul-96	31045	74385	3270660	206497	19.4	1.2	10.0
05-Aug-96	51482	85136	3137446	198072	20.9	1.8	11.0
09-Aug-96	61247	102185	3060515	193213	18.8	1.7	12.0
11-Aug-96	53619	107989	3019553	190626	19.8	1.2	11.0
20-Aug-96	72553	126875	2815255	177724	19.6	1.6	12.0
27-Aug-96	43065	70626	2635310	166361	19.4	1.6	13.0
30-Aug-96	49125	87096	2553289	161181	19.8	1.2	12.0
03-Sep-96	58924	124833	2440121	154035	19.4	1.5	12.0
09-Sep-96	64952	108799	2264177	142926	17.7	1.3	15.0
13-Sep-96	69211	110606	2144331	135358	16.3	0.0	19.0
16-Sep-96	23722	93393	2053927	129650	15.7	0.0	17.0
20-Sep-96	26415	94923	1933659	122057	15.1	0.0	17.0
23-Sep-96	43040	92426	1844312	116416	14.7	0.0	19.0
29-Sep-96	45825	75049	1669883	105403	12.2	0.0	19.0
05-Oct-96	31271	69160	1503962	94930	11.1	0.0	19.5
15-Oct-96	31095	53774	1254050	79152	9.8	0.0	19.5
19-Oct-96	31731	63215	1165360	73553	9.2	0.0	19.5
25-Oct-96	8701	56711	1045612	65994	7.3	0.0	19.5
09-Nov-96	22817	40152	801443	50582	3.4	0.0	19.5
20-Jan-97	7564	10111	515712	32547	0.0	0.0	19.0
15-Feb-97	8535	1202	101297	6393	0.0	0.0	19.0
16-May-97	71076	121347	3453350	218023	5.3	0.0	19.5
18-May-97	15900	64493	3467079	218891	5.1	0.0	19.5
30-May-97	19708	36468	3527340	222697	11.7	1.5	2.0
06-Jun-97	7086	12836	3546854	223929	15.5	1.3	4.0
13-Jun-97	10549	18379	3555709	224489	19.7	1.3	4.0
20-Jun-97	26663	49596	3553254	224333	16.6	1.0	7.0
24-Jun-97	19441	40326	3546234	223890	17.3	1.4	8.0
04-Jul-97	18323	34460	3508452	221504	16.1	1.0	11.0
08-Jul-97	18187	55832	3484399	219984	16.4	1.4	13.0
22-Jul-97	38156	86641	3352624	211662	21.0	1.4	10.0
30-Jul-97	23622	40195	3240102	204555	21.7	1.5	10.0
02-Aug-97	16113	37934	3190711	201436	21.6	1.6	10.0
13-Aug-97	26274	44619	2976948	187935	20.0	1.5	12.0
19-Aug-97	970	2935	2839519	179256	18.0	1.7	13.0
26-Aug-97	28351	46784	2662041	168049	19.0	1.4	12.0
03-Sep-97	29954	66843	2440121	154035	18.6	1.8	14.0
09-Sep-97	37598	62019	2264177	142926	17.5	1.1	12.0
22-Sep-97	32905	60048	1873976	118289	13.5	0.0	19.0
02-Oct-97	45943	74569	1585674	100087	13.2	0.0	14.0
06-Oct-97	30584	54200	1477370	93250	12.4	0.0	18.0
mean	31414	62015	2690734	169867	15.082	0.7	13.1
min	970	1202	101297	6393	0.000	0.0	2.0
max	72553	126875	3556216	224521	21.700	1.8	20.0

Table A.5.2 cont. -

date	light ext.	compensation pt	t. light	light history	Alk	ph	DIC	Chl-a	Particulate Volume	N	N/chla
03-Jun-96			40.54	281.38	193.20	8.50	46.368	4.30	2217598707	0.53	0.12
06-Jun-96			40.62	282.66	189.00	8.40	45.360	1.54	1667157227	0.14	0.09
09-Jun-96	21.80	15	40.68	283.52	195.30	8.45	46.872	1.89	686061840		
12-Jun-96	21.18	15	40.72	284.20	195.30	8.50	46.872	1.11		0.30	0.27
15-Jun-96	23.75	18	40.73	284.66	195.30	8.55	46.872	1.88	407477699	1.24	0.66
23-Jun-96	18.28	17	40.64	284.45	197.40	8.40	47.376	2.48		0.68	0.27
26-Jun-96	19.01	20	40.56	283.89	197.40	8.40	47.376	1.76	253627276	0.61	0.35
30-Jun-96	22.37	18	40.40	281.95	197.40	8.40	47.376	1.36		0.00	0.00
06-Jul-96	17.01	18	40.05	277.36	197.40	8.50	47.376	1.41	953294337	0.00	0.00
09-Jul-96	23.66	16	39.83	274.60	197.40	8.50	47.376	1.13		0.00	0.00
12-Jul-96	21.19	17	39.57	272.87	197.40	8.40	47.376	1.01	391518996	0.57	0.56
17-Jul-96	20.70	17	39.04	271.05	205.80	8.20	49.392	2.35	248371284	0.59	0.25
19-Jul-96	21.88	16	38.80	265.95	203.70	8.35	48.888	1.65		0.13	0.08
24-Jul-96	15.57	15	38.10	259.74	195.30	8.35	46.872	1.11	183373571	0.23	0.21
28-Jul-96	23.66	15	37.46	256.22	205.80	8.45	49.392	2.04	281074402	0.27	0.13
05-Aug-96	23.37	15	35.93	234.89	197.40	8.35	47.376	1.56		0.00	0.00
09-Aug-96	28.14	14	35.05	229.14	195.30	8.40	46.872	1.50	780641475	0.28	0.19
11-Aug-96	28.52	13	34.58	223.33	205.80	8.45	49.392	1.50	290724647	1.05	0.70
20-Aug-96	29.03	13	32.24	204.97	201.60	8.35	48.384	1.60	983509158	0.00	0.00
27-Aug-96	28.69	12	30.18	194.10	195.30	8.50	46.872	1.72	647098562	0.00	0.00
30-Aug-96	29.22	12	29.24	188.47	203.70	8.30	48.888	1.77		0.14	0.08
03-Sep-96	28.63	12	27.94	176.95	197.40	8.40	47.376	1.70	228030924	0.00	0.00
09-Sep-96	30.59	11	25.93	157.84	197.40	8.45	47.376	2.11	170572107	0.00	0.00
13-Sep-96	28.27	13	24.55	150.06	195.30	8.50	46.872	3.41			
16-Sep-96	32.05	11	23.52	142.73	197.40	8.40	47.376	2.12	586332309	1.71	0.80
20-Sep-96	31.10	12	22.14	136.13	195.30	8.35	46.872	1.50		0.51	0.34
23-Sep-96	31.17	12	21.12	120.23	193.20	8.40	46.368	1.75	391958966	0.30	0.17
29-Sep-96	30.48	11	19.12	111.08	203.70	8.35	48.888	1.66	213348610	0.22	0.13
05-Oct-96	27.68	13	17.22	90.06	199.50	8.40	47.880	1.82	624124540	0.26	0.14
15-Oct-96	25.04	13	14.36	64.25	205.80	8.35	49.392	2.35	756676276	0.96	0.41
19-Oct-96	23.62	12	13.34	51.05	197.40	8.45	47.376	2.58	159466530	0.73	0.28
25-Oct-96	25.20	13	11.97	37.71	201.60	8.40	48.384	2.35	243311227	0.53	0.22
09-Nov-96	23.54	15	9.18	25.74	205.80	8.35	49.392	4.95	624672058	0.43	0.09
20-Jan-97	22.87	2	5.90	9.49	214.20	8.15	53.550	1.29	38942407	0.25	0.19
15-Feb-97	22.66	2	1.16	1.16	220.50	8.10	55.125	0.89	172159141	0.35	0.39
16-May-97	19.74	15	39.55	252.85	207.90	8.50	49.896	3.35	7995772687	0.25	0.08
18-May-97	20.43	17	39.71	269.12	205.80	8.50	49.392	3.67	6000126677	0.77	0.21
30-May-97	22.61	16	40.40	278.05	191.10	8.40	45.864	2.24	1600456747	0.96	0.43
06-Jun-97	22.61	16	40.62	283.23	189.00	8.35	45.360	1.96	1127791078	1.42	0.73
13-Jun-97	25.34	16	40.72	284.55	213.40	8.40	51.216	0.83	1042500310	0.40	0.49
20-Jun-97	25.45	14	40.69	284.67	217.80	8.45	52.272	1.22	1341236173	0.45	0.37
24-Jun-97	46.03	9	40.61	284.03	209.00	8.35	50.160	2.35	1310941982	0.68	0.29
04-Jul-97	28.01	13	40.18	279.19	209.00	8.30	50.160	2.49	658808852	0.53	0.21
08-Jul-97	21.68	16	39.91	276.11	209.00	8.35	50.160	1.74	1128969780	0.19	0.11
22-Jul-97	23.77	15	38.40	263.09	204.60	8.30	49.104	2.02	688156205	1.62	0.80
30-Jul-97	28.16	13	37.11	245.82	202.40	8.35	48.576	1.28	2694776473	0.00	0.00
02-Aug-97	28.54	13	36.54	240.95	211.20	8.40	50.688	1.29	911676359	0.00	0.00
13-Aug-97	25.20	13	34.09	216.69	215.60	8.50	51.744	2.06	1501622444	0.13	0.06
19-Aug-97	20.15	20	32.52	210.54	182.60	7.35	43.824	1.54	3537014493	1.24	0.81
26-Aug-97	30.93	12	30.48	198.65	209.00	8.30	50.160	2.22	248049638	1.33	0.60
03-Sep-97	30.39	12	27.94	182.75	206.80	8.30	49.632	2.20	1306946101	0.83	0.38
09-Sep-97	22.90	13	25.93	164.64	204.60	8.30	49.104	3.23	1572016463	0.67	0.21
22-Sep-97	26.21	7	21.46	128.34	206.80	8.35	49.632	3.87	1173441689	0.11	0.03
02-Oct-97	29.35	12	18.16	101.14	213.40	8.35	51.216	4.54	1623430309	0.10	0.02
06-Oct-97	30.05	11	16.92	78.74	209.00	8.30	50.160	0.94	847246131	1.32	1.41
mean	25.35	14	31.17	203.95	201.90	8.37	48.536	2.04	1150224501	0.49	0.27
min	15.57	2	1.16	1.16	182.60	7.35	43.824	0.83	38942407	0.00	0.00
max	46.03	20	40.73	284.67	220.50	8.55	55.125	4.95	7995772687	1.71	1.41

Table A.5.2 cont. -

date	P	P/chla	T AlkPhos	T AlkPhos/chla	S AlkPhos	S AlkPhos/chla	AlkPhos/chla	TKN	NO4/NO3	PN	TP
03-Jun-96								0.50	0.09	0.41	0.053
06-Jun-96								0.48	0.05	0.43	0.005
09-Jun-96											
12-Jun-96	0.43	0.38									
15-Jun-96	0.57	0.30									
23-Jun-96	0.22	0.09						0.40	3.58	-3.18	0.010
26-Jun-96	0.28	0.16									
30-Jun-96	0.00	0.00									
06-Jul-96	1.11	0.79	0.0131	0.0093	-0.0062	-0.0044	0.0093				
09-Jul-96	0.07	0.07	0.0216	0.0192	0.0003	0.0002	0.0189	0.33	0.05	0.28	0.061
12-Jul-96	0.09	0.09	0.0215	0.0213	0.0042	0.0042	0.0171				
17-Jul-96	0.16	0.07	0.0159	0.0067	-0.0023	-0.0010	0.0067				
19-Jul-96	0.37	0.22	0.0163	0.0099	-0.0033	-0.0020	0.0099				
24-Jul-96	1.80	1.63	0.0343	0.0309	0.0193	0.0173	0.0136	0.43	0.05	0.38	0.037
28-Jul-96	0.00	0.00	0.0153	0.0075	-0.0028	-0.0014	0.0075				
05-Aug-96	0.79	0.50	0.0118	0.0075	-0.0026	-0.0017	0.0075				
09-Aug-96	0.00	0.00	0.0139	0.0093	-0.0013	-0.0009	0.0093				
11-Aug-96	0.10	0.06						0.79	0.05	0.74	0.048
20-Aug-96	0.00	0.00									
27-Aug-96	0.00	0.00									
30-Aug-96	0.36	0.21	0.0194	0.0109	0.0003	0.0001	0.0106				
03-Sep-96	0.34	0.19	0.0190	0.0112	0.0005	0.0003	0.0109	0.40	0.17	0.23	0.028
09-Sep-96	1.97	0.93									
13-Sep-96			0.0262	0.0077	0.0194	0.0057	0.0020				
16-Sep-96	0.20	0.10	0.0217	0.0102	0.0055	0.0026	0.0076	0.48	0.05	0.43	0.050
20-Sep-96	0.13	0.09	0.0129	0.0086	-0.0009	-0.0006	0.0086				
23-Sep-96	0.21	0.12	0.0200	0.0115	0.0058	0.0033	0.0081				
29-Sep-96	0.00	0.00	0.0241	0.0145	0.0100	0.0060	0.0085				
05-Oct-96	0.71	0.39	0.0118	0.0065	-0.0025	-0.0014	0.0065	0.36	0.19	0.17	0.244
15-Oct-96	0.33	0.14	0.0197	0.0084	-0.0006	-0.0002	0.0084				
19-Oct-96	0.29	0.11	0.0188	0.0073	-0.0010	-0.0004	0.0073				
25-Oct-96	0.37	0.16	0.0252	0.0107	-0.0021	-0.0009	0.0107				
09-Nov-96	0.50	0.10	0.0262	0.0053	0.0084	0.0017	0.0036				
20-Jan-97	0.31	0.24	0.0204	0.0158	-0.0005	-0.0004	0.0158	0.51	0.05	0.46	0.051
15-Feb-97	0.83	0.94	0.0182	0.0204	-0.0044	-0.0049	0.0204	0.41	0.05	0.36	0.015
16-May-97	0.71	0.21	0.0152	0.0045	-0.0014	-0.0004	0.0045	0.30	0.96	-0.66	0.005
18-May-97	0.40	0.11	0.0152	0.0041	-0.0017	-0.0005	0.0041				
30-May-97	0.31	0.14	0.0145	0.0065	-0.0014	-0.0006	0.0065				
06-Jun-97	0.50	0.25	0.0153	0.0078	-0.0020	-0.0010	0.0078				
13-Jun-97	0.43	0.52	0.0083	0.0100	-0.0112	-0.0135	0.0100				
20-Jun-97	0.59	0.48	0.0205	0.0168	0.0043	0.0035	0.0133				
24-Jun-97	0.56	0.24						1.25	0.05	1.20	0.100
04-Jul-97	0.50	0.20	0.0156	0.0063	-0.0015	-0.0006	0.0063				
08-Jul-97	0.00	0.00	0.0161	0.0093	-0.0016	-0.0009	0.0093				
22-Jul-97	0.64	0.32	0.0178	0.0088	-0.0164	-0.0081	0.0088				
30-Jul-97	0.68	0.53	0.0153	0.0119	-0.0123	-0.0096	0.0119				
02-Aug-97	0.80	0.62	0.0147	0.0114	-0.0096	-0.0074	0.0114				
13-Aug-97	1.19	0.58	0.0284	0.0138	-0.0092	-0.0045	0.0138				
19-Aug-97	0.39	0.25									
26-Aug-97	0.36	0.17	0.0256	0.0115	-0.0021	-0.0010	0.0115				
03-Sep-97	0.24	0.11	0.0152	0.0069	-0.0014	-0.0006	0.0069				
09-Sep-97	0.18	0.06	0.0133	0.0034	-0.0034	-0.0009	0.0034				
22-Sep-97	0.12	0.03	0.0206	0.0064			0.0064				
02-Oct-97	0.30	0.07	0.0149	0.0033	0.0099	0.0022	0.0011				
06-Oct-97	0.59	0.63	0.0149	0.0159	0.0096	0.0102	0.0057				
mean	0.43	0.27	0.0183	0.0105	-0.0002	-0.0003	0.0091	0.51	0.41	0.10	0.054
min	0.00	0.00	0.0083	0.0033	-0.0164	-0.0135	0.0011	0.30	0.05	-3.18	0.005
max	1.97	1.63	0.0343	0.0309	0.0194	0.0173	0.0204	1.25	3.58	1.20	0.244

Table A.5.2 cont. -

date	DP	PP	TOC	DOC	POC	Silicone	N/P	C/P	C/N	C/Chl-a
03-Jun-96	0.047	0.008	5.20	5.10	0.10	6.90	68.33	2.13	0.24	0.000021
06-Jun-96	0.005	0.000	5.50	5.30	0.20	6.64	0.00	40.00	0.47	0.000032
09-Jun-96										
12-Jun-96										
15-Jun-96										
23-Jun-96	0.005	0.005	5.10	5.10	0.00	7.03	0.00	0.00	0.00	0.001444
26-Jun-96										
30-Jun-96										
06-Jul-96										
09-Jul-96	0.038	0.023	6.10	5.90	0.20	6.56	12.17	5.26	0.71	0.000044
12-Jul-96										
17-Jul-96										
19-Jul-96										
24-Jul-96	0.017	0.020	5.70	5.70	0.00	8.00	19.00	0.00	0.00	0.000045
28-Jul-96										
05-Aug-96										
09-Aug-96										
11-Aug-96	0.041	0.007	6.20	6.20	0.00	5.75	105.71	0.00	0.00	0.000033
20-Aug-96										
27-Aug-96										
30-Aug-96										
03-Sep-96	0.012	0.016	5.20	4.82	0.38	7.52	14.38	31.67	1.65	0.000099
09-Sep-96										
13-Sep-96										
16-Sep-96	0.048	0.002	5.70	5.70	0.00	7.43	215.00	0.00	0.00	0.000024
20-Sep-96										
23-Sep-96										
29-Sep-96										
05-Oct-96	0.005	0.239	4.20	4.00	0.20	7.53	0.71	40.00	1.18	0.000104
15-Oct-96										
19-Oct-96										
25-Oct-96										
09-Nov-96										
20-Jan-97	0.049	0.002	5.20	5.00	0.20	7.63	230.00	4.08	0.43	0.000039
15-Feb-97	0.014	0.001	5.10	2.90	2.20	7.25	360.00	157.14	6.11	0.000562
16-May-97	0.005	0.000	5.10	4.90	0.20	7.11	0.00	40.00	0.00	0.000262
18-May-97										
30-May-97										
06-Jun-97										
13-Jun-97										
20-Jun-97										
24-Jun-97	0.060	0.040	6.30	5.20	1.10	6.87	30.00	18.33	0.00	0.000021
04-Jul-97										
08-Jul-97										
22-Jul-97										
30-Jul-97										
02-Aug-97										
13-Aug-97										
19-Aug-97										
26-Aug-97										
03-Sep-97										
09-Sep-97										
22-Sep-97										
02-Oct-97										
06-Oct-97										
mean	0.027	0.028	5.43	5.06	0.37	7.09	81.18	26.05	0.83	0.000210
min	0.005	0.000	4.20	2.90	0.00	5.75	0.00	0.00	0.00	0.000021
max	0.060	0.239	6.30	6.20	2.20	8.00	360.00	157.14	6.11	0.001444

Table A.5.3 - Station 2 Field Data in Clear Lake, Manitoba for the period of June 1996 to October 1997.

Date	Time	Altitude	N	W	Sample Depth	Total Depth	Notes		
1-Jun-96	10:30 cst	2094 ft	50'4 0.34'	99'5 6.39'	2 m	28 m	only 3 chl-a.	1 phyto. and drag	net
3-Jun-96	10:50 cst	2107 ft	50'4 0.33'	99'5 6.49'	2 m	31 m	no drag net	strong winds	and weather
6-Jun-96	08:00 cst				2 m	29 m	GPS died and	location	was estimated
9-Jun-96	09:10 cst	2060 ft	50'4 0.36'	99'5 6.51'	2 m	23 m	no NW taken	rain just before	and overcast
12-Jun-96	07:05 cst	2090 ft	50'4 0.31'	99'5 6.44'	2m & 5m	33.5 m	alot of drift	was occuring	no NW taken
15-Jun-96	08:40 cst	2090 ft	50'4 0.31'	99'5 6.44'	2m & 3m	30.5 m	some drift	was occuring	no NW taken
23-Jun-96	08:00 cst	2150 ft	50'4 0.31'	99'5 6.43'	2m & 14m	31 m	NW samples	taken	alot of wind
26-Jun-96	08:30 cst	2109 ft	50'4 0.33'	99'5 0.43'	2m & 10m		no NW	samples	taken
30-Jun-96	09:35 cst	2369 ft	50'4 1.33'	99'5 0.47'	2m & 9m	29 m	no NW	samples	taken
6-Jul-96	08:30 cst	2113 ft	50'4 0.31'	99'5 6.44'	0m - 10m	29 m	no NW	samples	taken
9-Jul-96	09:00 cst	1989 ft	50'4 0.31'	99'5 6.44'	0m - 10m	30 m	NW sample	2m mark	no wind
12-Jul-96	11:20 cst	2132 ft	50'4 0.31'	99'5 6.44'	0m - 10m	31 m	no NW	samples	
17-Jul-96	11:15 cst	2164 ft	50'4 1.31	99'5 6.47'	0m - 12m	30 m	no NW	samples	
19-Jul-96	08:30 cst	2166 ft	50'4 1.34	99'5 6.44'	0m - 11m	31.5 m	no NW	samples	rel. calm
24-Jul-96	10:45 cst	2166 ft	50'4 1.34	99'5 6.44'	0m - 11m	31.5 m	NW sample	2m mark	alot of drift
28-Jul-96	10:10 cst	2055 ft	50'4 1.32	99'5 6.45'	0m - 11m	31 m	no NW	samples	rel. calm
5-Aug-96	09:15 cst	2054 ft	50'4 1.30'	99'5 6.49'	0m - 11m	30 m	no NW	samples	rel. calm
9-Aug-96	08:50 cst	2192 ft	50'4 1.32'	99'5 6.42'	0m - 11m	31 m	no NW	samples	rel. calm
11-Aug-96	02:20 cst	2145 ft	50'4 1.29'	99'5 6.41'	0m - 12m	31.5 m	NW sample	2m mark	rel. calm
20-Aug-96	10:00 cst	2145 ft	50'4 1.32'	99'5 6.49'	0m - 13m	31.5 m	no NW	samples	rel. calm
27-Aug-96	08:40 cst	2091 ft	50'4 1.29'	99'5 6.38'	0m - 11m	31 m	no NW	samples	taken
30-Aug-96	08:30 cst	2145 ft	50'4 1.28'	99'5 6.39'	0m - 13m	31 m	no NW	samples	calm
3-Sep-96	07:00 cst	1976 ft	50'4 0.27'	99'5 6.40'	0 - 10 m	34 m	NW samples	taken 2 m	choppy waves
3-Sep-96	station 2-2	09:10 cst	1970 ft	50'4 0.26'	99'5 6.41'	0 - 15 m	31 m	no NW	choppy waves
3-Sep-96	station 2-3	11:15 cst	1932 ft	50'4 0.36'	99'5 6.28'	0 - 14 m	31 m	no NW	choppy waves
3-Sep-96	station 2-4	14:45 cst	2159 ft	50'4 0.33'	99'5 6.41'	0 - 14 m	30 m	no NW	choppy waves
3-Sep-96	station 2-5	16:45 cst	1897 ft	50'4 0.39'	99'5 6.47'	0 - 18 m	33.5 m	no NW	choppy waves
6-Sep-96	09:00 cst	1837 ft	50'4 0.30'	99'5 6.40'	0 - 17 m	32 m	no NW	choppy waves	windy couple days
9-Sep-96	08:05 cst	1950 ft	50'4 0.29'	99'5 6.39'	0 - 15 m	30 m	no NW	rel. calm	some drift
13-Sep-96	10:55 cst	2040 ft	50'4 0.30'	99'5 6.40'	0m - 19m	31 m	no NW	choppy waves	alot of drift
16-Sep-96	09:55 cst	2220 ft	50'4 0.33'	99'5 6.39'	0m - 17m	32 m	NW sample 2m	rel. calm	some drift
20-Sep-96	08:30 cst	1999 ft	50'4 0.27'	99'5 6.45'	0m - 17m	29 m	no NW	rel. calm	some drift
23-Sep-96	09:15 cst	1855 ft	50'4 0.36'	99'5 6.39'	0m - 19m	32 m	no NW	choppy waves	alot of drift
29-Sep-96	10:15 cst	1556 ft	50'4 0.27'	99'5 6.44'	0m - 26m	31.5 m	no NW	choppy waves	alot of drift
5-Oct-96	08:40 cst	1970 ft	50'4 0.32'	99'5 6.42'	0m - 31.5 m	31.5 m	NW sample 2m	rel. calm	some drift
15-Oct-96	10:15 cst	1556 ft	50'4 0.27'	99'5 6.44'	0m - 31.5m	31.5 m	no NW	choppy waves	alot of drift
19-Oct-96	09:30 cst	1897 ft	50'4 0.30'	99'5 6.38'	0m - 31.5m	31.5 m	no NW	calm overcast	huge N winds
25-Oct-96	10:30 cst	1907 ft	50'4 0.31'	99'5 6.40'	0m - 33m	33 m	no NW	foggy & no	visibility
2-Nov-96	11:15 cst	2194 ft	50'4 0.36'	99'5 6.49'	0m - 30m	30 m	NW - 2m sample	canoe to pt	sunny
9-Nov-96	10:10 cst	2063 ft	50'4 0.26'	99'5 6.35'	0m - 32m	32 m	no NW	snowing	overcast foggy
1-Jan-97	14:15 cst	1881 ft	50'4 0.30'	99'5 6.40'	0m - 29m	29 m	no NW	snow 15 cm	ice 41 cm
20-Jan-97	10:00 cst	2144 ft	50'4 0.33'	99'5 6.35'	0m - 31m	31 m	NW sample 2m	snow 17.5 cm	ice 44 cm
15-Feb-97	12:30 cst	2144 ft	50'4 0.35'	99'5 6.40'	0m - 31m	31 m	NW sample 2m	snow 26 cm	ice 59 cm
17-Mar-97	11:00 cst	2232 ft	50'4 0.33'	99'5 6.35'	0m - 31m	31 m	NW sample 2m	snow 25 cm	ice 74 cm
26-Apr-97	10:00 cst	1997 ft	50'4 0.28'	99'5 6.40'	0m - 27m	27 m	NW sample 2m	snow 5cm slush	ice 51 cm
16-May-97	10:30 cst	2040 ft	50'4 0.32'	99'5 6.45'	0m - 31.5m	31.5 m	NW sample 2m	calm	some wind
18-May-97	02:45 cst	2040 ft	50'4 0.34'	99'5 6.41'	0m - 31.5m	31.5 m	NW sample 2m	snowy	some wind
30-May-97	09:45 cst	2043 ft	50'4 0.29'	99'5 6.48'	0m - 4m	31.5 m	no NW	calm	some cloud
6-Jun-97	09:50 cst	2173 ft	50'4 0.32'	99'5 6.43'	0m - 4m	31.5 m	no NW	some wind	no clouds
13-Jun-97	03:30 cst	2055 ft	50'4 0.31'	99'5 6.34'	0m - 6m	26 m	no NW	some wind	some cloud
20-Jun-97	10:00 cst	2197 ft	50'4 0.32'	99'5 6.41'	0m - 10m	32.5 m	no NW	sunny	calm
24-Jun-97	10:23 cst	1914 ft	50'4 0.27'	99'5 6.40'	0m - 10m	31 m	NW	sunny	calm
4-Jul-97	10:00 cst	2193 ft	50'4 0.31'	99'5 6.42'	0m - 13m	31.5 m	no NW	sunny	wavy
8-Jul-97	10:45 cst	2093 ft	50'4 0.32'	99'5 6.39'	0m - 13m	31 m	no NW	cloudy	foggy
15-Jul-97	03:30 cst	2133 ft	50'4 0.30'	99'5 6.40'	0m - 8m	33.5 m	no NW	sunny	wavy
22-Jul-97	10:10 cst	1990 ft	50'4 0.32'	99'5 6.38'	0m - 14m	33 m	no NW	sunny	some wind
30-Jul-97	10:10 cst	2040 ft	50'4 0.35'	99'5 6.43'	0m - 13m	31 m	no NW	sunny	wavy
2-Aug-97	10:00 cst	2044 ft	50'4 0.29'	99'5 6.47'	0m - 10m	29 m	no NW	sunny	cloudy
13-Aug-97	3:00 cst	2082 ft	50'4 0.32'	99'5 6.41'	0m - 13m	31 m	no NW	sunny	some wind
19-Aug-97	9:25 cst	2013 ft	50'4 0.29'	99'5 6.44'	0m - 13m	32 m	no NW	no sun	rel. calm
26-Aug-97	10:15 cst	1975 ft	50'4 0.30'	99'5 6.36'	0m - 14m	33 m	no NW	sunny	rel. calm
3-Sep-97	11:00 cst	2001 ft	50'4 0.30'	99'5 6.40'	0m - 13m	32 m	no NW	sunny	cool
9-Sep-97	9:45 cst	2000 ft	50'4 0.31'	99'5 6.42'	0m - 15m	31 m	no NW	sunny	some wind
22-Sep-97	9:15 cst	2001 ft	50'4 0.29'	99'5 6.50'	0m - 26m	32 m	no NW	sunny	some wind
2-Oct-97	10:55 cst	1916 ft	50'4 0.32'	99'5 6.44'	0m - 31m	31 m	no NW	sunny	some wind
6-Oct-97	10:00 cst	2322 ft	50'4 0.31'	99'5 6.38'	0m - 31m	31 m	no NW	sunny	some wind

Table A.5.3 cont. - Station 2 Field D: Station 2 Field Data in Clear Lake, Manitoba for the period of June 1996 to October 1997.

Date			0 m	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	13 m	14 m
1-Jun-96			9.1	8.4	7.9	7.7	7.7	7.6	7.6	7.5	7.2	7	6.9	6.8	6.8	6.6	6.4
3-Jun-96	may have mixed	lake	9.7	9.6	9.6	9.4	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.2	9.2
6-Jun-96	by night		7.8	7.7	7.6	7.5	7.4	7.2	7	7	6.8	6.6	6.4	6.2	6.1	6	5.9
9-Jun-96			12.6	12.3	12	11.8	11.4	11.1	10.9	10.1	9.3	8.2	7.8	7.4	7	6.8	6.5
12-Jun-96			14.7	14.7	14.7	14.6	14.6	14.5	13.9	12.8	12.6	11.8	11.3	10.9	10.5	9.9	9.6
15-Jun-96			16.9	16.9	16.9	16.8	14.6	13.6	12.6	11.7	11.4	11.2	10.9	10.4	10.1	9.4	8.9
23-Jun-96	action days	before	13.4	13.4	13.4	13	12.8	12.5	12.3	12.2	12	11.9	11.6	11.5	11.3	11.1	10.9
26-Jun-96	thermometer	forgotten															
30-Jun-96	alot of drift	HUGE waves	18.5	18.4	18.4	18.4	18.3	18.3	18.1	18	18	18	17.7	11.9	11.2	10.6	10.3
6-Jul-96	alot of drift	HUGE waves	19.1	19	19	18.7	18.5	18.4	18.4	18.3	18.3	18.2	17.2	15.9	14.6	13.2	12.6
9-Jul-96	smooth/calm	1L at 3m depths	18.6	18.6	18.6	18.6	18.4	18	17.8	17.6	17.1	16.7	16.4	15.4	14.4	11.9	10.5
12-Jul-96			19	19.1	18.9	18.8	18.7	18.5	18.3	18.1	17.8	17.3	17	15.6	15	13.7	11.8
17-Jul-96			19.8	19.6	19.3	19	18.8	18.2	18.1	17.5	17.2	16.5	16.3	16.3	15.5	14.5	12.2
19-Jul-96	dark	overcast	19.4	19.4	19.4	19.3	19.1	19	18.9	18.9	18.4	18.2	17.8	16.3	13.5	13.4	11.9
24-Jul-96	HUGE waves	GPS died	19.5	19.5	19.5	19.5	19.5	19.5	19.4	19.4	19.4	19.3	19.2	19	18.4	14.9	12.1
28-Jul-96	dark	overcast	19.1	19.1	19.1	19.1	19.1	19.1	18.9	18.7	18.6	18.4	18.3	18.1	16.9	13.4	11.8
5-Aug-96	some	drift	21.1	21.1	21.1	21.1	21	21	21	20.9	20.5	19.8	19.4	18.7	17.3	15.6	13.9
9-Aug-96	some	drift	19.3	19.4	19.5	19.5	19.5	19.4	19.4	19.4	19.4	19.4	19.4	19.2	15.8	12.7	11.6
11-Aug-96	some	drift	20.5	20.5	20.5	20.4	20.4	20.4	20.3	20.3	20.2	20.2	19.5	19	18.4	17.3	13.2
20-Aug-96	some	drift	19.6	19.6	19.6	19.6	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.2	18.3	15.4
27-Aug-96	alot of drift		20	20	20	20	20	20	20	20	20	19.9	19.5	18.3	17.5	16.8	14.6
30-Aug-96			19.9	19.9	19.9	19.9	19.9	19.7	19.6	19.5	19.4	19.3	19.2	19	18.8	18.3	16.6
3-Sep-96	windy	alot of drift	19.8	19.9	20	20	20	20	20	21.1	21.1	21.1	21.1	20	19.9	19.8	19.8
3-Sep-96	windy	alot of drift		20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.0	20.0	20.0	19.9
3-Sep-96	windy	alot of drift		20.2	20.2	20.2	20.2	20.2	20.1	20.1	20.1	20.1	20.1	20.1	20.0	20.0	20.0
3-Sep-96	windy	alot of drift		20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.8	19.8	19.8	19.8	19.8
3-Sep-96	windy	alot of drift		20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.6	19.6	19.5	19.5
6-Sep-96	alot of drift	ppt before dark	18.1	18.1	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.1	18.1	18.1	18.1	18.1
9-Sep-96			18	18	18	18	18	18	18.1	18.1	18	18	17.9	17.4	17.2	16.8	16
13-Sep-96			16.3	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.2	16	16
16-Sep-96			15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.1	14.9	14.9	14.9
20-Sep-96	sampler broke	deep 6ed	14.9	15	15	15	15	15	15	15	15	15	14.9	14.9	14.9	14.9	14.8
23-Sep-96			14.4	14.4	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.6	14.6	14.6	14.6	14.6	14.6
29-Sep-96			12.6	12.6	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.9	12.9	12.9	12.9	12.8	12.7
5-Oct-96			11	11.1	11.1	11.1	11.1	11	11	10.9	10.9	10.9	10.9	10.9	10.8	10.8	10.7
15-Oct-96			9.9	9.9	10	10	10	10	10	10	10	10	10	10.1	10.1	10.1	10.1
19-Oct-96	previous days	no drag net	9	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9	9	9	9
25-Oct-96	some wind	& drift	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
2-Nov-96	sampled thru	2 cm ice	2.4	3	3.4	3.7	3.9	3.9	4	4	4	4.1	4.1	4.1	4.1	4.1	4.1
9-Nov-96	extreme cold	no drag net	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.6	2.7	2.9	2.9	3	3	3	3
1-Jan-97	overcast	no sun	1.2	1.6	2.1	2.4	2.6	2.7	2.8	2.9	3	3	3	3	3	3.1	3.1
20-Jan-97	some cloud	sunny	0.1	0.1	1.6	2.2	2.5	2.7	2.8	2.9	2.9	3	3	3	3	3.1	3.1
15-Feb-97	some cloud	sunny	0.5	1	2	2.5	2.7	2.8	2.9	2.9	3	3	3.1	3.1	3.1	3.2	3.2
17-Mar-97	some wind	sunny	0.5	0.7	1.7	2.3	2.6	2.8	2.9	3	3	3.1	3.1	3.1	3.1	3.1	3.2
26-Apr-97	dark clouds	windy no sun	2.5	4.4	4	4	3.9	3.9	3.9	4	3.9	3.9	3.9	4	3.9	3.9	3.9
16-May-97	no clouds	sunny	5.7	5.6	5.5	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5	5	5	4.9	4.9
18-May-97	cloudy	cold	5.1	5.1	5.1	5.1	5	5	5	5	5	5	5	5	5	5	5
30-May-97	sunny		11.2	10.6	10.4	10.2	10	8.6	8.5	8	7.7	7.5	7.3	7.1	7	6.8	6.7
6-Jun-97	sunny		13.2	13.1	13	12.5	12	10.4	9.4	9.1	8.8	8.3	8.1	7.8	7.5	7.5	7.4
13-Jun-97	sunny		17.7	17.6	16.8	16.7	16.5	16.4	16	15.1	14.2	11.8	10.2	9	8.2	7.5	7.2
20-Jun-97	no wind		16.2	16.1	16.1	16.1	16.1	16	16	16	15.9	15.8	15.2	13	11.9	11	10.5
24-Jun-97	little wind	cloud cover	17.3	17.2	17.1	17.1	17.1	17.1	17.1	17	17	16.9	16.6	14.5	11.7	10.7	9.6
4-Jul-97	wind		16.9	16.9	16.9	16.9	16.8	16.4	16.3	16.1	16	15.8	15.4	15.1	14.8	14	12.6
8-Jul-97	some wind	no sun	16.7	16.7	16.6	16.5	16.3	16.2	16.1	15.9	15.7	15.5	15.3	15	15.2	13.4	11.6
15-Jul-97	wind		21.3	21.3	21.3	21.3	21.2	20.9	20.6	20.1	18.8	17.4	17	16.8	15.8	15	14.5
22-Jul-97	no clouds		21	20.9	20.9	20.9	20.8	20.7	20.6	19.8	19.1	18.2	17.8	17.4	17.1	16.4	15.7
30-Jul-97	wind		21.9	21.9	21.9	21.9	21.9	21.9	21.8	21.7	21.4	19.7	18.5	17.7	17	15.8	14.3
2-Aug-97	little wind		21.9	21.9	21.9	22	22	22	22	22	22	22	21.8	17	15.1	13.9	12.5
13-Aug-97	little clouds		20.2	20.3	20.2	19.9	19.6	19.6	19.5	19.4	19.2	19.2	18.8	18.2	18.4	18	11.6
19-Aug-97	cloudy	cool	18.2	18.3	18.4	18.4	18.4	18.4	18.4	18.2	18	17.6	17.4	17.1	16.7	15	13.8
26-Aug-97	no clouds		19.1	19.1	19.1	19.1	19.1	19.1	19	19	19	19	19	19	18.9	18.8	18.7
3-Sep-97	no clouds		18.8	18.8	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.8	18.8	18.6	18.1	17.2	13.9
9-Sep-97	some clouds		17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.6
22-Sep-97	some clouds	cool	13.7	13.9	13.9	14	14	14	14	14	14	14.1	14	14.1	14	13.8	13.6
2-Oct-97	cool		13.3	13.3	13.3	13.3	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
6-Oct-97	cool		12.3	12.5	12.6	12.6	12.7	12.7	12.7	12.7	12.7	12.7	12.8	12.8	12.8	12.8	12.8

Table A.5.3 cont. -

Date	15 m	16 m	17 m	18 m	19 m	20 m	21 m	22 m	23 m	24 m	25 m	26 m	27 m	28 m	29 m	30 m	31 m	32 m	33 m	34 m
1-Jun-96	6.3	6.3	6.1	5.8	5.7	5.5	4.6	4.3	4.2	4.1	4.1	4.1	4.1	4.1						
3-Jun-96	9.1	9.1	9	8.9	8.7	8.4	7	6.8	5.8	5.4	5.1	4.9	4.8	4.6	4.4	4.3	4			
6-Jun-96	5.8	5.6	5.6	5.5	5.4	5.3	5.2	5.1	5.1	5	5	5	5	5	4.9					
9-Jun-96	6.4	6	5.8	5.7	5.6	5.4	5.4	5.4	5.3											
12-Jun-96	9.4	9	8.7	8.3	7.7	7.3	7	6.6	6.4	6	5.9	5.7	5.5	5.4	5.4	5.4	5.4	5.3	5.3	5.2
15-Jun-96	8.6	8.3	8.1	7.7	7.4	7	6.5	6.2	6.1	6	5.9	5.8	5.7	5.6	5.6	5.3				
23-Jun-96	10.3	9.9	9.7	9.4	9	8.4	8.2	7.8	7.5	7.3	7.1	7	6.8	6.7	6.6	6.5	6.3			
26-Jun-96																				
30-Jun-96	10	9.4	9.2	8.9	8.5	7.6	7.4	7.3	7.2	7.1	7	6.8	6.6	6.6	6.6					
6-Jul-96	12.3	12	11.8	11.4	11.1	10.9	10.1	9.3	8.2	7.8	7.4	7	6.8	6.5	6.4					
9-Jul-96	10	9.7	9	8.8	8.6	8.4	8.3	8	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.3				
12-Jul-96	11	10.3	10	9.6	9	8.9	8.9	8.5	8	7.9	7.8	7.7	7.7	7.6	7.6	7.6	7.4			
17-Jul-96	10.7	10.1	9.5	9.2	9.1	9	8.8	8.7	8.3	8	7.7	7.5	7.5	7.4	7.4	7.3				
19-Jul-96	11.1	10.8	10.5	10.3	9.8	9.5	9.3	9.2	9	8.9	8.6	8.4	8	7.8	7.7	7.7	7.7	7.5		
24-Jul-96	11.4	11	10.5	10.2	9.8	9.5	9.2	9.1	8.5	8.4	8.3	8.3	8.2	8.1	7.9	7.7	7.6			
28-Jul-96	10.8	10.3	10.2	9.9	9.7	9.5	9.2	9.1	8.9	8.8	8.6	8.7	8.2	8.1	8	8	7.9			
5-Aug-96	12.2	11.4	10.6	10.2	10	9.8	9.6	9.4	9	8.6	8.4	8.2	8.1	8.1	8	7.8				
9-Aug-96	11	10.6	10.4	10.1	10	9.8	9.5	9.3	9.2	8.8	8.6	8.4	8.3	8.3	8.2	8.1	7.9			
11-Aug-96	10.2	9.9	9.6	9.3	9.1	9	9	8.8	8.8	8.8	8.8	8.6	8.4	8.3	8.2	8.2	8.2	8.2		
20-Aug-96	13	11.2	10.2	10	9.8	9.6	9.5	9.3	9.1	9	8.9	8.9	8.7	8.5	8.4	8.3	8.2	8.2		
27-Aug-96	12	11.5	10.8	10.6	10	9.8	9.5	9.4	9.2	8.9	8.7	8.6	8.5	8.5	8.4	8.3	8.3			
30-Aug-96	12.5	11.3	10.7	10.4	10	9.8	9.7	9.5	9.1	8.8	8.6	8.5	8.5	8.4	8.3	8.3	8.3			
3-Sep-96	19.4	16.4	12.9	11.1	10.5	10	9.6	9.5	9.2	9.1	9	8.8	8.7	8.7	8.6	8.6	8.6	8.6	8.5	8.4
3-Sep-96	19.1	18.5	14.2	11.6	11.1	10.3	9.9	9.6	9.2	9.1	8.9	8.8	8.7	8.6	8.6	8.6	8.6	8.5		
3-Sep-96	19.8	17.1	15.1	12.8	11.2	10.8	10.1	9.8	9.5	9.2	9.0	8.9	8.8	8.7	8.7	8.6	8.6	8.4		
3-Sep-96	19.2	18.8	18.5	14.1	11.5	10.6	10.4	9.3	9.2	9.0	8.9	8.8	8.8	8.6	8.6	8.4	8.3			
3-Sep-96	19.5	19.4	19.4	19.4	19.4	13.8	13.8	10.8	10.4	9.7	9.5	9.4	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.5
6-Sep-96	17.8	17.7	17.6	16.2	13.4	10.6	10.1	9.8	9.6	9.5	9.4	9.1	8.7	8.6	8.6	8.6	8.6	8.5		
9-Sep-96	15.6	13.5	12.5	11.6	11	10.2	10	9.7	9.2	9	9	8.9	8.9	8.9	9	9				
13-Sep-96	15.9	15.9	15.5	15.2	14.6	13.6	12	11	10.5	10.2	10	9.9	9.7	9.4	9.3	9.3				
16-Sep-96	14.8	14.6	13.8	12.6	11.6	10.8	10.3	9.8	9.7	9.6	9.3	9.1	8.9	8.7	8.7	8.7	8.7	8.6		
20-Sep-96	14.7	14.5	14.3	12.2	10.8	10.3	10	9.8	9.6	9.2	9.1	8.9	8.8	8.7	8.7					
23-Sep-96	14.5	14.4	14.4	14.4	14.1	10.1	9.6	9.3	9	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5		
29-Sep-96	12.7	12.6	12.6	12.6	12.4	12.3	12.3	12.2	12.2	12	11.5	11.1	9.7	9.2	9.1	9	8.9			
5-Oct-96	10.7	10.7	10.7	10.6	10.6	10.6	10.6	10.5	10.5	10.4	10.4	10.3	10.1	10	9.8	9.7	9.4	9.4		
15-Oct-96	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10	10	10	10	
19-Oct-96	9	9	9	9	9	9	9	9	9	9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9		
25-Oct-96	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.3	7.3	7.3	7.3	7.3	7.3	7.3	
2-Nov-96	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.5				
9-Nov-96	3	3.1	3.1	3.1	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.3	3.3	3.3	3.4	3.4	3.6		
1-Jan-97	3.1	3.1	3.1	3.2	3.2	3.2	3.2	3.3	3.3	3.4	3.4	3.4	3.6	3.6	3.9					
20-Jan-97	3.1	3.2	3.2	3.3	3.2	3.3	3.3	3.2	3.3	3.3	3.4	3.3	3.3	3.4	3.7	3.9	4.2	4.3		
15-Feb-97	3.2	3.2	3.3	3.3	3.2	3.3	3.3	3.4	3.4	3.4	3.4	3.5	3.3	3.5	3.7	3.9	4.2			
17-Mar-97	3.2	3.2	3.3	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.3	3.4	3.6	3.7	4.1			
26-Apr-97	3.9	3.8	3.8	3.6	3.4	3.4	3.4	3.3	3.3	3.4	3.4	3.4	3.5							
16-May-97	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7		
18-May-97	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4.9		
30-May-97	6.6	6.4	6.4	6.3	6.2	6.2	6.2	6.1	6	6	5.9	5.9	5.8	5.7	5.7	5.6	5.5	5.4		
6-Jun-97	6.9	6.5	6.4	6.3	6.2	6.2	6.1	6.1	5.9	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7		
13-Jun-97	7.1	7	6.8	6.5	6.4	6.3	6.2	6.1	6.1	6.1	6.1	6								
20-Jun-97	9.9	9.5	9.1	8.4	8.2	7.8	7.7	7.5	7.3	7.2	7	6.9	6.9	6.8	6.7	6.7	6.7	6.6	6.5	
24-Jun-97	8.6	8.4	8.1	7.7	7.7	7.5	7.4	7.3	7.1	7	6.9	6.9	6.8	6.8	6.8	6.7	6.7			
4-Jul-97	10.3	9.4	8.6	8.2	8	7.9	7.8	7.6	7.4	7.3	7.1	7	6.9	6.9	6.8	6.7	6.7	6.7		
8-Jul-97	10.6	9.2	8.7	8.4	8.1	7.9	7.8	7.6	7.4	7.3	7.3	7.1	7	6.8	6.8	6.7	6.7			
15-Jul-97	13.6	9.6	9	8.5	8.3	8	7.8	7.8	7.4	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8
22-Jul-97	13.6	10.5	9.9	8.9	8.5	8.3	8.2	8	7.8	7.6	7.5	7.3	7.2	7.1	7.1	7.1	7.1	7.1	7.1	7.1
30-Jul-97	11.9	10.9	10.5	9.7	9.4	8.9	8.7	8.4	8.2	8	7.9	7.8	7.7	7.5	7.4	7.4	7.4			
2-Aug-97	12	11.7	10.1	9.4	9.2	9	8.9	8.7	8.6	8.3	7.8	7.7	7.6	7.7	7.5					
13-Aug-97	10.8	10.1	9.5	9.3	9	8.7	8.5	8.5	8.3	8	7.9	7.8	7.7	7.6	7.5	7.5	7.4			
19-Aug-97	11.8	10.4	9.7	9.4	9.1	8.8	8.7	8.5	8.4	8.1	7.9	7.7	7.7	7.7	7.7	7.6	7.6	7.7		
26-Aug-97	17.8	12.9	11.7	10.1	9.6	9.2	8.8	8.4	8.2	8	8	8	7.9	7.9	7.7	7.7	7.6	7.6	7.5	
3-Sep-97	12.5	11.6	10.9	10.6	10.3	9.9	9	9.1	8.6	8.3	8.2	8.1	8	7.9	7.8	7.8	7.8	7.3	7	
9-Sep-97	17.6	17.3	15.8	11.9	10.9	10.1	9.2	8.8	8.7	8.5	8.4	8.2	8.1	8	8	7.9	7.9			
22-Sep-97	13.5	13.4	12.7	12	11.9	11.4	11	10.7	10.4	10.2	9.4	9	8.8	8.7	8.7	8.6	8.6	8.5		
2-Oct-97	13.2	13.2	13.2	13.2	13.1	13	13.1	13	12.8	12.7	12.5	12.1	11.5	11.2	10.4	10.2	9.6			
6-Oct-97	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.6	12.6	12.6	12.6	12.4	12.2	11.7	11.2			

Table A.5.4 - Variable and parameter data compiled from Clear Lake, Manitoba (Station 2) for the period of June 1996 to October 1997.

	date #	St 2 Pmax	error bar (ase)	upper 95%	lower 95%	St 2 A	error bar (ase)	upper 95%	lower 95%	St 2 Ik
03-Jun-96	3	1.699	0.107	1.952	1.447	0.014	0.002	0.018	0.011	121.357
06-Jun-96	6	3.198	0.132	3.511	2.886	0.036	0.003	0.042	0.029	88.833
09-Jun-96	9	3.749	0.181	4.177	3.321	0.026	0.002	0.031	0.021	144.192
12-Jun-96	12	4.114	0.187	4.555	3.673	0.023	0.002	0.027	0.019	178.870
15-Jun-96	15	2.596	0.204	3.079	2.112	0.013	0.002	0.018	0.009	199.692
23-Jun-96	23	5.576	1.412	9.030	2.122	0.058	0.028	0.125	-0.010	96.138
26-Jun-96	26	4.154	1.081	6.799	1.509	0.021	0.008	0.041	0.001	197.810
30-Jun-96	30	3.840	0.261	4.457	3.224	0.027	0.003	0.034	0.019	142.222
06-Jul-96	36	6.688	1.743	10.808	2.567	0.024	0.005	0.035	0.012	278.667
09-Jul-96	39	3.869	0.236	4.427	3.311	0.026	0.003	0.003	0.019	148.808
12-Jul-96	42	4.022	0.213	4.525	3.519	0.024	0.002	0.028	0.019	167.583
17-Jul-96	47	5.808	0.570	7.157	4.460	0.034	0.005	0.045	0.022	170.824
19-Jul-96	49	6.605	0.055	7.897	5.314	0.048	0.006	0.062	0.033	137.604
24-Jul-96	54	4.187	0.633	5.684	2.690	0.044	0.016	0.083	0.006	95.159
28-Jul-96	58	5.907	0.418	6.896	4.918	0.071	0.010	0.095	0.047	83.197
05-Aug-96	66	6.858	0.616	8.316	5.401	0.058	0.008	0.076	0.039	118.241
09-Aug-96	70	7.693	0.652	9.233	6.152	0.065	0.008	0.085	0.045	118.354
11-Aug-96	72	5.770	0.470	6.881	4.659	0.050	0.007	0.066	0.034	115.400
20-Aug-96	81	7.333	1.009	9.720	4.946	0.062	0.012	0.091	0.033	118.274
27-Aug-96	86	8.785	0.475	9.908	7.662	0.051	0.004	0.059	0.043	172.255
30-Aug-96	91	7.467	0.534	8.730	6.204	0.059	0.007	0.074	0.043	126.559
03-Sep-96	95	10.246	0.836	12.231	8.279	0.074	0.009	0.094	0.053	138.459
09-Sep-96	101	6.954	0.624	11.617	8.665	0.069	0.007	0.099	0.065	100.783
13-Sep-96	105	9.027	0.853	8.970	4.938	0.080	0.015	0.105	0.033	112.838
16-Sep-96	108	7.467	0.716	10.721	7.333	0.072	0.010	0.103	0.056	103.708
20-Sep-96	112	8.840	0.390	8.390	6.544	0.086	0.006	0.087	0.057	102.791
23-Sep-96	115	7.765	0.437	8.798	6.731	0.115	0.012	0.144	0.086	67.522
29-Sep-96	121	5.229	0.259	5.842	4.616	0.084	0.008	0.103	0.065	62.250
06-Oct-96	127	7.161	0.373	8.043	6.278	0.103	0.010	0.128	0.078	69.524
15-Oct-96	137	6.370	0.309	7.100	5.640	0.086	0.009	0.108	0.065	74.070
19-Oct-96	141	7.182	0.320	7.938	6.426	0.092	0.008	0.110	0.073	78.065
25-Oct-96	147	6.509	0.249	7.098	5.921	0.104	0.008	0.124	0.084	62.587
09-Nov-96	162	3.999	0.276	4.651	3.347	0.069	0.011	0.094	0.043	57.957
20-Jan-97	234	0.830	0.032	0.906	0.753	0.028	0.005	0.039	0.017	29.643
15-Feb-97	260	1.447	0.090	1.660	1.234	0.043	0.010	0.065	0.020	33.651
16-May-97	350	2.516	0.099	2.750	2.282	0.037	0.004	0.045	0.027	68.000
18-May-97	352	2.975	0.193	3.431	2.519	0.044	0.009	0.065	0.024	67.614
30-May-97	364	2.281	0.116	2.565	1.997	0.016	0.002	0.020	0.011	142.563
06-Jun-97	371	3.353	0.391	4.277	2.428	0.009	0.001	0.011	0.006	372.556
13-Jun-97	378	2.528	0.254	3.130	1.927	0.006	0.001	0.008	0.004	421.333
20-Jun-97	385	3.674	0.354	4.657	2.690	0.025	0.004	0.036	0.014	146.960
24-Jun-97	389	3.002	0.744	4.762	1.242	0.019	0.008	0.038	0.001	158.000
04-Jul-97	399	3.434	0.705	5.246	1.622	0.023	0.007	0.041	0.005	149.304
08-Jul-97	403	5.379	0.193	5.835	4.923	0.058	0.003	0.066	0.050	92.741
22-Jul-97	417	5.156	0.783	7.008	3.303	0.030	0.005	0.043	0.017	171.867
30-Jul-97	425	6.796	1.262	9.781	3.810	0.039	0.007	0.056	0.023	174.256
02-Aug-97	428	4.930	0.291	5.642	4.218	0.031	2.000	0.036	0.025	159.032
13-Aug-97	439	6.374	0.468	7.481	5.267	0.035	0.003	0.041	0.029	182.114
19-Aug-97	445	0.717	0.016	0.756	0.678	0.008	0.000	0.009	0.007	89.625
26-Aug-97	452	5.805	0.347	6.626	4.985	0.040	0.003	0.046	0.034	145.125
03-Sep-97	460	6.626	0.336	7.419	5.832	0.070	0.005	0.081	0.059	94.657
09-Sep-97	466	7.031	0.453	8.103	5.960	0.053	0.004	0.062	0.044	132.660
22-Sep-97	479	7.824	0.514	9.039	6.609	0.064	0.005	0.007	0.051	122.250
02-Oct-97	489	8.784	0.425	9.789	7.780	0.056	0.004	0.065	0.048	156.857
06-Oct-97	493	8.464	2.060	13.384	3.545	0.086	0.037	0.175	-0.002	98.419
mean		5.393	0.490	6.607	4.226	0.049	0.043	0.063	0.032	131.997
min		0.717	0.016	0.756	0.678	0.006	0.000	0.003	-0.010	29.643
max		10.246	2.060	13.384	8.665	0.115	2.000	0.175	0.086	421.333

Table A.5.4 cont.-

	St 2 Spmax	error bar (ase)	upper 95%	lower 95%	St 2 A/Chla	error bar (ase)	upper 95%	lower 95%	St 2 Ik
03-Jun-96	0.311				0.003				103.667
06-Jun-96	1.259	0.037	1.347	1.172	0.014	0.001	0.017	0.011	89.929
09-Jun-96	2.694	0.116	2.967	2.420	0.018	0.002	0.022	0.014	149.667
12-Jun-96	4.241	0.196	4.704	3.778	0.024	0.002	0.028	0.020	176.708
15-Jun-96	1.708	0.111	1.971	1.445	0.009	0.001	0.012	0.006	189.778
23-Jun-96	1.479	0.262	2.119	0.839	0.015	0.007	0.033	-0.002	98.600
26-Jun-96	2.221	0.298	2.951	1.491	0.011	0.004	0.020	0.003	201.909
30-Jun-96	1.829	0.086	2.032	1.625	0.013	0.001	0.016	0.009	140.692
06-Jul-96	4.305	0.667	5.881	2.729	0.015	0.003	0.022	0.009	287.000
09-Jul-96	2.529	0.126	2.828	2.230	0.017	0.002	0.021	0.013	148.765
12-Jul-96	2.247	0.087	2.453	2.041	0.013	0.001	0.016	0.011	172.846
17-Jul-96	3.090	0.237	3.650	2.529	0.018	0.003	0.024	0.012	171.667
19-Jul-96	3.513	0.239	4.077	2.949	0.025	0.003	0.033	0.017	140.520
24-Jul-96	3.460	0.487	4.612	2.309	0.037	0.013	0.068	0.005	93.514
28-Jul-96	3.045	0.179	3.469	2.621	0.037	0.005	0.049	0.024	82.297
05-Aug-96	2.241	0.136	2.563	1.920	0.019	0.003	0.025	0.013	117.947
09-Aug-96	4.662	0.349	5.487	3.838	0.040	0.005	0.051	0.028	116.550
11-Aug-96	2.721	0.169	3.120	2.323	0.024	0.003	0.031	0.016	113.375
20-Aug-96	2.853	0.262	3.473	2.233	0.024	0.005	0.035	0.013	118.875
27-Aug-96	3.904	0.150	4.259	3.550	0.023	0.002	0.026	0.019	169.739
30-Aug-96	3.473	0.194	3.932	3.015	0.027	0.003	0.034	0.020	128.630
03-Sep-96	5.957	0.252	4.586	3.396	0.043	0.003	0.037	0.021	138.535
09-Sep-96	3.037	0.058	1.825	1.549	0.030	0.001	0.016	0.011	101.233
13-Sep-96	2.950	0.286	3.714	2.360	0.026	0.007	0.045	0.015	113.462
16-Sep-96	2.894	0.164	3.339	2.561	0.028	0.003	0.034	0.019	103.357
20-Sep-96	4.313	0.105	3.142	2.646	0.042	0.002	0.033	0.022	102.690
23-Sep-96	3.751	0.176	4.166	3.336	0.056	0.006	0.069	0.042	66.982
29-Sep-96	3.111	0.130	3.419	2.803	0.050	0.005	0.061	0.039	62.220
05-Oct-96	4.590	0.217	5.104	4.076	0.066	0.007	0.082	0.050	69.545
15-Oct-96	2.251	0.082	2.444	2.058	0.031	0.003	0.038	0.023	72.613
19-Oct-96	2.426	0.077	2.609	2.244	0.031	0.003	0.037	0.025	78.258
25-Oct-96	1.972	0.040	2.066	1.878	0.035	0.002	0.040	0.030	56.343
09-Nov-96	0.939	0.049	1.054	0.823	0.016	[illegible]	[illegible]	0.010	52.688
20-Jan-97	0.864	0.034	0.944	0.784	[illegible]	[illegible]	[illegible]	[illegible]	29.793
15-Feb-97	0.817	0.044	0.922	0.712	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16-May-97	0.792	0.032	0.866	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18-May-97	0.843	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30-May-97	0.938	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06-Jun-97	1.667	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13-Jun-97	1.676	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20-Jun-97	1.475	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24-Jun-97	2.159	[illegible]	[illegible]	[illegible]	0.014	0.006	[illegible]	[illegible]	154.214
04-Jul-97	1.780	[illegible]	[illegible]	[illegible]	0.012	0.004	0.021	0.003	148.333
08-Jul-97	[illegible]	[illegible]	[illegible]	2.677	0.031	0.002	0.035	0.027	92.290
22-Jul-97	2.508	[illegible]	[illegible]	1.936	0.015	0.003	0.021	[illegible]	[illegible]
30-Jul-97	4.221	[illegible]	[illegible]	2.793	0.024	0.004	0.036	0.014	175.875
02-Aug-97	2.901	[illegible]	3.206	2.595	0.018	0.001	0.021	0.015	161.167
13-Aug-97	2.519	0.102	2.760	2.278	0.014	0.001	0.016	0.012	179.929
19-Aug-97	0.223				0.003				74.333
26-Aug-97	2.391	0.079	2.577	2.205	0.017	0.001	0.020	0.015	[illegible]
03-Sep-97	2.772	0.098	3.004	2.540	0.029	0.002	0.034	0.025	95.586
09-Sep-97	2.394	0.093	2.615	2.174	0.018	0.001	0.021	0.015	133.000
22-Sep-97	2.201	0.077	2.383	2.019	0.019	0.001	0.022	0.015	115.842
02-Oct-97	3.018	0.090	3.232	2.804	0.019	0.001	0.022	0.017	158.842
06-Oct-97	10.322	2.623	16.252	4.119	0.105	0.046	0.214	-0.003	98.305
mean	2.679	0.217	3.193	2.166	0.024	0.004	0.033	0.015	131.711
min	0.223	0.032	0.866	0.712	0.003	0.000	0.005	-0.003	29.793
max	10.322	2.623	16.252	4.119	0.105	0.046	0.214	0.050	419.000

Table A.5.4 cont.-

	Prod model 1	Prod model 2	Prod model 3 Pmax	Prod model 3 Spmax	surface temp	gradient	thermo depth	light ext
03-Jun-96					9.7	0.0	23.0	
06-Jun-96					7.8	0.0	29.0	
09-Jun-96	28030	47738	3551968	224252	12.6	0.0	9.0	22.52
12-Jun-96	25852	42270	3555108	224451	14.7	0.5	7.0	23.40
15-Jun-96	15191	23900	3556216	224521	16.9	0.9	4.0	24.36
23-Jun-96	13845	106367	3548398	224027	13.4	0.0	14.0	21.72
26-Jun-96	15513	38443	3541067	223564	15.0			18.49
30-Jun-96	31179	49228	3527227	222690	18.5	2.3	11.0	12.04
06-Jul-96	25647	43392	3497109	220787	19.1	0.9	10.0	21.01
09-Jul-96	29794	46738	3477519	219550	18.6	1.1	10.0	24.70
12-Jul-96	26282	42860	3454664	218106	19.0	1.1	10.0	20.34
17-Jul-96	34473	59913	3408830	215211	19.8	1.2	12.0	22.90
19-Jul-96	25206	84051	3387629	213872	19.4	1.2	11.0	20.71
24-Jul-96	41797	75658	3327122	210051	19.5	1.9	11.0	22.20
28-Jul-96	50080	120011	3270860	206497	19.1	1.3	11.0	21.48
05-Aug-96	56873	94053	3137446	198072	21.1	1.3	11.0	25.56
09-Aug-96	61627	102819	3060515	193213	19.3	1.7	11.0	28.67
11-Aug-96	38746	78032	3019553	190626	20.5	1.6	12.0	27.48
20-Aug-96	51566	90211	2815255	177724	19.6	1.5	13.0	29.17
27-Aug-96	42241	69470	2635310	166361	20.0	1.5	11.0	30.73
30-Aug-96	43914	77658	2553269	161181	19.9	1.6	13.0	31.37
03-Sep-96	43464	92065	2440121	154035	19.8	1.6	10.0	30.18
09-Sep-96	46203	80733	2264177	142926	18.0	1.0	15.0	33.94
13-Sep-96	55377	88652	2144331	135358	16.3	1.1	19.0	24.80
16-Sep-96	19413	76420	2053927	129650	15.4	1.0	17.0	29.86
20-Sep-96	23914	85933	1933659	122057	14.9	0.0	17.0	26.55
23-Sep-96	51023	109573	1844312	116416	14.4	0.0	19.0	28.49
29-Sep-96	44244	72461	1669683	105403	12.6	0.0	26.0	25.62
05-Oct-96	36181	80029	1503982	94930	11.0	0.0	31.5	26.99
15-Oct-96	32218	55717	1254050	79152	9.9	0.0	31.5	30.46
19-Oct-96	27603	55390	1165360	73553	9.0	0.0	31.5	24.67
25-Oct-96	8618	56171	1045612	65994	7.2	0.0	33.0	25.55
09-Nov-96	16231	28563	801443	50582	2.1	0.0	32.0	24.38
20-Jan-97	5577	7453	515712	32547	0.1	0.0	31.0	22.87
15-Feb-97	15962	2248	101297	6393	0.5	0.0	31.0	23.13
16-May-97	36669	66023	3453350	218023	5.7	0.0	31.5	17.86
18-May-97	19434	78625	3467079	218891	5.1	0.0	31.5	20.43
30-May-97	19708	36468	3527340	222697	11.2	0.0	4.0	17.73
06-Jun-97	9086	16504	3546854	223929	13.2	0.9	4.0	23.13
13-Jun-97	6332	11031	3555709	224489	17.7	1.2	6.0	20.44
20-Jun-97	24684	45919	3553254	224333	16.2	1.2	10.0	24.19
24-Jun-97	16792	34830	3546234	223890	17.3	1.2	10.0	21.19
04-Jul-97	22178	41713	3508452	221504	16.9	1.2	13.0	24.11
08-Jul-97	34019	104446	3484399	219984	16.7	1.1	13.0	22.36
22-Jul-97	22900	51993	3352624	211662	21.0	1.3	14.0	25.91
30-Jul-97	36390	50247	3240102	204555	21.9	1.2	13.0	27.80
02-Aug-97	21719	51129	3190711	201436	21.9	1.7	10.0	29.28
13-Aug-97	34134	53659	2976948	187935	20.2	2.1	13.0	24.90
19-Aug-97	19405	58707	2839519	179256	18.2	1.2	13.0	20.73
26-Aug-97	33350	55037	2662041	168049	19.1	1.8	14.0	30.93
03-Sep-97	39549	86267	2440121	154036	18.8	1.4	13.0	29.84
09-Sep-97	37599	62020	2264177	142926	17.8	1.5	15.0	15.03
22-Sep-97	33961	61980	1873976	118289	13.7	0.0	26.0	23.98
02-Oct-97	28277	45891	1585674	100067	13.3	0.0	31.0	26.87
06-Oct-97	37045	65650	1477370	93250	12.3	0.0	31.0	29.12
mean	30629	61603	2690734	169867	15.1	0.8	16.7	24.57
min	5577	2248	101297	6393	0.1	0.0	4.0	12.04
max	61627	120011	3556216	224521	21.9	2.3	33.0	33.94

Table A.5.4 cont.-

	compensation	t. light	light history	Alk	ph	DIC	Chl-a	Particulate Volume	N	N/chla	P
03-Jun-96		40.54	281.38	184.80	8.50	44.352	5.47	1785040720	0.08	0.01	
06-Jun-96		40.62	282.66	195.30	8.40	46.872	2.54	698415312	0.25	0.10	
09-Jun-96	15	40.68	283.52	195.30	8.50	46.872	1.61	1170616131	0.11	0.08	
12-Jun-96	15	40.72	284.20	193.20	8.45	46.368	0.97		0.55	0.56	0.45
15-Jun-96	18	40.73	284.66	193.20	8.45	46.368	1.52	746846318	1.26	0.83	0.45
23-Jun-96	17	40.64	284.45	195.30	8.50	46.872	3.77		0.78	0.21	0.34
26-Jun-96	20	40.56	283.89	195.30	8.40	46.872	1.87	527057359	0.36	0.19	0.29
30-Jun-96	18	40.40	281.95	195.30	8.50	46.872	2.10		0.00	0.00	0.00
06-Jul-96	18	40.05	277.36	197.40	8.40	47.376	1.55	498695972	0.00	0.00	1.44
09-Jul-96	16	39.83	274.60	195.30	8.40	46.872	1.53		0.00	0.00	0.24
12-Jul-96	17	39.57	272.87	197.40	8.30	47.376	1.79	507644915	0.34	0.19	0.33
17-Jul-96	17	39.04	271.05	201.60	8.15	48.384	1.88	377625502	0.45	0.24	0.34
19-Jul-96	16	38.80	265.95	207.90	8.30	49.896	1.88		0.17	0.09	0.22
24-Jul-96	15	38.10	259.74	193.20	8.35	46.368	1.21	280967022	1.70	1.40	1.80
28-Jul-96	15	37.46	256.22	199.50	8.40	47.880	1.94	379816899	1.38	0.71	0.00
05-Aug-96	15	35.93	234.89	195.30	8.35	46.872	3.06		0.00	0.00	0.59
09-Aug-96	14	35.05	229.14	203.70	8.35	48.888	1.65	384436322	0.03	0.02	0.00
11-Aug-96	13	34.58	223.33	199.50	8.35	47.880	2.12	221347815	0.00	0.00	0.25
20-Aug-96	13	32.24	204.97	193.20	8.45	46.368	2.57	1677100062	0.00	0.00	0.00
27-Aug-96	12	30.18	194.10	197.40	8.40	47.376	2.25	487360101	0.00	0.00	0.47
30-Aug-96	12	29.24	188.47	191.10	8.35	45.864	2.15		0.10	0.05	0.33
03-Sep-96	12	27.94	176.95	193.20	8.35	46.368	1.72	395307144	0.00	0.00	0.00
09-Sep-96	11	25.93	157.84	195.30	8.35	46.872	2.29	230593026	0.00	0.00	1.86
13-Sep-96	13	24.55	150.06	197.40	8.40	47.376	3.06				
16-Sep-96	11	23.52	142.73	195.30	8.35	46.872	2.58	779732789	3.91	1.52	0.10
20-Sep-96	12	22.14	136.13	197.40	8.35	47.376	2.05		0.91	0.45	0.31
23-Sep-96	12	21.12	120.23	193.20	8.35	46.368	2.07	132808980	0.43	0.21	0.55
29-Sep-96	11	19.12	111.08	201.60	8.30	48.384	1.68	354485367	0.00	0.00	0.00
05-Oct-96	13	17.22	90.08	203.70	8.35	48.888	1.56	289963831	0.66	0.42	0.33
15-Oct-96	13	14.36	64.25	205.80	8.25	49.392	2.83	394527568	0.17	0.06	0.11
19-Oct-96	12	13.34	51.05	199.50	8.45	47.880	2.96	291543768	0.73	0.25	0.15
25-Oct-96	13	11.97	37.71	197.40	8.35	47.376	3.30	213256320	0.32	0.10	0.42
09-Nov-96	5	9.18	25.74	210.00	8.35	50.400	4.26	469577384	0.12	0.03	0.42
20-Jan-97	2	5.90	9.49	222.60	7.90	55.650	0.98	78137554	0.19	0.20	0.60
15-Feb-97	2	1.16	1.16	210.00	8.20	52.500	1.77	759919644	0.06	0.03	0.90
16-May-97	15	39.55	252.85	205.80	8.50	49.392	3.18	2532166893	0.25	0.08	0.21
18-May-97	17	39.71	269.12	205.80	8.50	49.392	3.53	623253591	0.64	0.18	0.17
30-May-97	16	40.40	278.05	195.30	8.40	46.872	2.35	2318110702	0.92	0.39	0.56
06-Jun-97	16	40.62	283.23	189.00	8.30	45.360	2.24	1093316628	0.83	0.37	0.45
13-Jun-97	16	40.72	284.55	215.60	8.40	51.744	1.51	1364623675	0.86	0.57	0.45
20-Jun-97	14	40.69	284.67	211.20	8.35	50.688	2.49	1630729645	0.55	0.22	0.23
24-Jun-97	9	40.61	284.03	202.40	8.50	48.576	1.39	2063362880	0.66	0.47	0.59
04-Jul-97	13	40.18	279.19	213.40	8.35	51.216	1.93	532462478	0.55	0.29	0.50
08-Jul-97	16	39.91	276.11	217.80	8.35	52.272	1.88	1335610480	0.00	0.00	0.00
22-Jul-97	16	38.40	263.09	209.00	8.25	50.160	2.03	810675809	1.86	0.91	0.69
30-Jul-97	15	37.11	245.82	204.60	8.30	49.104	1.61	1997621042	0.00	0.00	1.17
02-Aug-97	13	36.54	240.95	213.40	8.35	51.216	1.70	1461776280	0.00	0.00	0.99
13-Aug-97	13	34.09	216.69	211.20	8.45	50.688	2.53	1934134073	0.26	0.10	0.90
19-Aug-97	20	32.52	210.54	204.60	8.40	49.104	2.71	309287790	1.43	0.53	0.00
26-Aug-97	12	30.48	198.65	202.40	8.35	48.576	2.35	1597758442	1.20	0.51	0.25
03-Sep-97	12	27.94	182.75	209.00	8.35	50.160	2.39	2297190930	0.16	0.07	0.24
09-Sep-97	13	25.93	164.64	202.40	8.35	48.576	2.94	2357671846	0.07	0.02	0.09
22-Sep-97	7	21.46	128.34	209.00	8.35	50.160	3.46	1245154432	0.16	0.05	0.16
02-Oct-97	12	18.16	101.14	215.60	8.35	51.744	2.91	798861500	0.00	0.00	0.52
06-Oct-97	11	16.92	78.74	206.80	8.40	49.632	0.82	1866911896	1.24	1.51	0.47
mean	13	31.17	203.95	201.58	8.37	48.468	2.28	963054690	0.49	0.28	0.43
min	2	1.16	1.16	184.80	7.90	44.352	0.82	78137554	0.00	0.00	0.00
max	20	40.73	284.67	222.60	8.50	55.650	5.47	2532166893	3.91	1.52	1.86

Table A.5.4 cont.-

	P/chla	T AlkPhos	T AlkPhos/chla	S AlkPhos	S AlkPhos/chla	AlkPhos/chla	TKN	NO4/NO3	PN	TP
03-Jun-96							0.50	0.05	0.45	0.0530
06-Jun-96							0.44	0.05	0.39	0.0050
09-Jun-96										
12-Jun-96	0.46									
15-Jun-96	0.29									
23-Jun-96	0.09						0.43	0.08	0.35	0.0240
26-Jun-96	0.15									
30-Jun-96	0.00									
06-Jul-96	0.93	0.0146	0.0094	0.0060	0.0038	0.0056				
09-Jul-96	0.15	0.0224	0.0146	0.0113	0.0074	0.0073	0.33	0.05	0.28	0.0720
12-Jul-96	0.19	0.0235	0.0131	0.0015	0.0008	0.0123				
17-Jul-96	0.18	0.0291	0.0155	-0.0032	-0.0017	0.0155				
19-Jul-96	0.12	0.0164	0.0087	-0.0018	-0.0010	0.0087				
24-Jul-96	1.49	0.0229	0.0190	-0.0015	-0.0012	0.0190	0.37	0.05	0.32	0.0320
28-Jul-96	0.00	0.0178	0.0092	-0.0010	-0.0005	0.0092				
05-Aug-96	0.19	0.0211	0.0089	-0.0035	-0.0012	0.0089				
09-Aug-96	0.00	0.0239	0.0145	-0.0033	-0.0020	0.0145				
11-Aug-96	0.12						1.03	0.05	0.98	0.0430
20-Aug-96	0.00									
27-Aug-96	0.21									
30-Aug-96	0.19	0.0245	0.0114	0.0015	0.0007	0.0114				
03-Sep-96	0.00	0.0178	0.0103	-0.0011	-0.0007	0.0103	0.52	0.11	0.41	0.0160
09-Sep-96	0.81									
13-Sep-96		0.0082	0.0027	0.0001	0.0000	0.0026				
16-Sep-96	0.04	0.0127	0.0049	0.0018	0.0007	0.0042	0.56	0.05	0.51	0.0480
20-Sep-96	0.15	0.0116	0.0057	0.0019	0.0009	0.0048				
23-Sep-96	0.26	0.0187	0.0090	-0.0035	-0.0017	0.0090				
29-Sep-96	0.00	0.0158	0.0094	0.0070	0.0042	0.0052				
05-Oct-96	0.21	0.0246	0.0158	0.0014	0.0009	0.0149	0.33	0.05	0.28	0.2420
15-Oct-96	0.04	0.0157	0.0055	-0.0010	-0.0004	0.0055				
19-Oct-96	0.05	0.0337	0.0114	-0.0041	-0.0014	0.0114				
25-Oct-96	0.13	0.0097	0.0029	-0.0008	-0.0002	0.0029				
09-Nov-96	0.10	0.0112	0.0026	-0.0027	-0.0006	0.0026				
20-Jan-97	0.63	0.0185	0.0192	-0.0033	-0.0035	0.0192	0.52	0.05	0.47	0.0540
15-Feb-97	0.51	0.0100	0.0057	-0.0020	-0.0011	0.0057	0.44	0.05	0.39	0.0290
16-May-97	0.07	0.0156	0.0049	-0.0015	-0.0005	0.0049				
18-May-97	0.05	0.0152	0.0043	-0.0015	-0.0004	0.0043	0.20	0.78	-0.58	0.0050
30-May-97	0.24	0.0151	0.0064	-0.0017	-0.0007	0.0064				
06-Jun-97	0.20	0.0146	0.0065	-0.0017	-0.0008	0.0065				
13-Jun-97	0.30	0.0091	0.0060	-0.0113	-0.0075	0.0060				
20-Jun-97	0.09	0.0182	0.0073	0.0037	0.0015	0.0058				
24-Jun-97	0.42						0.28	0.05	0.23	0.0700
04-Jul-97	0.26	0.0135	0.0070	-0.0018	-0.0009	0.0070				
08-Jul-97	0.00	0.0219	0.0116	-0.0027	-0.0015	0.0116				
22-Jul-97	0.34	0.0142	0.0070	-0.0164	-0.0081	0.0070				
30-Jul-97	0.72	0.0143	0.0089	-0.0093	-0.0057	0.0089				
02-Aug-97	0.58	0.0143	0.0084	-0.0094	-0.0055	0.0084				
13-Aug-97	0.35	0.0276	0.0109	-0.0030	-0.0012	0.0109				
19-Aug-97	0.00									
26-Aug-97	0.11	0.0107	0.0046	-0.0065	-0.0028	0.0046				
03-Sep-97	0.10	0.0131	0.0055	-0.0031	-0.0013	0.0055				
09-Sep-97	0.03	0.0195	0.0086			0.0086				
22-Sep-97	0.05	0.0132	0.0038	-0.0066	-0.0019	0.0038				
02-Oct-97	0.18	0.0133	0.0046	0.0100	0.0034	0.0011				
06-Oct-97	0.58	0.0163	0.0199	0.0097	0.0119	0.0080				
mean	0.24	0.0172	0.0086	-0.0013	-0.0005	0.0080	0.46	0.11	0.34	0.0633
min	0.00	0.0082	0.0026	-0.0164	-0.0081	0.0011	0.20	0.05	-0.58	0.0050
max	1.49	0.0337	0.0199	0.0113	0.0119	0.0192	1.03	0.78	0.98	0.2420

Table A.5.4 cont.-

	DP	PP	TOC	DOC	POC	Silcone	N/P	C/P	C/N	C/Chl-a
03-Jun-96	0.0470	0.0060	5.10	5.10	0.00	6.63	75.00	0.00	0.00	0.000009
06-Jun-96	0.0050	0.0000	5.60	5.50	0.10	7.09	0.00	20.00	0.26	0.000020
09-Jun-96										
12-Jun-96										
15-Jun-96										
23-Jun-96	0.0210	0.0030	5.10	5.10	0.00	7.05	0.00	0.00	0.00	0.000021
26-Jun-96										
30-Jun-96										
06-Jul-96										
09-Jul-96	0.0050	0.0670	5.90	5.30	0.60	6.57	4.18	120.00	2.14	0.000033
12-Jul-96										
17-Jul-96										
19-Jul-96										
24-Jul-96	0.0190	0.0130	5.70	5.70	0.00	8.00	24.62	0.00	0.00	0.000041
28-Jul-96										
05-Aug-96										
09-Aug-96										
11-Aug-96	0.0370	0.0060	5.90	5.90	0.00	5.68	163.33	0.00	0.00	0.000024
20-Aug-96										
27-Aug-96										
30-Aug-96										
03-Sep-96	0.0120	0.0040	5.39	4.95	0.44	7.49	102.50	36.67	1.07	0.000064
09-Sep-96										
13-Sep-96										
16-Sep-96	0.0450	0.0030	5.70	5.60	0.10	7.56	170.00	2.22	0.20	0.000019
20-Sep-96										
23-Sep-96										
29-Sep-96										
05-Oct-96	0.0160	0.2260	4.10	4.00	0.10	7.68	1.24	6.25	0.36	0.000032
15-Oct-96										
19-Oct-96										
25-Oct-96										
09-Nov-96										
20-Jan-97	0.0490	0.0050	5.00	4.90	0.10	7.63	94.00	2.04	0.21	0.000521
15-Feb-97	0.0130	0.0160	4.20	3.90	0.30	7.39	24.38	23.08	0.77	0.000028
16-May-97							0.00	#DIV/0!	0.00	
18-May-97	0.0050	0.0000	5.10	4.90	0.20	7.15				0.000221
30-May-97										
06-Jun-97										
13-Jun-97										
20-Jun-97										
24-Jun-97	0.0600	0.0100	5.10	4.90	0.20	6.93	23.00	3.33	0.00	0.000036
04-Jul-97										
08-Jul-97										
22-Jul-97										
30-Jul-97										
02-Aug-97										
13-Aug-97										
19-Aug-97										
26-Aug-97										
03-Sep-97										
09-Sep-97										
22-Sep-97										
02-Oct-97										
06-Oct-97										
mean	0.0257	0.0276	5.22	5.06	0.16	7.14	52.46	#DIV/0!	0.39	0.000062
min	0.0050	0.0000	4.10	3.90	0.00	5.68	0.00	#DIV/0!	0.00	0.000009
max	0.0600	0.2260	5.90	5.90	0.60	8.00	170.00	#DIV/0!	2.14	0.000521

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	1-Jun-96	6-Jun-96	9-Jun-96	15-Jun-96	26-Jun-96	6-Jul-96	12-Jul-96	17-Jul-96
Bacillariophyceae	Centrales	Aulacoseira	ambigua	383743	278476	928800	501905	566667	226667	258459	278476
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	0	0	349850	1504586	4819373	1222475	1054884	975214
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizienals	0	0	0	571844	190615	333576	1120050	530357
Bacillariophyceae	Pennales	Asterionella	formosa	268641	567643	198675	353249	290911	561042	510597	1072214
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	2779730	4880500	9653175	6618634	17724477	15368892	39550220	52777500
Bacillariophyceae	Pennales	Nitzchia	palaecea	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	7407847	8027143	11425300	5641816	26874834	21685731	25051816	34249143
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0	0
			TOTAL	10839961	13753782	22555800	15192032	50566975	39398182	67547027	89882905
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp								
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	0	0	0	2636	2636	0	2816	0
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	0	0	0	83597	83597	417987	89312	1014971
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	0	0	0	35958	71916	71916	76832	127333
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	1-Jun-96	6-Jun-96	9-Jun-96	15-Jun-96	26-Jun-96	6-Jul-96	12-Jul-96	17-Jul-96
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	122191	158148	489903	168960	1142305
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	0	0	0	0	0	47818	153262	84667
Cyanobacteria		Chroococcus	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Coelosphaerium	sp	0	0	0	11437	20332	22238	41408	38571
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	11437	20332	70057	194670	123238
Dinophyceae	Gonyaulacales	Ceratium	sp	815657	1915000	1005375	378547	567820	378547	1415487	3638500
Dinophyceae	Gymnodiniales	Gymnodinum	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	0	0	0	7844003	0	0	0	15872571
Dinophyceae	Peridiniales	Peridinium	gatunense	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0	0
			TOTAL	815657	1915000	1005375	8222550	567820	378547	1415487	19511071

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	24-Jul-96	28-Jul-96	9-Aug-96	11-Aug-96	20-Aug-96	27-Aug-96	3-Sep-96	9-Sep-96
Bacillariophyceae	Centrales	Aulacoseira	ambigua	437143	262085	1377880	118085	917473	172000	376862	327619
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	3128715	1950429	983321	1203789	1356873	374625	573274	168500
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizlensis	2525644	1448429	2002747	292814	1700259	253125	581021	241071
Bacillariophyceae	Pennales	Asterionella	formosa	1287540	609680	3427680	1425773	2507686	1633550	1151609	883000
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	37019477	36208500	98596250	45953859	93588709	84018375	76470625	33482500
Bacillariophyceae	Pennales	Nitzchia	paleacea	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	19748367	20692190	35195934	15347288	18501585	9177700	12897813	6778476
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0	0
			TOTAL	64122875	61167333	142583832	64339388	118572588	95629375	92051205	41879167
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp								
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elaktothrix	gelatinosa	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elaktothrix	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	2638	0	5538	2899	5532	8400	37978	4000
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	501585	169162	834424	599287	1272041	888100	92661	1184133
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	413516	0	188801	220948	377341	114600	99641	254667
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	24-Jul-96	28-Jul-96	9-Aug-96	11-Aug-96	20-Aug-96	27-Aug-96	3-Sep-96	9-Sep-96
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	0	1327538	13486277	0	15565138	11696765	15175886	3463143
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0	0
			TOTAL	817736	1496700	14515141	822934	17220052	12707865	15406166	4905943
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	caegana	0	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	35864	169333	401934	148913	476715	139700	238512	169333
Cyanobacteria		Chroococcus	sp	27533	32500	16071	281969	56181	86125	76296	35595
Cyanobacteria		Coelosphaerium	sp	66715	48214	66759	44850	125352	111375	151418	96429
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0	0
			TOTAL	130112	250048	484764	475732	658248	337200	466226	301357
Dinophyceae	Gonyaulacales	Ceratium	sp	3028372	2489500	9545538	4070543	24231990	33981675	12587622	18575500
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	0	0	0	0	24694430	49998600	39124921	15872571
Dinophyceae	Peridiniales	Peridinium	gostaviense	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0	0
			TOTAL	3028372	2489500	9545538	4070543	48926420	83980275	51712543	34448071

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	16-Sep-96	23-Sep-96	29-Sep-96	5-Oct-96	15-Oct-96	19-Oct-96	25-Oct-96	9-Nov-96
Bacillariophyceae	Centrales	Aulacoseira	ambigua	815532	2546537	2752441	3113200	3048580	1683200	1614073	1048200
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	582080	814124	1163579	889100	1821254	1518538	1480226	7117875
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizensis	200030	800122	307644	0	102548	97718	500076	1063125
Bacillariophyceae	Pennales	Asterionella	formosa	1373785	4688245	8048885	12362000	29378429	25033307	10357752	128800125
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	44734226	48798256	33876105	33728525	58730358	50032714	48500050	135263625
Bacillariophyceae	Pennales	Nitzchia	palacea	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	602314	1505785	1028279	2642250	5022881	3295488	6424883	5182875
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	9805840	6475555	9485084	10488800	10812973	3798092	3145270	4307800
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0	0
			TOTAL	58123787	68628624	58462988	63231875	108817030	85467054	70022129	280584725
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp								
Chlorophyceae	Chlorococcales	Coelastrum		0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	4685825	7307547	7479338	29283225
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	0	42871	5872	8400	38285	35130	17978	11200
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	570225	701816	674614	1021315	539882	299982	877270	577265
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	188671	338807	174104	286500	212794	460843	2131979	229200
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	237271	0	0	0	0	231821	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1986 to October 1987.

x100 average		Particulate Volume	(um3/L)	16-Sep-96	23-Sep-96	28-Sep-96	5-Oct-96	15-Oct-96	19-Oct-96	25-Oct-96	9-Nov-96
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	2693986	14667149	9821118	10302850	27928804	23396349	21551729	18181500
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0	0
			TOTAL	3880133	15751443	10875508	11619085	33385499	31731682	32058294	48282390
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0	0	29867	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	29867	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	288538	577076	707455	673100	810358	1005072	639801	101600
Cyanobacteria		Chroococcus	sp	64207	240777	218906	203125	172813	72142	221515	251875
Cyanobacteria		Coelosphaerium	sp	110017	123352	187485	184950	311063	415627	340052	786375
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0	0
			TOTAL	462762	941205	1083846	1061175	1294233	1492842	1201368	1139850
Dinophyceae	Gonyaulacales	Ceratium	sp	12910486	13903601	7738810	7841925	2647488	0	0	804300
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	65851815	24694430	42199673	0	0	8042410	37041646	66664800
Dinophyceae	Peridiniales	Peridinium	gosleviense	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0	0
			TOTAL	78762301	38598031	49938483	7841925	2647488	8042410	37041646	67469100

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	20-Jan-97	15-Feb-97	17-Mar-97	28-Apr-97	16-May-97	18-May-97	30-May-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	238549	95556	67162	0	369380	265134	146074
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	558539	4245750	2121081	7202083	16407980	29973767	54237987
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizianensis	378067	337500	583036	1412791	7412946	13835238	4808503
Bacillariophyceae	Pennales	Asterionella	formosa	882975	343389	0	57086977	258593	923621	778683
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	10878979	11255417	9772350	47670000	84893700	87916278	165552477
Bacillariophyceae	Pennales	Nitzchia	paleacea	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	8673542	8130000	17757750	64472791	87003086	124315119	126893686
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	1598578	832444	1097043	1045385	8959183	16291992	12498143
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	22811229	25240056	31408440	178890047	205104892	273621149	364811755
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrum		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	354764	712424	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	5974	3111	4100	0	8200	12332	6794
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	189485	0	0	0	0	488924	107747
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	0	0	37290	0	223743	147211	463456
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	20-Jan-97	15-Feb-97	17-Mar-97	26-Apr-97	16-May-97	18-May-97	30-May-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	1939705	1683472	2780815	0	0	2669179	0
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0
			TOTAL	2135174	2041347	3634429	0	231943	3317646	577997
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	capena	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	0	0	0	0	0	0	0
Cyanobacteria		Chroococcus	sp	13869	21667	79315	0	63452	0	39430
Cyanobacteria		Coelosphaerium	sp	111620	93750	197679	31395	144964	713484	536402
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
			TOTAL	125489	115417	276994	31395	208417	713484	575832
Dinophyceae	Gonyaulacales	Ceratium	sp	0	0	0	0	785150	0	0
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	17780441	74072000	548091768	5193653023	3762295446	4679356154	1440676572
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	17780441	74072000	548091768	5193653023	3763080596	4679356154	1440676572

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	6-Jun-97	13-Jun-97	20-Jun-97	24-Jun-97	4-Jul-97	8-Jul-97	15-Jul-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	329530	344000	7559810	696821	523286	483813	643162
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	59248232	78108026	40871589	40345832	45989710	34585283	25815385
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizensis	0	1278847	570538	820385	0	0	108173
Bacillariophyceae	Pennales	Asterionella	formosa	447807	185895	0	894321	3022206	1719526	7664931
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	108788750	108830263	72528500	78215469	40487373	43192226	76394231
Bacillariophyceae	Pennales	Nitzchia	paleacea	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	152668173	129888063	114644292	57538888	46377008	42328893	44515224
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	23218254	15772632	16484562	23712880	18894480	19047643	22612073
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	344702746	330185816	252437288	202222174	155374081	141357384	177553178
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrum		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elaktothrix	gelantinosa	0	0	0	0	0	2072568	584778
Chlorophyceae	Chlorococcales	Elaktothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	20511	5895	448511	5872	8519	18175	37393
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	0	280453	350306	359784	90084	432384	474412
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	430508	120832	4348130	154759	251806	289292	612179
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	6-Jun-97	13-Jun-97	20-Jun-97	24-Jun-97	4-Jul-97	8-Jul-97	15-Jul-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	2049026	1275895	2732035	2455279	7375294	11802026	20072169
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0
			TOTAL	2500045	1682874	7876962	2975505	7725683	14614427	21780929
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagens	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	0	80211	0	90040	154552	137398	203526
Cyanobacteria		Chroococcus	sp	82411	51316	192282	82282	123596	45709	190972
Cyanobacteria		Coelosphaerium	sp	528696	511579	517286	321317	269021	290645	625240
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
			TOTAL	611107	643105	708577	493640	547169	473751	1019738
Dinophyceae	Gonyaulacales	Ceratium	sp	0	846632	2266083	2036529	2650886	3480596	11815304
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	70434536	52630105	187825429	421996731	177466148	405690395	578687500
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	70434536	53476737	190091512	424033260	180117034	409170991	590502804

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	22-Jul-97	30-Jul-97	2-Aug-97	13-Aug-97	18-Aug-97	26-Aug-97	3-Sep-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	353556	543344	362752	344000	204880	217263	210222
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	17292632	32275385	15648831	17318000	6484737	7492500	10775325
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizensis	3724342	5815385	10362880	11137500	4381579	9592105	14850000
Bacillariophyceae	Pennales	Asterionella	formosa	6113871	3550113	1944426	2148633	788116	952711	5072344
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	88863092	123208615	70228125	85808000	31717276	37885105	58891625
Bacillariophyceae	Pennales	Nitzchia	paleacea	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	56270943	36818538	25718530	26884500	22428816	13157763	20370167
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	16210760	7261477	10456410	5244400	1823711	2563053	3204911
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	190829196	208572856	134721073	148861033	67828825	71880500	113474584
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrum		0	21682	18733	0	0	0	18456
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	3029	8041	0	11200	0	5895	3422
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	98081	255044	275445	414447	288243	140226	325637
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	82655	0	188564	358533	208637	140737	140067
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	22-Jul-97	30-Jul-97	2-Aug-97	13-Aug-97	18-Aug-97	26-Aug-97	3-Sep-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	30816402	28717446	29172422	45251733	393401	9569211	26295836
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0
			TOTAL	30988167	29002213	29856163	46033913	888281	9856068	26783417
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	capena	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	1016743	419426	1024117	848667	480882	467895	686500
Cyanobacteria		Chroococcus	sp	149433	186667	131030	130000	140643	68421	79444
Cyanobacteria		Coelosphaerium	sp	904796	751154	680880	648000	438158	383684	748625
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
			TOTAL	2070972	1357246	1848015	1624667	1058683	920000	1524569
Dinophyceae	Gonyaulacales	Ceratium	sp	14792535	34646769	26182684	31367700	22841414	21165789	56770175
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	157788487	161533838	465212538	583317000	270480263	315780832	585631750
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	172581022	196180708	491405202	614684700	293301678	336946421	642401925

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	9-Sep-97	22-Sep-97	2-Oct-97	6-Oct-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	229333	1216647	3108366	2605146
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	9460500	23101875	32422610	26479342
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizienis	12420000	14598357	[illegible]	22181743
Bacillariophyceae	Pennales	Asterionella	formosa	3080500	0	19744881	17314675
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	45604300	43446298	90783309	78848531
Bacillariophyceae	Pennales	Nitzchia	paleacea	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	25474000	27869162	27315870	30874704
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	2497333	4484182	5356801	2834249
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0
			TOTAL	98805867	114717521	187416479	180538390
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp				
Chlorophyceae	Chlorococcales	Coelastrium		0	57513	0	32673
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	148041
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	7467	9141	0	9088
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	592067	1258400	457110	1201012
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	229200	457278	1354477	557921
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	4807925	1143408
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0	0	0	0
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0

Table A.5.5 - Particulate Biovolume x100 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x100 average		Particulate Volume	(um3/L)	9-Sep-97	22-Sep-97	2-Oct-97	6-Oct-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerium	12829067	24864093	27727778	37700917
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0
			TOTAL	13757600	26644424	34347280	40793080
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0
			TOTAL	0	0	0	0
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0	0	0	0
Cyanobacteria	Chroococcales	Radiocystis	sp	0	0	0	0
Cryptophyceae		Rhodomonas	minute	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0	0	0	0
Cyanobacteria	Chroococcales	Woronichinia	sp	0	0	0	0
			TOTAL	0	0	0	0
Cyanobacteria		Anabaena	sp	338667	368976	382206	41219
Cyanobacteria		Chroococcus	sp	0	0	338276	35161
Cyanobacteria		Coelosphaerium	sp	243000	617029	837664	565654
Cyanobacteria		Microcystis	sp	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0
Cyanobacteria		Radiocystis	geminata	0	0	0	0
			TOTAL	581667	1004006	1588186	642334
Dinophyceae	Gonyaulacales	Ceratium	sp	55226800	20131156	15178181	6308581
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	333324000	328461447	214454779	193829855
Dinophyceae	Peridiniales	Peridinium	gostaviense	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0
			TOTAL	388552600	348592603	228633871	200138436

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	1-Jun-96	6-Jun-96	9-Jun-96	15-Jun-96	26-Jun-96	6-Jul-96	12-Jul-96
Bacillariophyceae	Centrales	Aulacoseira	ambigua	4222010	2202763	6013543	3048009	0	15240047	5582364
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	12261011	7676373	17463749	5058075	23393598	39200083	45932792
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizensis	27614869	11870162	34037972	24350531	35864984	66643560	112278101
Bacillariophyceae	Pennales	Asterionella	formosa	0	1130637	10686410	0	2235376	1117688	3582287
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	81258367	42734884	121794419	60339952	33186974	153666878	208511058
Bacillariophyceae	Pennales	Nitzchia	paleac	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	0	0	854374273	783837446	366955297	173400466	124235890
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	102166269	33581891	30223702	18866517	18866517	37933033	167170696
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	227525545	98866810	1074584088	905700531	483622755	487401755	668291288
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrum		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum	0						
Chlorophyceae	Chlorococcales	Monoraphidium	sp	0						
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	1069139	0	527126	283536	212652	70884	0
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	3633301	0	4776948	4466573	0	3372430	14411910
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	2083731	6849056	1541036	967059	4835297	1934119	10331700
Chlorophyceae	Chlorococcales	Selenastrium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii	0						
Chlorophyceae	Chlorococcales	Thorakochloris	sp	0						
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	1-Jun-96	6-Jun-96	9-Jun-96	15-Jun-96	26-Jun-96	6-Jul-96	12-Jul-96
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	0	0	0	0	0
			TOTAL	6786171	6848056	6845112	5747168	5047949	5377433	24743611
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	7057138	13785199	35807791	15088001	33407220	77033120	29852464
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	7057138	13785199	35807791	15088001	33407220	77033120	29852464
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	0	0	0	0	0	643019	1373954
Cyanobacteria		Chroococcus	sp	0	0	0	0	0	82276	0
Cyanobacteria		Coelosphaerium	sp	184099	69157	181536	119617	153793	205057	401638
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp	0						
Cyanobacteria	Chroococcales	Radiocystis	sp	0						
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp	0						
Cyanobacteria	Chroococcales	Woronichinia	sp	0						
			TOTAL	184099	69157	181536	119617	153793	930352	1775592
Dinophyceae	Gonyaulacales	Ceratium	sp	0	0	0	0	0	0	0
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	3750085053	2241120580	784382203	421916388	421916388	843832777	225379820
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	3750085053	2241120580	784382203	421916388	421916388	843832777	225379820

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	17-Jul-96	24-Jul-96	28-Jul-96	9-Aug-96	11-Aug-96	20-Aug-96	27-Aug-96
Bacillariophyceae	Centrales	Aulacoseira	ambigua	6608289	2612579	37446972	3659976	1783701	4569390	1850321
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	25587910	38200083	31345190	33215076	25899958	20568233	5373461
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizensis	88777871	57672311	62240863	67327856	7874987	68590664	14976708
Bacillariophyceae	Pennales	Asterionella	formosa	0	3353083	0	12917639	0	9383190	3562137
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	213674419	135784892	244198336	523032712	256446528	405251776	285255349
Bacillariophyceae	Pennales	Nitzchia	paleac	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	69759713	59172266	58308626	84876987	72191272	90713021	53022588
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	105543086	61641179	115137912	149457867	97118361	139323894	35260986
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	508051288	359416375	548878880	874488113	461314807	738400189	389301549
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum		0					
Chlorophyceae	Chlorococcales	Monoraphidium	sp		0					
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	502025	212652	143436	0	217777	0	0
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	2274737	6744880	3412106	14173362	11512388	0	4776948
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	1958873	0	978437	9144619	0	10148297	2054717
Chlorophyceae	Chlorococcales	Selenastrium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii		0					
Chlorophyceae	Chlorococcales	Thorakochloris	sp		0					
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	17-Jul-96	24-Jul-96	28-Jul-96	9-Aug-96	11-Aug-96	20-Aug-96	27-Aug-96
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	0	0	31046152	91884670	23568573	101432891	35858306
			TOTAL	4733835	6957512	35580130	115202850	35298739	111581187	42689970
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	9676149	7860522	11531849	12801270	8589853	824881	556710
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	9676149	7860522	11531849	12801270	8589853	824881	556710
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	1301167	1288037	0	1351212	0	0	0
Cyanobacteria		Chroococcus	sp	457842	1234140	168488	950802	0	690722	568140
Cyanobacteria		Coelosphaerium	sp	345783	187989	345783	628393	297500	1165593	417532
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp		0					
Cyanobacteria	Chroococcales	Radiocystis	sp		0					
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp		0					
Cyanobacteria	Chroococcales	Woronichinia	sp							
			TOTAL	2104791	2708146	512270	2930507	297500	1856315	985672
Dinophyceae	Gonyaulacales	Ceratium	sp	0	50903528	0	0	20852188	96152455	54077513
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	0	0	0	0	0	1549852889	448224116
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	0	50903528	0	0	20852188	1645805344	502301629

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	3-Sep-96	9-Sep-96	16-Sep-96	23-Sep-96	29-Sep-96	5-Oct-96	15-Oct-96
Bacillariophyceae	Centrales	Aulacoseira	ambigua	0	881105	3655512	2741634	9838726	12027086	7964683
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	2803228	3838187	9952371	1990474	13805879	18807114	12245291
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassiziensis	21308324	2593369	12104235	14794085	6894871	9530632	11031794
Bacillariophyceae	Pennales	Asterionella	formosa	0	0	4691595	2345797	31267645	32652921	45898686
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	123731396	192308977	348263245	189961770	126802093	211537675	123355886
Bacillariophyceae	Pennales	Nitzchia	paleac	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	5703265	15097251	22678255	18898546	39307916	38263723	21591672
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	31534215	38379304	94541214	0	0	35260986	15305593
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	185080418	253096193	495886427	230732287	227517131	358080136	237193785
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrum		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	1490827	0	24103312
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum							
Chlorophyceae	Chlorococcales	Monoraphidium	sp							
Chlorophyceae	Chlorococcales	Monoraphidium	contortum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	314276	143436	74385	223156	610154	677734	419481
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	2492039	4549474	0	4718692	4838191	4776948	7257286
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	5359526	1956873	10148297	2029659	4682384	3062075	6243178
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	3370047	1845711	1276241	0	6542807	8074984	3598544
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii							
Chlorophyceae	Chlorococcales	Thorakochloris	sp							
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	1285681
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	3-Sep-96	9-Sep-96	16-Sep-96	23-Sep-96	29-Sep-96	5-Oct-96	15-Oct-96
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	28910152	54330766	45081285	61181743	87493430	81498150	95747527
			TOTAL	40446040	62828260	56580208	68153251	105657892	96107890	138655009
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	1452123	0	1088842	5499208	10572136	33958306	60613579
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	1452123	0	1088842	5499208	10572136	33958306	60613579
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	0	0	0	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	0	0	0
Cyanobacteria		Anabaena	sp	2138198	0	2024346	2381737	2421547	3415563	2075612
Cyanobacteria		Chroococcus	sp	319186	832440	1856315	863402	2788592	3277731	2965646
Cyanobacteria		Coelosphaerium	sp	454578	518674	1219380	537986	1323815	1361519	1544451
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp							
Cyanobacteria	Chroococcales	Radiocystis	sp							
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp							
Cyanobacteria	Chroococcales	Woronichinia	sp							
			TOTAL	2911962	1351113	5100060	3783105	6533955	8054813	6585709
Dinophyceae	Gonyaulacales	Ceratium	sp	22568835	36051675	37392622	0	21908326	0	0
Dinophyceae	Gymnodiniales	Gymnodinum	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	467659308	0	664136952	221378984	226985290	672336174	567463224
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	490228243	36051675	701529574	221378984	248893615	672336174	567463224

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	19-Oct-96	25-Oct-96	9-Nov-96	20-Jan-97	15-Feb-97	17-Mar-97	26-Apr-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	2232219	5483268	1850321	987013	0	0	0
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	6482519	5307931	9403567	5016122	67168265	8523973	0
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassiziensis	13140240	5379880	32678453	8715270	18153585	15949221	22797525
Bacillariophyceae	Pennales	Asterionella	formosa	33232803	23457974	118737883	3800268	2638620	1159108	0
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	88612677	110811033	144230233	27355189	14244961	18772824	101371120
Bacillariophyceae	Pennales	Nitzchia	paleac	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	22157385	18888546	38823849	27892157	22472345	42155170	325432329
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	24307822	29855120	20149135	10748116	0	0	9371691
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	188165646	199193532	363671441	84614155	124677776	86560295	458972665
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	1420703	11875168	44161621	0	6542462	3353012	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum							
Chlorophyceae	Chlorococcales	Monoraphidium	sp							
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	218031	297542	225911	160677	209177	0	0
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	2305155	7078039	2388474	0	0	0	0
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	2478801	5074148	4623113	2192088	0	0	119460284
Chlorophyceae	Chlorococcales	Selenastrium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	2493855	4468845	0	2067563	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii							
Chlorophyceae	Chlorococcales	Thorakochloris	sp							
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	19-Oct-96	25-Oct-96	9-Nov-96	20-Jan-97	15-Feb-97	17-Mar-97	26-Apr-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	47191956	25760734	48897690	15650043	3622051	9546692	0
			TOTAL	56108502	54552475	100296809	20070371	10373691	12899704	119460284
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	92010883	81663238	170074887	0	618567	0	517870
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	92010883	81663238	170074887	0	618567	0	517870
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	65740182	0	22826452	0	0
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	0	0	65740182	0	22826452	0	0
Cyanobacteria		Anabaena	sp	1318566	5398256	2049338	0	0	0	0
Cyanobacteria		Chroococcus	sp	1560806	2028995	2840700	466240	1456769	725263	0
Cyanobacteria		Coelosphaerium	sp	2470395	1237322	988447	154936	423584	248099	0
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp							
Cyanobacteria	Chroococcales	Radiocystis	sp							
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp							
Cyanobacteria	Chroococcales	Woronichinia	sp							
			TOTAL	5349538	8664573	5888485	621187	1880353	973362	0
Dinophyceae	Gonyaulacales	Ceratium	sp	0	0	0	0	0	0	0
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	0	0	0	0	747040193	0	0
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniaire	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	0	0	0	0	747040193	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	16-May-97	18-May-97	30-May-97	6-Jun-97	13-Jun-97	20-Jun-97	24-Jun-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	2708399	0	3367312	3127924	3408486	5213206	1874043
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	54422287	25884603	70887091	56773176	41007993	40119711	440150193
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizianensis	31888442	26983949	41298089	16878512	11465422	15344102	27579485
Bacillariophyceae	Pennales	Asterionella	formosa	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	128280864	56464190	116856806	256480178	94466585	63078649	162310376
Bacillariophyceae	Pennales	Nitzchia	palea	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	632327546	827563284	1505428306	1087306772	1464378574	1161230244	777853835
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	38338787	38824313	12222821	28384694	31814423	34061632	30611185
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	888977424	975720338	1748888404	1448830254	1648541483	1338047544	1440379117
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelatinosa	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum							
Chlorophyceae	Chlorococcales	Monoraphidium	sp							
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	147022	165827	0	0	158534	169732	76269
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	0	2629843	0	0	5028366	0	2419095
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	295854770	0	0	3473450	0	3473450	2081059
Chlorophyceae	Chlorococcales	Selenastrum	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	1891853	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii							
Chlorophyceae	Chlorococcales	Thorakochloris	sp							
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	16-May-97	18-May-97	30-May-97	6-Jun-97	13-Jun-97	20-Jun-97	24-Jun-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	15911153	0	0	36737947	0	27553460	21460653
			TOTAL	313804798	2795670	0	40211397	5186900	31198642	26037077
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	5842141	7815351	5085651	108383914	292272719	206258824	37918727
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	5842141	7815351	5085651	108383914	292272719	206258824	37918727
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	caqena	44120271	27143854	0	0	0	0	41614378
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	44120271	27143854	0	0	0	0	41614378
Cyanobacteria		Anabaena	sp	0	0	0	0	0	0	0
Cyanobacteria		Chroococcus	sp	0	0	0	197011	1840129	985053	442634
Cyanobacteria		Coelosphaerium	sp	407591	339798	264295	450094	573271	613764	1139952
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp							
Cyanobacteria	Chroococcales	Radiocystis	sp							
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp							
Cyanobacteria	Chroococcales	Woronichinia	sp							
			TOTAL	407591	339798	264295	647104	2413401	1598818	1582586
Dinophyceae	Gonyaulacales	Ceratium	sp	0	0	0	0	0	0	0
Dinophyceae	Gymnodiniales	Gymnodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	0	19740790631	815701976	378856098	471814859	1136568294	2723823474
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	0	19740790631	815701976	378856098	471814859	1136568294	2723823474

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	4-Jul-97	8-Jul-97	15-Jul-97	22-Jul-97	30-Jul-97	2-Aug-97	13-Aug-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	4691122	2001809	0	3002714	0	2295511	0
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	144407457	37787059	40803751	10173439	20253815	4166452	18807114
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassizîensis	2761489	0	5818457	10310918	43010032	6756409	29045736
Bacillariophyceae	Pennales	Asterionella	formosa	0	8992139	10148536	8349843	23869361	0	4749516
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	104011989	100558181	154092129	121363321	239315349	159050883	128204651
Bacillariophyceae	Pennales	Nitzchia	paleac	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	532169587	487886444	258880292	561808632	313958753	186489413	287888964
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	30850481	49047236	21526853	21798771	28832091	24997047	0
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	818892125	686272866	492370020	736807638	869339402	383755716	468895981
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	gelantinosa	17416472	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elakatothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum							
Chlorophyceae	Chlorococcales	Monoraphidium	sp							
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	305468	162938	160905	122203	0	93422	200810
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	4844401	0	5103577	0	3429604	2963144	0
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	1562798	1111470	1097805	0	2950363	1274542	2739623
Chlorophyceae	Chlorococcales	Selenastrium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	3450848	0	0	0	0
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii							
Chlorophyceae	Chlorococcales	Thorakochloris	sp							
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	0	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	4-Jul-97	8-Jul-97	15-Jul-97	22-Jul-97	30-Jul-97	2-Aug-97	13-Aug-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	24794079	10580202	38310156	77588147	152126146	145590114	139086762
			TOTAL	48823219	11854809	48123091	77710351	158508112	149921222	142027194
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	6351424	3312587	26021431	49688804	142888885	8978517	12989899
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	6351424	3312587	26021431	49688804	142888885	8978517	12989899
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	0	0	70235238	26670807	47198080	152920067	82175228
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	0	0	70235238	26670807	47198080	152920067	82175228
Cyanobacteria		Anabaena	sp	1385517	0	8028034	2586640	4904399	4237353	1821634
Cyanobacteria		Chroococcus	sp	1329606	803779	606987	2127650	1255063	650617	0
Cyanobacteria		Coelosphaerium	sp	1196645	824873	1629168	2317502	3206202	968419	2468888
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp							
Cyanobacteria	Chroococcales	Radiocystis	sp							
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp							
Cyanobacteria	Chroococcales	Woronichinia	sp							
			TOTAL	3911768	1628652	10264189	7031791	9365664	5856389	4290521
Dinophyceae	Gonyaulacales	Ceratium	sp	0	0	23110048	52654420	108709666	67088644	122575695
Dinophyceae	Gymnodiniales	Gymnodinum	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	1136383349	1333532275	718307878	484920827	4022524118	1251151903	2241120580
Dinophyceae	Peridiniales	Peridinium	gostaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	1136383349	1333532275	741417926	537575248	4131233785	1318240546	2363696276

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	18-Aug-97	26-Aug-97	3-Sep-97	9-Sep-97	22-Sep-97	2-Oct-97	6-Oct-97
Bacillariophyceae	Centrales	Aulacoseira	ambigua	0	0	0	0	4530565	4232760	7006332
Bacillariophyceae	Centrales	Chaetoceros	sp	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	bodanica	2906897	7070344	5746818	7612403	6578539	19206612	55953914
Bacillariophyceae	Centrales	Cyclotella	cf ocellata	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	meneghiniana	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	stelligera	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Cyclotella	cf distinguenda	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	cf alpinus	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	niagarae	0	0	0	0	0	0	0
Bacillariophyceae	Centrales	Stephanodiscus	agassiziensis	4418965	10032244	24861179	19968944	53339504	49633371	103109178
Bacillariophyceae	Pennales	Asterionella	formosa	2569182	0	4353723	2374758	40702651	37348112	27618712
Bacillariophyceae	Pennales	Cymatopleura	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Fragilaria	crotonensis	90155610	57354712	66595194	72649302	191835636	201629047	194181314
Bacillariophyceae	Pennales	Nitzchia	paleac	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Nitzchia	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Surirella	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	acus	277947429	149602526	143640802	173097795	309325223	290729268	310473191
Bacillariophyceae	Pennales	Synedra	cf acus	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Synedra	sp	0	0	0	0	0	0	0
Bacillariophyceae	Pennales	Tabellaria	fenestrata	21798771	31814423	0	20149135	0	23046398	21798771
Bacillariophyceae	Pennales	Tabellaria	flocculosa	0	0	0	0	0	0	0
			TOTAL	389788854	255874250	245297516	295852337	606312119	628025586	720141413
Chlorophyceae	Chlorococcales	Ankistrodesmus		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Botryococcus	sp							
Chlorophyceae	Chlorococcales	Coelastrium		0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	tetrapedia	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Crucigenia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Elaktothrix	gelatinosa	0	0	0	0	0	3367444	3981433
Chlorophyceae	Chlorococcales	Elaktothrix	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Lagerheimia	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	arcuatum							
Chlorophyceae	Chlorococcales	Monoraphidium	sp							
Chlorophyceae	Chlorococcales	Monoraphidium	contortium	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Monoraphidium	minutum	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Oocystis	sp	81469	0	184076	100405	0	258395	0
Chlorophyceae	Chlorococcales	Pediastrum	boryanum	0	0	5838492	3184632	0	8195744	2584021
Chlorophyceae	Chlorococcales	Pediastrum	duplex	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Scenedesmus	sp	0	3244280	1255880	2739623	3354023	5287874	2222939
Chlorophyceae	Chlorococcales	Selenastrium	sp	0	0	0	0	0	0	0
Chlorophyceae	Chlorococcales	Tetraedron	minimum	0	0	0	0	0	21797178	13628306
Chlorophyceae	Chlorococcales	Thorakochloris	cf nygaardii							
Chlorophyceae	Chlorococcales	Thorakochloris	sp							
Chlorophyceae	Tetrasporales	Botryococcus	braunii	0	0	0	0	0	1451935	0
Chlorophyceae	Tetrasporales	Chodatella	sp	0	0	0	0	0	0	0

Table A.5.6 - Particulate Biovolume x400 (Station 1 and 2 combined) for each phytoplankton species found in Clear Lake, Manitoba for the period of June 1996 to October 1997.

x400 average		Particulate Volume	(um3/L)	18-Aug-97	26-Aug-97	3-Sep-97	9-Sep-97	22-Sep-97	2-Oct-97	6-Oct-97
Chlorophyceae	Volvocales	Carteria	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Closterium	sp	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	tetracerum	0	0	0	0	0	0	0
Chlorophyceae	Zygnematales	Staurastrum	sp	40557441	60049794	49803203	65198920	129483000	50335857	75824780
			TOTAL	40638909	63294084	57081430	71221579	132837023	90694427	98241479
Chrysophyceae	Chrysocapsales	Chrysocapsa	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	divergens	301144	2344042	5103174	12618759	8330182	11939245	12045771
Chrysophyceae	Ochromonadales	Dinobryon	sociale	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Dinobryon	stipitatum	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Mallomonas	sp	0	0	0	0	0	0	0
Chrysophyceae	Ochromonadales	Uroglena	sp	0	0	0	0	0	0	0
			TOTAL	301144	2344042	5103174	12618759	8330182	11939245	12045771
Cryptophyceae		Cryptomonas	cf erosa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	reflexa	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	sp	0	0	0	0	0	0	0
Cryptophyceae		Cryptomonas	cagena	17780805	69200192	140610946	120523968	156495471	122188656	177806049
Cryptophyceae		Rhodomonas	minuta	0	0	0	0	0	0	0
			TOTAL	17780805	69200192	140610946	120523968	156495471	122188656	177806049
Cyanobacteria		Anabaena	sp	3695200	1438132	0	910817	0	0	1478080
Cyanobacteria		Chroococcus	sp	1891244	0	0	0	998744	649833	1512995
Cyanobacteria		Coelospharium	sp	746314	1242087	1442201	1573311	4385937	3176877	2788858
Cyanobacteria		Microcystis	sp	0	0	0	0	0	0	0
Cyanobacteria		Pseudoanabaena	cf articulata	0	0	0	0	0	0	0
Cyanobacteria		Oscillatoria	sp	0	0	0	0	0	0	0
Cyanobacteria	Oscillatoriales	Planktothrix	sp							
Cyanobacteria	Chroococcales	Radiocystis	sp							
Cyanobacteria		Radiocystis	geminata	0	0	0	0	0	0	0
Cyanobacteria	Chroococcales	Snowella	sp							
Cyanobacteria	Chroococcales	Woronichinia	sp							
			TOTAL	6332758	2680219	1442201	2484128	5384681	3826711	5779933
Dinophyceae	Gonyaulacales	Ceratium	sp	29252456	0	92532633	50472345	23539623	49482691	35102947
Dinophyceae	Gymnodiniales	Gymnodinum	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Glenodinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	cf cinctum	6061510341	2359074295	2739147376	2988160774	1097489931	1153517946	1454762482
Dinophyceae	Peridiniales	Peridinium	goslaviense	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	inconspicuum	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	sp	0	0	0	0	0	0	0
Dinophyceae	Peridiniales	Peridinium	willei	0	0	0	0	0	0	0
			TOTAL	6090762797	2359074295	2831680009	3038633119	1121029554	1203000637	1489865429

Table A.5.7 - Average Particulate Biovolume (um3/L) of each major taxonomic group at Station 1 in Clear Lake, Manitoba for the period of June 1996 to October 1997.

	Bacillariophyceae	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria	Dinophyceae	total
1-Jun-96	161500932	3283922	6915995	0	0	2045897858	2217598707
6-Jun-96	54281607	3424528	6892599	0	34578	1602523914	1667157227
9-Jun-96	439928461	3453484	18093073	0	72614	224514208	686061840
15-Jun-96	402897091	167421	262017	0	39895	4111275	407477699
26-Jun-96	237730147	2567091	13100871	0	39895	189273	253627276
6-Jul-96	293987313	3459782	22664506	0	118880	633063856	953294337
12-Jul-96	361775718	11234677	16795774	0	1106189	606637	391518996
17-Jul-96	235967049	2828834	6097299	0	988603	2489500	248371284
24-Jul-96	177473601	607792	3275218	0	692048	1324913	183373571
28-Jul-96	247633058	25661549	6627499	0	194796	957500	281074402
9-Aug-96	668302094	96455114	10323605	0	1981085	3579577	780641475
11-Aug-96	261851427	22062581	4293326	0	191288	2326024	290724647
20-Aug-96	402182900	48771680	412441	0	914962	531227175	983509158
27-Aug-96	294562335	37568090	278355	0	760594	313929189	647098562
3-Sep-96	140871588	24747769	726061	0	1838625	57846880	226030924
9-Sep-96	132639622	19031967	0	0	748540	18151979	170572107
16-Sep-96	309728155	21904857	412441	0	1829154	252457703	586332309
23-Sep-96	197917489	68755005	4124406	0	1534544	119627521	391958966
29-Sep-96	129908807	39351696	4510778	0	3042967	36534363	213348610
5-Oct-96	184937960	74137358	19484848	0	5776937	339787437	624124540
15-Oct-96	172820664	89116044	34535644	0	4604122	455599802	756676276
19-Oct-96	107715599	11785266	38281900	0	1703765	0	159486530
25-Oct-96	119365884	43706452	51830035	0	3714426	24694430	243311227
9-Nov-96	342381376	95420331	92831382	53413898	3326121	37498950	624872058
20-Jan-97	30955426	7608849	0	0	378133	0	38942407
15-Feb-97	29314680	3058377	309283	13695871	1274231	124506699	172159141
17-Mar-97	44590890	6792175	0	0	735330	628287070	680405465
16-May-97	482926336	148950922	271727	36098404	401633	7327123664	7995772687
18-May-97	620057485	3123494	2451875	13571927	705659	5360216237	6000126677
30-May-97	1120132077	288999	3377101	0	357471	676301100	1800456747
6-Jun-97	901005238	21142834	55211487	0	667975	149763545	1127791078
13-Jun-97	765885006	2677462	229276594	0	379511	44281737	1042500310
20-Jun-97	864759717	15918287	90189219	0	407324	369961625	1341236173
24-Jun-97	1055738500	15425092	27205630	20807189	1256084	190509488	1310941982
4-Jul-97	542876725	10694991	2822855	0	1672761	300739520	858806852
8-Jul-97	346335558	12879765	1806866	0	1200085	766747506	1128969780
15-Jul-97	339307367	37390814	9665103	35117619	1558668	456798509	879838079
22-Jul-97	481002011	53163394	24844402	13335454	5255049	110555895	688156205
30-Jul-97	598468674	163658977	86932398	29498800	6347127	1809870496	2694776473
2-Aug-97	275367102	115526138	6043233	35681349	1515002	477543535	911676359
13-Aug-97	275542419	48172561	7422799	54783485	1657601	1114043579	1501622444
18-Aug-97	313235349	26935973	150572	8890302	1849595	3185952701	3537014493
26-Aug-97	119144850	23737740	0	0	328985	102838263	246049838
3-Sep-97	185797962	44577931	2551587	50218195	1542707	1024259719	1308948101
9-Sep-97	228378638	25469810	7051659	0	1313639	1309802716	1572016463
22-Sep-97	353376534	890395887	5301025	89425984	2215259	634083301	1173441689
2-Oct-97	426520648	53513797	4775698	75193019	2856425	1060570721	1623430309
6-Oct-97	391787828	48896779	3011443	111128781	2275728	290147572	847248131

Table A.5.8 - Average Particulate Biovolume (um3/L) of each major taxonomic group at Station 2 in Clear Lake, Manitoba for the period of June 1996 to October 1997.

	Bacillariophyceae	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria	Dinophyceae	total
1-Jun-96	76730254	3502250	141143	0	92050	1704575024	1785040720
6-Jun-96	57903646	0	0	0	0	640511666	698415312
9-Jun-96	590805968	1003154	17814718	0	108922	560883370	1170616131
15-Jun-96	517900400	2909026	14803984	0	85440	211147467	746846318
26-Jun-96	295196440	83597	20306350	0	134230	211336741	527057359
6-Jul-96	231642543	1207741	54368613	0	518881	210958194	498695972
12-Jul-96	372271453	8540916	13156690	0	177096	113498760	507644915
17-Jul-96	361967145	2578270	3578850	0	415952	9085286	377625502
24-Jul-96	244389118	3951255	4585305	0	886121	27155223	280967022
28-Jul-96	362211174	10769764	4904349	0	399611	1532000	379816899
9-Aug-96	348749851	25808657	2477665	0	1434186	5965962	384436322
11-Aug-96	200653456	7941803	0	0	581944	12170612	221347815
20-Aug-96	450098241	74177766	412441	0	1254241	1151157374	1677100062
27-Aug-96	200282590	13904163	278355	0	562279	272352714	487380101
3-Sep-96	119091313	25481115	0	0	470464	250264252	395307144
9-Sep-96	141849402	43844431	0	0	487711	44411482	230593026
16-Sep-96	244182055	37233583	687401	0	2721485	494908265	779732789
23-Sep-96	98270523	12681101	1374802	0	3169767	17312787	132808980
29-Sep-96	153556681	73531404	6061358	0	4584834	116751091	354485367
5-Oct-96	236374052	31553695	14474458	0	3339051	4222575	289963831
15-Oct-96	171238877	79424028	26077935	0	3275819	114510909	394527568
19-Oct-96	165868242	63689891	53728983	0	4235447	4021205	291543768
25-Oct-96	132232388	32691998	29833203	0	6151516	12347215	213256320
9-Nov-96	290875062	56937789	77243504	12326284	2626745	29568000	469577384
20-Jan-97	56924799	12194050	0	0	128484	8890220	78137554
15-Feb-97	84943043	5565821	0	9130581	710705	659569495	759919644
17-Mar-97	74182538	8324176	0	0	426669	1035936514	1118869897
16-May-97	578079683	59605433	4904349	7826212	210917	1881540298	2532166893
18-May-97	580415989	31426562	4036147	0	325609	7049284	623253591
30-May-97	808003569	50156427	1310087	0	448100	1458192519	2318110702
6-Jun-97	775532467	15513556	43887917	0	468136	257914551	1093316628
13-Jun-97	1086038410	942542	56333744	0	1579101	219729878	1364623675
20-Jun-97	645953254	19483021	103573942	0	1322482	860396946	1630729645
24-Jun-97	528876266	10469315	9278499	0	574696	1514164104	2063362880
4-Jul-97	387897104	32670382	3275218	0	1965592	106654183	532462478
8-Jul-97	432085830	12556733	1325500	0	747731	888894686	1335610480
15-Jul-97	302435178	26827248	13764806	0	5329387	818242147	1166598766
22-Jul-97	408082557	50907416	22137464	0	3507950	326240422	810875809
30-Jul-97	182379696	16202549	38494456	12175964	958684	1747409695	1997621042
2-Aug-97	205056618	50591714	2366017	94501512	3253902	1106006516	1461776280
13-Aug-97	280377172	95201421	4356368	21434595	2767843	1529996672	1934134073
18-Aug-97	128952023	12598441	0	0	2481478	165255847	309287790
26-Aug-97	180385964	40391373	1099842	32469236	2408948	1341003079	1597758442
3-Sep-97	146016476	29974181	0	73055782	1214121	2046930369	2297190930
9-Sep-97	167474935	18310005	4228854	62421567	783021	2104453461	2357671845
22-Sep-97	342237257	63270770	2783550	61631421	3853182	771378253	1245154432
2-Oct-97	343321987	64588102	6343282	41614378	2331426	338462325	796661500
6-Oct-97	463583480	82132736	8059347	59481488	3075362	1249579583	1865911996