LOVELL LAKE

1993
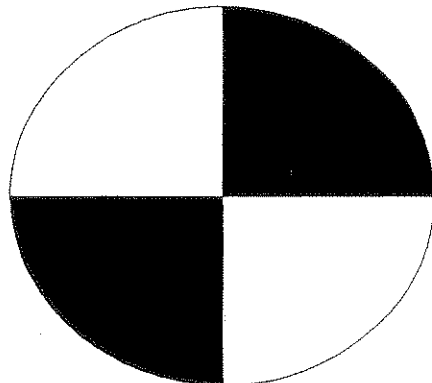## LAKES LAY MONITORING PROGRAM

by
Jeffrey A. Schloss
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edited by
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NEW HAMPSHIRE LAKES LAY MONITORING PROGRAM
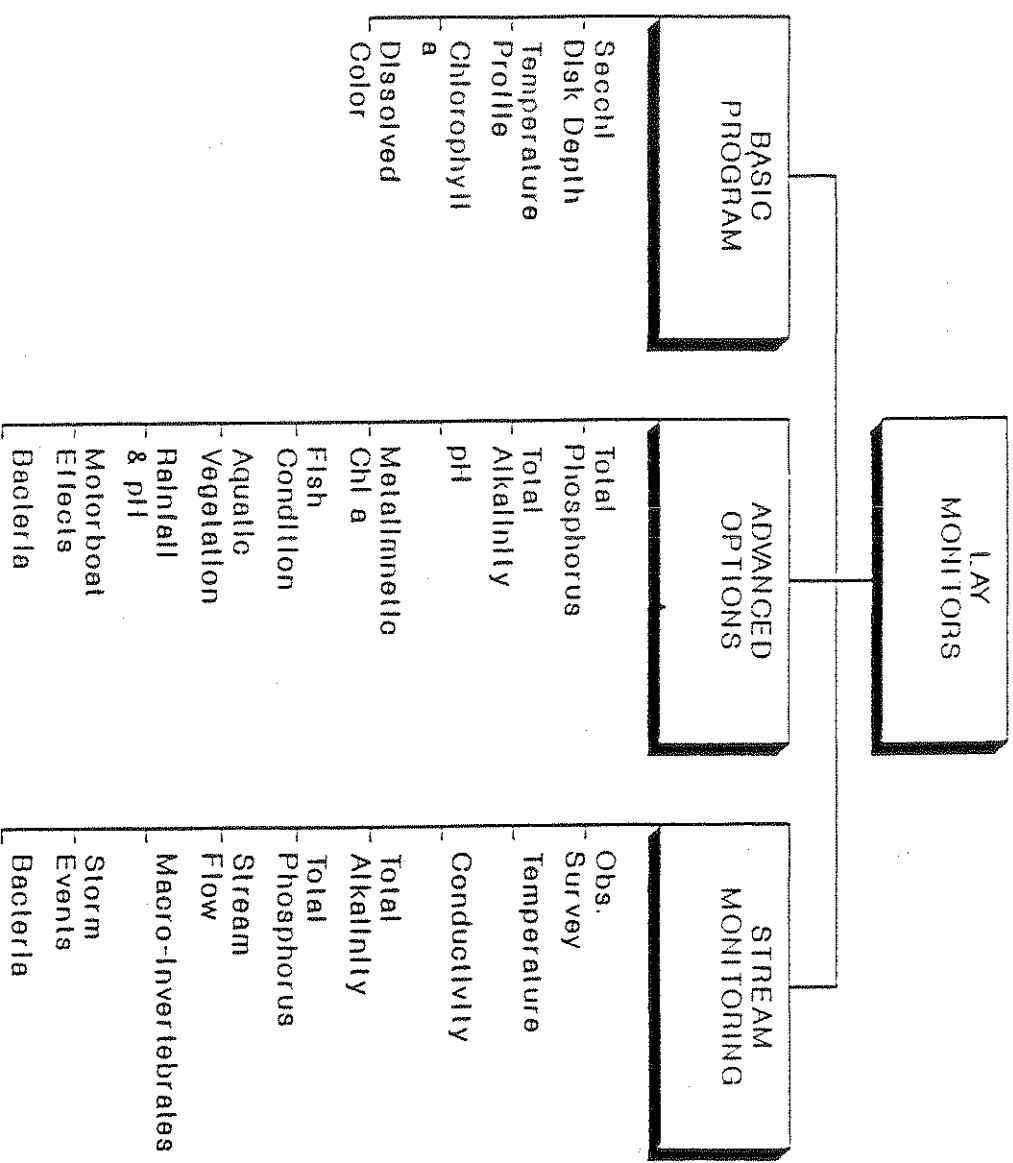

NH LLMP

FRESHWATER BIOLOGY GROUP
University of New Hampshire
Durham

UNIVERSITY OF
NEW HAMPSHIRE

COOPERATIVE / EXTENSION

Helping You To Put Knowledge And Research To Work

PARAMETERS SAMPLED
NH LAKES LAY MONITORING PROGRAM

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                    LAY
                  MONITORS
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     BASIC       ADVANCED      STREAM
    PROGRAM       OPTIONS    MONITORING
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BASIC PROGRAM
- Secchi Disk Depth
- Temperature Profile
- Chlorophyll a
- Dissolved Color

ADVANCED OPTIONS
- Total Phosphorus
- Total Alkalinity
- pH
- Metalimnetic Chl a
- Fish Condition
- Aquatic Vegetation
- Rainfall & pH
- Motorboat Effects
- Bacteria

STREAM MONITORING
- Obs. Survey
- Temperature
- Conductivity
- Total Alkalinity
- Total Phosphorus
- Stream Flow
- Macro-Invertebrates
- Storm Events
- Bacteria

FBG Team corraborate tests above and sample plankton

PREFACE

This report contains the findings of a water quality survey of Lovell Lake, Sanbornville, New Hampshire, conducted in the summer of 1993 by the **Freshwater Biology Group (FBG)** of the University of New Hampshire and the Lovell Lake Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1993 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

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ACKNOWLEDGEMENTS

Island Pond, Bow Lake Camp Owners, Chalk Pond, Chesham Pond, Lake Chocorua, Cunningham Pond, Crystal Lake, Dublin Lake, Glines Island, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mascoma Lake, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pea Porridge Pond, Pemaquid Watershed, Perkins Pond, Pleasant Lake, Silver Lake (Hollis), Silver Lake (Harrisville), Silver Lake (Madison), Silver Lake (Tilton), Squam Lakes, Lake Sunapee, Sunset Lake, Lake Waukewan, Lake Winona, Wentworth Lake and the towns of Alton, Amherst, Enfield, Errol, Hollis, Madison, Meredith, Merrimack, Milan, Strafford and Wolfeboro.

LOVELL LAKE

1993 NON-TECHNICAL SUMMARY

Weekly sampling of Lovell Lake was undertaken by the volunteer monitors from June 13 through October 10, 1993 while additional FBG sampling was undertaken on August 3 to more completely assess the condition of Lovell Lake. The following section summarizes the 1993 water quality conditions for Lovell Lake and when applicable, compares the current year's data to previous yearly data.

1)   Water transparency measurements collected during the 1993 sampling season were high, and averaged 5.9 meters (19.2 feet) at Site 1 North and averaged 6.4 meters (20.8 feet) at Site 2 South. Transparency values greater than 4 meters are typical of clear, less productive lakes while transparency values less than 2.5 meters are generally an indication of a very productive lake. Secchi Disk readings between 2.5 meters and 4.0 meters are considered indicative of a moderately productive lake. While the seasonal average Secchi Disk transparency remained high, a new seasonal average Secchi Disk transparency low was set at the 1 North sampling station in 1993 (see figures 12 and 14).

2)   Chlorophyll a concentrations (a measure of microscopic plant abundance) in the surface waters of Lovell Lake were low to moderate in 1993. Concentrations in the mixed layer of water, collected by the volunteer monitors, averaged 2.6 milligrams per cubic meter (2.6 mg m^{-3} equivalent to 2.6 parts chlorophyll per billion parts water) at both the 1 North and 2 South sampling stations. Concentrations below 3 mg m^{-3} are common to less productive, clear, lakes while values in excess of 7 mg m^{-3} are common to productive lakes. Chlorophyll a concentrations between 3 mg m^{-3} and 7 mg m^{-3} are considered indicative of intermediate productivity. The seasonal average chlorophyll a concentrations

decreased in 1993 and set a new record seasonal average low at the 1 North and the 2 South sampling stations (see figures 13 and 15).

3)   Dissolved lakewater color levels for Lovell Lake were low in 1993, 10.2 platinate color units (ptu), and less than the average of 23 ptu for **LLMP** program lakes. Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color may occur naturally but also occur during deforestation and development within the watershed. High color levels can actually mask the ability of the Secchi Disk transparency to predict chlorophyll levels.

4)   Total phosphorus concentrations (generally considered the limiting nutrient in freshwater systems), collected in the surface waters of Lovell Lake, were low when sampled by the **FBG** and volunteer monitors in 1993 and ranged from 4.2 to 9.9 parts per billion (ppb). A Higher phosphorus concentration was documented in the bottom waters of the 2 South sampling station which measured 15.9 ppb on the August 3 sampling date. With the exception of the bottom water sample collected at the 2 South sampling station, all phosphorus concentrations remained below the concentration of 15 ppb commonly considered the boundary between moderately and highly productive lakes. Refer to Appendix A for a more complete listing of the 1993 total phosphorus results.

5)   The alkalinity of the lake (a measurement of the lake's resistance to acidification) is moderate, 13.5 units, and over 7 units greater than the average of 6.3 units for **LLMP** program lakes. Lovell Lake has a sufficient buffering capacity at this time to neutralize acid loadings. PH readings were also collected by the **FBG** on August 3 and ranged from

7.2 to 7.3 in the surface waters, which is within the tolerable range for most aquatic organisms.

6)   The specific conductivity of the deep Lovell Lake sampling stations was moderate and ranged from 86.6 to 91.5 micro-Siemans at Site 1 North and ranged from 86.8 to 93.9 micro-Siemans at Site 2 North. Additional conductivity samples analyzed from the town beach sampling site were moderate and similar to the in-lake conductivity levels, with the exception of a higher reading at the 1 North sampling station on August 14. The conductivity of the 1 North sampling stations measured 91.5 micro-Siemans while a reading collected at the town beach measured 82.0 micro-Siemans. High conductivity values can indicate the presence of septic leachate or deicing road salt runoff.

7)   Temperature profiles, collected by the volunteer monitors, indicate the upper mixed layer of water (epilimnion) extended to about 9.5 meters (30.9 feet) during the 1993 sampling season. The formation of temperature stratification limits water circulation and can favor anoxic conditions in the deeper waters (hypolimnion). Dissolved oxygen data collected at the 1 North sampling station remained high throughout the water column while the dissolved oxygen concentration of Site 2 South remained above 5 milligrams per liter (generally considered the minimum oxygen requirement for the successful growth and reproduction of most coldwater fish) only down to about 8.5 meters when measured on August 3 by the FBG (see figure 16). Low oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. macroscopic plant and algal production) as well as external (i.e. leaf litter and grass clippings) sources. As oxygen concentrations become depleted, chemical reactions convert previously insoluble nutrients into a soluble form. The nutrients can then be utilized by layering mid-lake algal cells or utilized by surface algae when thermal stratification is disrupted and the nutrients are dispersed throughout the water column.

8)   Based upon the current and historical Secchi Disk and chlorophyll *a* data, Lovell Lake would be considered a relatively clear and borderline unproductive/moderately productive lake. However, the low dissolved oxygen concentrations documented at the 2 South sampling station are more characteristic of a moderately productive system.

9)   Data collected by the volunteer monitors of Lovell lake compare well with the data collected by the **FBG**. Alkalinity readings taken by the lay monitors are slightly higher than the alkalinity readings taken by the **FBG**.

COMMENTS AND RECOMMENDATIONS

1)   We recommend that each participating association, including the Lovell Lake Association, continue to develop its data base on lake water quality through continuation of the long term monitoring program. The data base will provide information on the short and long-term cyclic variability that occurs in the lake and will eventually enable more reliable predictions of water quality trends.

2)   We recommend initiating phosphorus sampling of the Lovell Lake tributary inlets to discern potential problem areas within the watershed and build upon the current database for Lovell Lake. The FBG will include tributary sampling during it's site visit to Lovell Lake in 1993 while additional sampling by the volunteer monitors is also encouraged.

3)   Changing land use within your watershed, the surrounding land which drains into the lake, can accelerate the natural aging process. A lake typically fills in and becomes more productive on a geological time frame (thousands of years), however, this process can be accelerated to occur in tens of years when development, agriculture and other landscape changes occur that do not incorporate best management practices (i.e. maintaining vegetative buffer strips along the shoreline, minimizing fertilizer and pesticide applications, installing proper erosion control structures, etc.) which are set to minimize water quality impacts. We invite interested persons to take part in a new assessment manual, produced jointly by the UNH LLMP and the New Hampshire Soil Conservation Service (NH SCS), which provides the layperson with a systematic method for recognizing and evaluating erosion, sedimentation and related non-point source (NPS) pollutant problems in New Hampshire watersheds. Contact the LLMP coordinator for further information:

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AWARDS

and

RECOGNITION
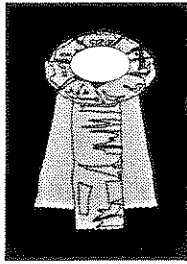
1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" request funded
1990- New Hampshire Journal on PBS
1991- Renew America Success Award
- Environmental Success Index
- UN Environmental Programme
- Soviet Embassy Reception
- White House Environment Briefing
1992- EPA Administrators Award
- Environmental Exchange Network
1993- NH Lakes Association

NH LLMP Directly Involved with the Initiation, Expansion or Support of Volunteer Programs in 22 States.

NH LAKES

LAY MONITORING
PROGRAM
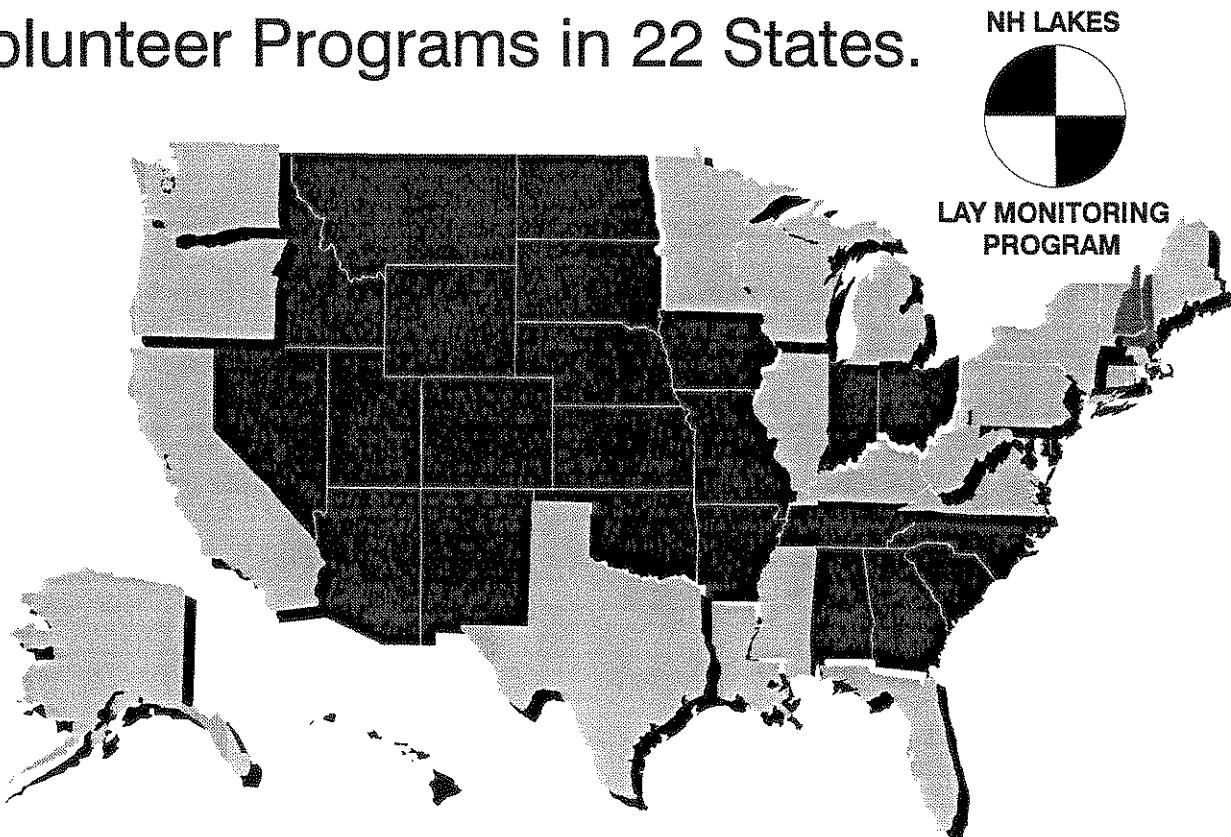
INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

In this sixteenth year of operation, the **NH Lakes Lay Monitoring Program** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide. The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets, and investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 1993 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program**. National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences. We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America and on the Environmental Network Clearinghouse. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty two states and nine countries!

The General Scenario - 1993

The Winter of 1992-93 was off to a white start with several major snowstorms occurring in the early months. The accumulated snowpack in many areas resulted in considerable runoff in late March and early April during the spring snowmelt. For those lakes which were monitored early enough, the winter conditions translated into lower alkalinities (buffering capacity) and lower pH levels in the tributary streams and in some lakes, when compared to results from a few years back; years with little snow pack. Thus, while many lakes have had steady or even increasing buffering levels for the last few years, a more typical (in terms of what was "normal" for New Hampshire in the last 30 years) snowfall amount this winter indicates that acid rain should still be one of our concerns.

The spring and summer months proved to be dry, once again (1993 was one of the driest summers in the past decade). This generally minimized sediment and nutrient runoff from the surrounding watershed and resulted in continued optimum water quality conditions for most participating LLMP lakes. In fact, several lakes recorded record high water clarity (secchi transparency) in 1993.

Lakes were clearer due to a combination of factors that once again included lower dissolved color compounds (dissolved organic matter from the breakdown of vegetation and soils) washed in from surrounding wetland areas, lower algae growth (measured as chlorophyll *a*) in the surface waters, due to lower nutrient runoff, and lower suspended sediment levels. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes.

As with dissolved color and nutrients, the dry spring and summer season brought less suspended sediment load to many of our streams and lakes. If increased clarity was not

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the result of decreased dissolved color or chlorophyll *a* levels than it was due to decreased suspended sediment by default. To find out how these water quality indicators inter-relate for your particular lake site, compare the Secchi Disk, chlorophyll *a* and dissolved color graphs enclosed in this report (see figures 4 to 9). Note whether changes in clarity (Secchi Disk depth) correspond to chlorophyll *a* or dissolved color concentration changes or whether it is a combination of the two. If neither seem to exhibit a consistent effect, then suspended sediment likely plays an important role in your lake's clarity.

In addition to limited watershed runoff, the hot and dry weather conditions in the early part of the summer resulted in a low water table. This sometimes translates into less of a chance of septic system failure; minimizing algae and some aquatic plant growth by further limiting nutrient loading. However, some lakes did experience increased aquatic plant and/or algae growth in 1993 which could be the result of a variety of factors: a lower water level and thus a greater surface area exposed to penetrating light (for photosynthesis) occurring simultaneously with a large number of clear and sunny days; warmer water temperatures (conducive to plant growth); longer water detention times and limited water movement, and thus nutrients entering the lake, from shoreline areas and during and following minimal storm events, remain longer in the shallow shoreline areas stimulating greater plant and algae growth.

In addition, several lakes experienced "algal blooms" late in the season. "Algal blooms" are often "green water events" associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate at the lake bottom as "mats" or the water surface as "scums" and "clouds". All types of "algal blooms" were observed in several participating LLMP lakes in 1993. "Algal blooms" are naturally occurring phenomenon and are not necessarily associated with changes in lake productivity, although increases in the occurrence of "bloom" conditions can be a sign of eutrophication (the "greening" of a lake). Algal blooms of varied extent typically occur

even in our most pristine lakes late in the fall and early in the spring as a result of lake mixing at those times.

In many lakes, particularly those within the Lakes Region of New Hampshire, cotton-candy like "clouds" of the nuisance green filamentous algae, *Mougeotia*, or a related species formed within the weed beds and then drifted freely into shallow areas around the lake. These algae often take advantage of nutrients that leak from particularly active submerged weeds or from bottom areas that have been disturbed by weed removal or other activities. While the summer of 1993 was in most cases a banner year for submerged aquatic plants, for reasons described above, there were many reports of these "blooms".

For some lakes, weather conditions became conducive to the formation of "blooms" of other algae species late in the season when the water temperatures were above average and several storm events following the extremely dry conditions flushed materials (sediment, dissolved color, nutrients) down through the watershed and into the lake. With this sudden inoculation of nutrients followed by improved lake flushing, these blooms tended to occur suddenly, but were generally short lived.

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. Dry summers can result in substantial populations of these algae to develop well out of site of the observer (and even the Secchi Disk!) until they "decide" to surface. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication nutrient loading.

The **LLMP** will continue to monitor "bloom" phenomenon in 1994 as it can be a sign of the changing land use practices and impacts within the lake watershed that can result in a long-term increase in lake productivity. However, it is possible that these phenomena were signs of short-term perturbations in water quality, the "noise" within the true long-term signal, induced by the atypical weather conditions of this past summer.

As in 1992, a few **NH LLMP** lakes were actually worse off during the 1993 sampling season. These lakes included those more productive lakes in which a good deal of nutrients come internally from sediment release. Lakes with significant nutrient input from septic systems or shoreline fertilization and watering would also have a bad year under the 1993 conditions. Other lakes that fared worse this year were seepage lakes, shallow lakes that rely on groundwater (springs) in-flow and out-flow for replenishment and cleansing. With a low water table, these lakes became great "growth chambers" for algae.

To see how your lake fared in 1993, relative to previous years of monitoring, refer to figures 12 and 14 (Secchi Disk transparency) and figures 13 and 15 (chlorophyll *a* concentration) in the back of this report.

Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For almost a decade and a half, data collected weekly from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake response to storm run-off will be missed. These short-term fluctuations

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may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

To determine if a change in water quality is occurring, a lake must be sampled on a frequent basis over a substantial amount of time. A poorly designed sampling program may even mislead the investigator away from the actual trend: Consider the hypothetical lake in Figure 1. Sampling only once a year during August from 1982 to 1986 would produce a plot (Fig. 2) suggesting a decrease in eutrophication. The actual long-term trend of the lake, increasing eutrophy, can only be clearly discerned by sampling additional times a year for a ten year period (Fig. 1). Frequent monitoring carried out over the course of many summers can provide the information required to distinguish between short-term fluctuation ("noise") and long-term trends ("signal"). To that end, the lake must establish a long-term data base.

The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data is collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a lay monitor in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may

seem that one week's data is just the same as the next. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Study

1993 marked the fifth year that monitoring of Lovell Lake was undertaken by the **Freshwater Biology Group** and the Lovell Lake Association. The program of sampling was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on two open water deep stations from Lovell Lake while additional sampling was also undertaken at the town beach and a mid lake sampling station (see figure 3 for site locations).

The primary purpose of this report is to discuss results of the 1993 monitoring with emphasis on current conditions of Lovell Lake including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys by the New Hampshire Water Supply and Pollution Control Commission and the **FBG** surveys. Care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various testing facilities and technological improvements in testing.

DISCUSSION OF LAKE MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1993 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion**. Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion. Lovell Lake became stratified into three distinct thermal layers (discussed above) during the summer months.

Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values of greater than 4 meters are typical of clear, less productive lakes. Values less than

2.5 meters are generally an indication of a very productive lake. In 1993 the average transparency for lakes participating in the NH LLMP was 5.6 meters with a range of 1.2 to 11.6 meters.

Lovell Lake continued to exhibit high water clarity during the 1993 sampling season which remained within the range characteristic of an unproductive, New Hampshire, lake. Table 1 summarizes the historical Secchi Disk transparency data for Lovell Lake while a more complete listing of the 1993 data is included in Appendix A.

Table 1. Historical Lay Monitor Secchi Disk Data comparison

for Lovell Lake

Site	Year	Trans-parency (m) Minimum	Trans-parency (m) Average	Trans-parency (m) Maximum	Sample Number
1 North	1989	5.6	6.3	6.9	12
1 North	1990	5.0	6.1	7.2	19
1 North	1991	5.9	6.6	7.2	17
1 North	1992	5.3	6.2	7.3	17
1 North	1993	5.0	5.9	6.6	16
2 South	1989	4.8	6.3	7.1	12
2 South	1990	5.0	6.1	8.0	19
2 South	1991	5.3	6.3	7.5	17
2 South	1992	5.5	6.5	7.8	17
2 South	1993	4.9	6.4	7.2	15

Chlorophyll a

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer

chlorophyll a concentrations average above 7 mg m^{-3} (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll a concentrations are generally less than 3 mg m^{-3}. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll a generally between 3 mg m^{-3} and 7 mg m^{-3}. In 1993 the average chlorophyll for lakes participating in the **NH LLMP** was 3.0 mg m^{-3} with a range of 0.1 to 43.7 mg m^{-3}.

The 1993 Lovell Lake chlorophyll a data, averaged for the season, are indicative of an unproductive, New Hampshire, lake. Table 2 summarizes the historical chlorophyll a data for Lovell Lake while a more complete listing of the 1993 data is included in Appendix A.

Table 2. Historical Lay Monitor Chlorophyll a Data comparison for Lovell Lake.

Site	Year	Chl a (ppb) Minimum	Chl a (ppb) Average	Chl a (ppb) Maximum	Sample Number
1 North	1989	1.8	2.6	3.7	12
1 North	1990	1.3	3.2	15.6	19
1 North	1991	1.7	3.0	7.9	17
1 North	1992	1.8	3.0	4.1	17
1 North	1993	1.4	2.4	3.8	16
2 South	1989	1.6	3.2	5.2	12
2 South	1990	0.7	2.7	5.5	19
2 South	1991	1.7	2.7	3.7	17
2 South	1992	1.6	2.9	4.6	17
2 South	1993	1.0	2.6	3.8	16

Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected

in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

FBG sampling, conducted on August 3, 1993 documented no stratifying mid-lake algal layer at that the time of sampling. However, 1992 FBG sampling documented a metalimnetic algal population at the 2 South sampling station which suggests a higher level of productivity than that indicated by the surface sampling alone. The FBG will continue to monitor for elevated mid-lake chlorophyll a concentrations at they can be an early indication of increasing productivity levels.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from humic substances, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information is important when interpreting the Secchi Disk transparency.

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 15 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing phosphorus to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Sediment Erosion, Septic Systems, etc) will show greater concentrations of nutrients as the summer progresses or after major storm events. Circulation of nutrients from the bottom waters of more productive lakes in late fall can result in algal blooms.

Total phosphorus analysis, performed by the FBG, indicate the phosphorus concentrations in the surface waters of the Lovell Lake deep sampling stations remained

within the range typical of an unproductive lake and ranged from 4.2 to 9.9 ppb. A higher phosphorus concentration was documented in the hypolimnion of the 2 South sampling station (15.9 ppb) and is likely the result of internal nutrient loading at the site. With the initiation of fall turnover, these nutrient "reserves" can become available to the algal population and result in elevated algal growth and a corresponding reduction in the water clarity. Refer to Appendix A for a complete listing of the 1993 total phosphorus results.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (ie: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

PH levels, measured on August 3 by the **FBG**, ranged from 6.7 to 7.3 pH units. The lowest pH reading of 6.7 was measured in the hypolimnion of Site 2 South (11.0 meters) and correspond to an elevated carbon dioxide concentration (12.6 milligrams per liter) near the lakebottom.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the

disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (grey color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 9 mg per liter (calcium carbonate alkalinity), while the average alkalinity of the lakes studied by the **Freshwater Biology Group** in the NH LLMP is approximately 6.3 mg per liter. When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

The alkalinity of Lovell Lake averaged 13.5 mg per liter in 1993, which is high for a New Hampshire lake and over 7 units greater than the average of 6.3 units for **NH LLMP** lakes. The current alkalinity of Lovell Lake remains sufficient to buffer against acid inputs.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micromhos (the opposite of the measurement of resistance ohms) per centimeter, more commonly referred to as micro-Siemans.

The specific conductivity levels at the Lovell Lake deep sampling stations were moderate, and ranged from 86.6 to 91.5 micro-Siemans at Site 1 North and ranged from 86.8 to 93.9 micro-Siemans at Site 2 South. Additional samples collected at the town beach sampling station were similar to the samples collected at the deep sampling stations, with the single exception of the data collected on August 14. The conductivity reading was significantly higher at the 1 North sampling station (91.5 micro-Siemans) relative to the town beach sampling station (82.0 micro-Siemans) at that time. Refer to Appendix A for a complete listing of the 1993 specific conductivity results.

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in free carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen

concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

The dissolved oxygen concentrations, measured at the Lovell Lake deep sampling sites, were high at the 1 North sampling station but became depleted in the hypolimnion of Site 2 South when measured by the **FBG** on August 3, 1993. The dissolved oxygen concentrations remained above 5 milligrams per liter only down to about 8.5 meters at the 2 South sampling station. A high carbon dioxide concentration (12.6 milligrams per liter) was also noted in the hypolimnion of the 2 South sampling station which is indicative of accumulating organic matter from both internal (i.e. plant and algal productivity) as well as external (i.e. leaf litter and grass clippings) sources.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only

waterproofed !). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the level where light is reduced, by the absorption and scattering properties of the lake water, to one percent of the surface intensity. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the transparency information.

Light measurements collected by the **FBG** indicate the photic zone in Lovell Lake extended down to about 11.0 meters on the August 3 sampling date. That is to say, sufficient light is available to support aquatic plant growth over the majority of Lovell Lake.

Indicator Bacteria *

Coliform bacteria in water indicate the possibility of fecal contamination. Although they are usually considered harmless to humans, they are much easier to test for than harmful pathogenic enteric bacteria (**Salmonella**, **Shigella** etc.) and viruses that may be present in fecal material. **Total coliform** includes all coliform bacteria which arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform

bacteria thought to be a better indicator of human contamination. The new state standard requires Class A bathing waters to be under 88 organisms per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high concentrations of coliform at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the zooplankton are discussed below in a separate section). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms,** tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae.** By late season **Blue-green bacteria** generally

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dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa, rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

Macro-zooplankton samples, collected by the **FBG** in Lovell Lake, were moderate in density at the 1 North (18.2 animals per liter) and the 2 South (11.9 animals per liter) sampling stations on August 3, 1993 (see figure 17). The macro-zooplankton community was dominated by the Calanoid copepod, *Diaptomus*, at both deep sampling stations while

the Cyclopoid copepods were the sub-dominant taxa. Both sampling stations also supported a population of the cladoceran, *Diaphanosoma*, which the FBG commonly finds in moderately productive systems. Current research at Dartmoth College is addressing the use of zooplankton as indicators of lake productivity. Future FBG reporting will incorporate the results of this study as they become available.

Fish Condition

As with the plankton discussed above, the health of the fish species of a lake will be indicative of the overall water quality. Condition is determined by comparing the length of the fish to its weight. As would be expected, the heavier the fish for its length, the better its condition will be. By also examining a scale collected from the fish under a microscope, the approximate age and growth history can also be determined.

CURRENT CONCERNS

Zebra Mussels

Since first being introduced to North America in 1986, zebra mussels (*Dreissena polymorpha*) have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least a year, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when

zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

What are Zebra Mussels?

Zebra mussels are non-native, freshwater mollusks. Their shells are marked by varying patterns of alternating dark and light bands. They are typically less than two inches long. The veligers (larval form) are free swimming, nearly invisible, and profuse. The adults secrete strong byssal threads by which they attach and reattach themselves to a variety of surfaces. These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in northwestern freshwater since the 1700s. Zebra mussels were first found in North America during 1988 in the waters of Lake Saint Clair, which is located between Lake Erie and Lake Huron. It is suspected that they arrived there as free-floating veligers (microscopic larvae) within the ballast waters of a transoceanic ship during 1986.

What do Zebra Mussels do?

In areas they infest, zebra mussels...
 * attach themselves to boat hulls, creating drag and fouling moving parts.
 * enter boat engine cooling systems, clogging them and causing overheating.
 * colonize and clog raw water intake pipes and screens at municipal water facilities, power generating plants, industrial facilities, and shoreline residences.
 * produce foul smells and bad tastes in water supplies where they are decomposing.
 * litter beaches, making walking hazardous and producing unpleasant odors.

* colonize and contaminate shoals, creating inhospitable fish nesting areas and crowding them.

* compete with zooplankton (an important fish food) for phytoplankton (microscopic algae). This causes a decrease in the amount of phytoplankton and makes the water clearer. However it adversely impacts other members of aquatic food webs, including fish.

* compete with native shellfish

* become prey for diving ducks and some species of fish. However, no predator capable of controlling them has been found.

What can you do?

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

Inspect your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

Flush the cooling system, bilge areas and live wells with tap water.

Discard all bait that has contacted waters that might be infested.

Leave your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**

Wash down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

Learn more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

Share information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group or civic organization.

Report any sightings to the **New Hampshire Lakes Lay Monitoring Program**. Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

Remember, so far **no** zebra mussel sightings have been substantiated in New Hampshire waterways. Confirm suspect specimens with an authority before alarming others.

How do you recognize one?

Zebra mussels commonly collect in vegetation, on docks or pilings, and along shoreline cobble and rocks.

* Adult zebra mussels are about the size of a dime and have dark and light stripes on their shells.

* Each half of the adult shell has a ridge running lengthwise down it. This creates a flat side where the two shells meet.

* Zebra mussels are the only freshwater mussels that attach to objects with byssal threads.

* A gritty feeling on your boat's hull may indicate that zebra mussel veligers have settled.

Where can you get more information?

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

Jeff Schloss
Lakes Lay Monitoring Program
109 Pettee Hall   or
University of New Hampshire
Durham NH 03824-3512
(603) 862-3848

Julia Dahlgran
Sea Grant/Cooperative Extension
Kingman Farm
University of New Hampshire
Durham NH 03824-3512
(603) 749-1565

Sleuthing Fish Condition in New Hampshire Lakes

Anglers are an important component of New Hampshire's recreation and tourism industry. The state offers warm water fishing in over 400 lakes for species such as bass, crappie, and sometimes, pickerel. In addition, almost 200 lakes offer the chance to catch the much desired cold water species such as land-locked salmon and lake trout. As the demand to fish our lakes continues to increase, so does the concern about the health of our fishery; in light of the increased fishing and boating pressure on NH lakes, increased development throughout our watersheds, and the planned (ie: Rainbow Trout) and accidental (ie: water milfoil) introduction of non-native species, knowledge of native fish condition is critical.

Enter the **Freshwater Biology Group (FBG)**, the applied aquatic research unity of the University of New Hampshire that along with Cooperative Extension, oversees the **NH Lakes Lay Monitoring Program**. In a cooperative study with NH Fish and Game, Dr. Lin Wu, a post doctorate UNH research scientist, and **FBG** co-directors Dr. James Haney of the department of Zoology and Dr. Alan Baker of the department of Plant Biology, have been assessing growth and condition of several sport and non-sport fish in lakes and ponds throughout the state.

The study uses two techniques to investigate fish health: the first, scale analysis, provides age and yearly growth information. Like trees, fish scales have annual growth rings (annuli) that reflect their growth rates and condition. Utilizing a computerized measurement and analysis system, each fish scale sample provides the information to calculate the current age, as well as, to back-calculate yearly growth for each fish to its first year. As the average fish age measured was 5 to 8 years, depending on species, much historical information was gained. The second technique uses a condition index, a function of the length and weight of the fish to indicate the fish's health at the time of collection. Essentially, the more weight a fish has for a given length, the healthier it is. Both

techniques allow for the return of fish unharmed after measurements are taken and a few scales are carefully scraped off.

Fish from over 50 NH lakes were obtained from NH Fish and Game, and **FBG** research teams using nets and traps. Samples were also taken at winter fishing derbies and provided by volunteer lay monitors who were outfitted with special fish measurement kits. In two years, scales and measurements were taken from over 6400 fish representing 29 different species.

For their initial analyses, the **FBG** investigators selected 33 lakes representative of the wide range of water quality conditions throughout the state and 11 target fish species. Results from the scale analysis indicate that a high percentage of the population of the different species studied reached maturity. This is good news since a high number of mature individuals indicates that reproduction of the population can generally be maintained. There is some indication of fishing pressure on the more popular sport species in that the less popular species, the yellow perch and white perch, had the highest percentage of older individuals.

Weight-length relationships for all of the fish species indicated that the fish populations are not crowded or stunted in any of the study lakes. The study also calculated a relative weight condition index that allows for comparisons to national and regional standards and the development of an in-state standard. In the majority of study lakes, smallmouth and largemouth bass populations, especially those in the Lakes Region and northern lakes, are in very good condition. On the other hand, lake trout, white perch and yellow perch populations in the majority of lakes had relative weights below the national mean.

Study results will provide managers and researchers with a baseline for further investigations into the changing health of the state's fishery resources, insight into the use of water quality data to predict fish growth, and information helpful to predict the effects

of species introduction (stocking and non-native invasions). Efforts of the **FBG** researchers are currently focused on such a situation on Newfound Lake, Where Fish and Game is planning to introduce alewife to replace the declining smelt (a major food source for salmonoids) population in hopes of invigorating the trout and salmon fishery there. Lab experiments and field surveys will try to predict potential effects. Further field work will determine the effectiveness of the stocking.

For those Lakes which participated in the UNH Fish Condition Program, specific reports were distributed to the appropriate persons. Further information concerning results of this study can be obtained by contacting:

Dr. Lin Wu / Dr. James Haney
Department of Zoology
Spaulding Life Sciences/UNH
Durham NH 03824
(603) 862-2100

Dr. Alan Baker
Department of Plant Biology
Nesmith Hall/UNH
Durham NH 03824
(603) 862-3845

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REPORT FIGURES

ALGAL STANDING CROP 1980-1989
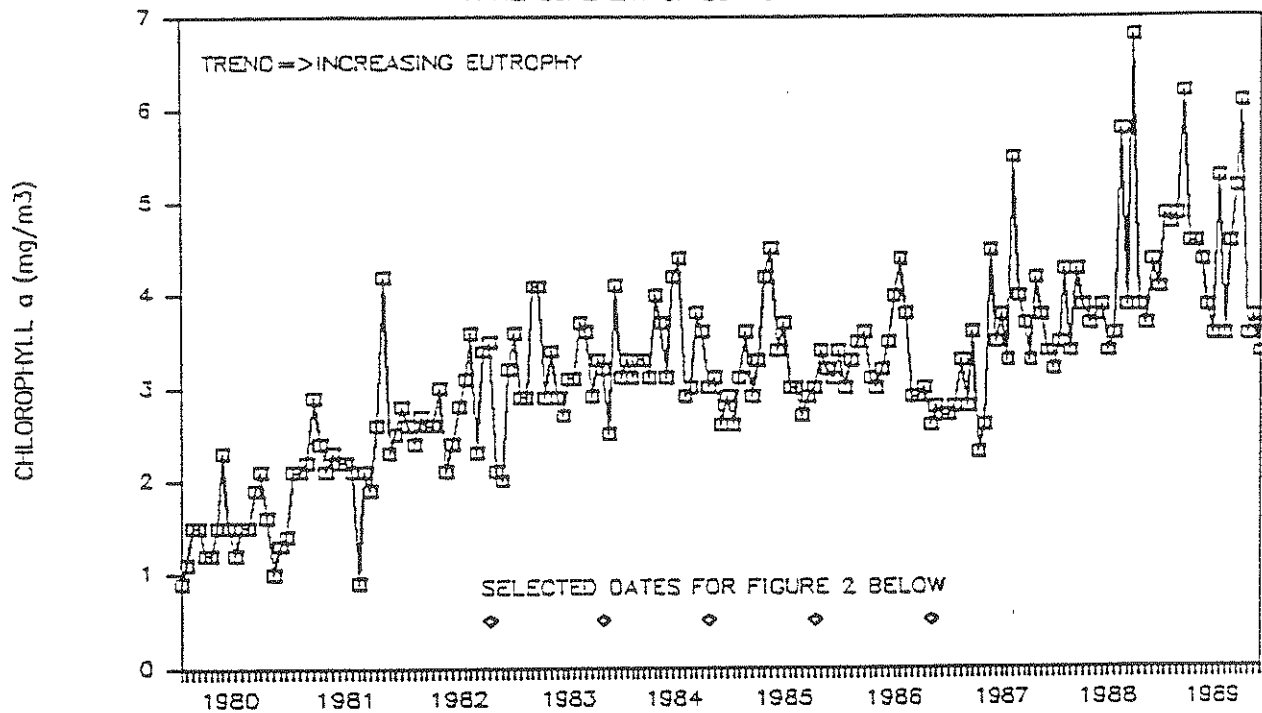
A MEASUREMENT OF EUTROPHICATION

.Figure 1. The upper graph depicts weekly chlorophyll concentrations of a model lake measured weekly during ice-free conditions. The long-term trend is that of increased eutrophication (lake has become "greener"). Diamonds below the curve represent late summer (August) dates the data set was subsampled to create Figure 2.

ALGAL STANDING CROP 1982-1986

LATE SEASON SAMPLE FROM FIG.1 ABOVE

☐   LATE AUGUST SAMPLE
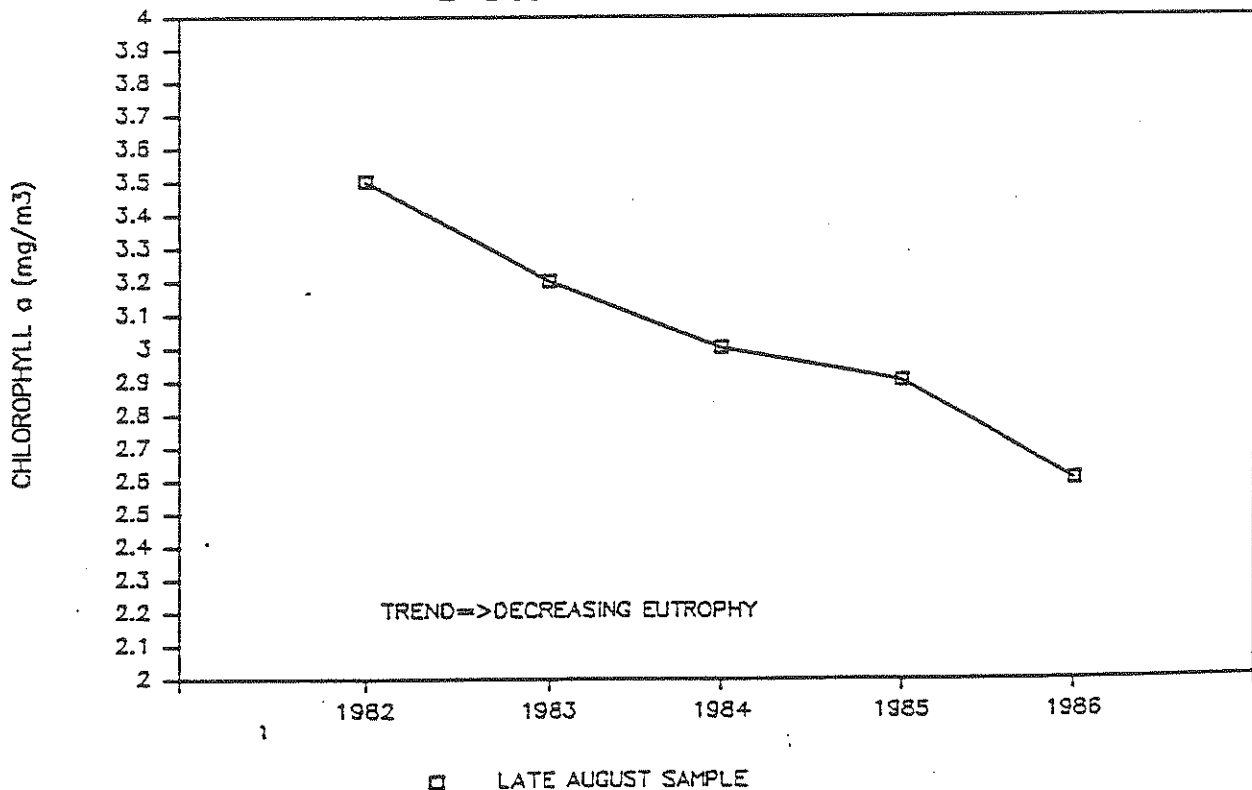
Figure 2.   The lower graph depicts late summer chlorophyll data of the model lake in Figure 1. Note how limited sampling over a five year period suggests a much different trend, that of decreasing eutrophy. Thus, limited sampling can mislead the investigator of long-term trends.

Figure 3. Location of the 1993 Lovell Lake deep and beach sampling stations, Sanbornville, New Hampshire.

LOVELL LAKE
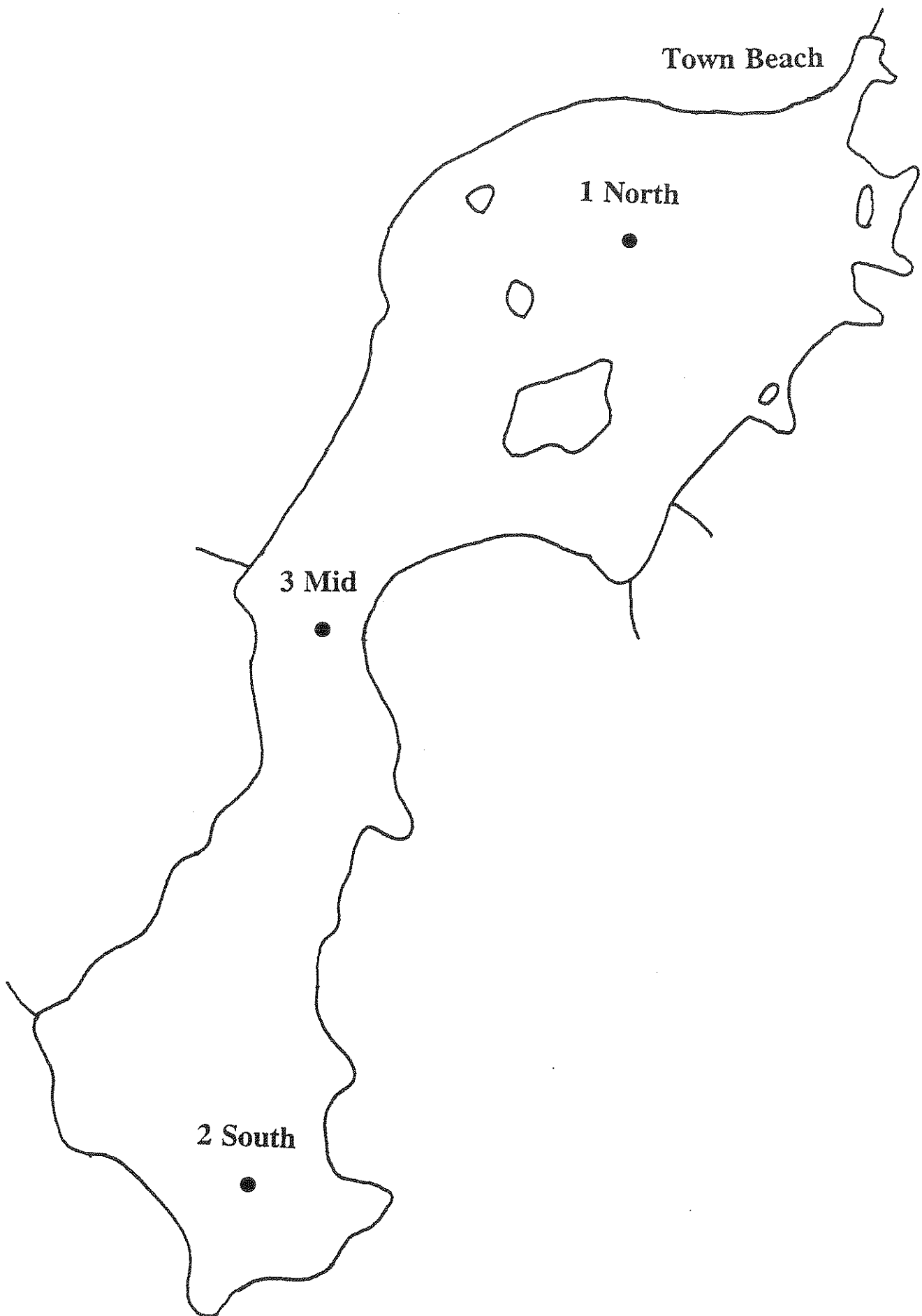
Town Beach

1 North

3 Mid

2 South

Figure 4. Lovell Lake, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 1 North. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid horizontal line denotes the maximum site depth.

Figure 5. Lovell Lake, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 1 North. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 6. Lovell Lake, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 1 North. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

LOVELL LAKE — 1 NORTH
SECCHI DISK TRANSPARENCY 1993

SECCHI DISK DEPTH (meters)

- EUTROPHIC -

- MESOTROPHIC v

v OLIGOTROPHIC v

LAKE BOTTOM AT SITE

11—Apr 01—May 21—May 10—Jun 30—Jun 20—Jul 09—Aug 29—Aug 18—Sep 08—Oct 28—Oct

DATE

LOVELL LAKE
CHLOROPHYLL CONCENTRATION 1993

CHLOROPHYLL a (ppb)

- EUTROPHIC -

- MESOTROPHIC v

v OLIGOTROPHIC v

04/11   05/01   05/21   06/10   06/30   07/20   08/09   08/29   09/18   10/08   10/28

□   SITE 1 NORTH

LOVELL LAKE
DISSOLVED COLOR CONCENTRATION 1993

DISSOLVED COLOR (ptu)

1993 NH LLMP LAKES AVERAGE

04/11   05/01   05/21   06/10   06/30   07/20   08/09   08/29   09/18   10/08   10/28
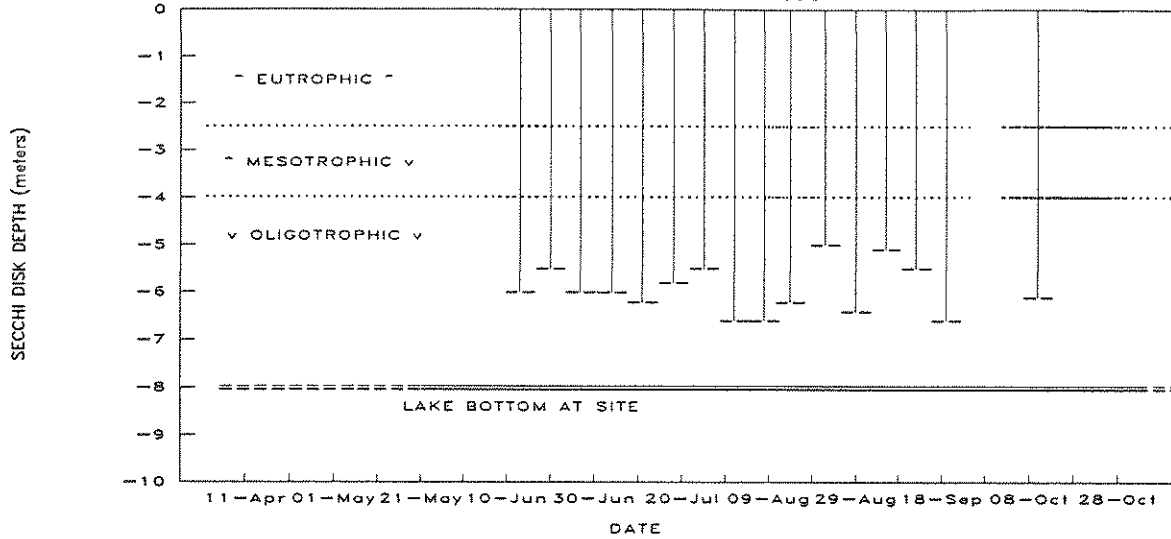
□   SITE 1 NORTH

Figure 7. Lovell Lake, 1993. Seasonal trends for Secchi Disk Depth (water transparency) of lay monitor Site 2 South. Dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 8. Lovell Lake, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Site 2 South. Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 9. Lovell Lake, 1993. Seasonal trends for dissolved color concentration of lay monitor Site 2 South. Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.
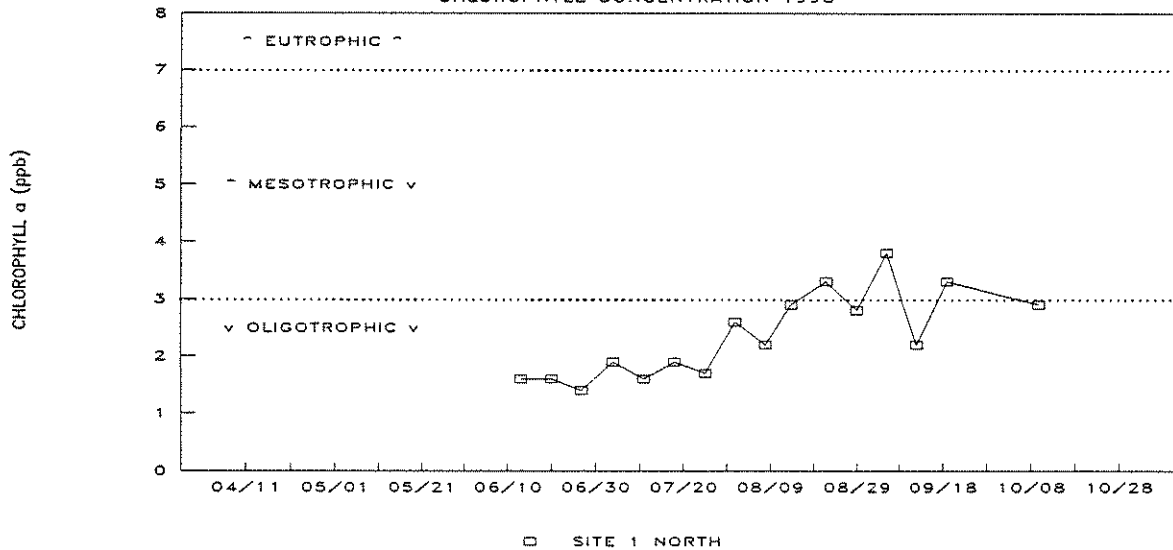
LOVELL LAKE — 2 SOUTH
SECCHI DISK TRANSPARENCY 1993

LOVELL LAKE
CHLOROPHYLL CONCENTRATION 1993

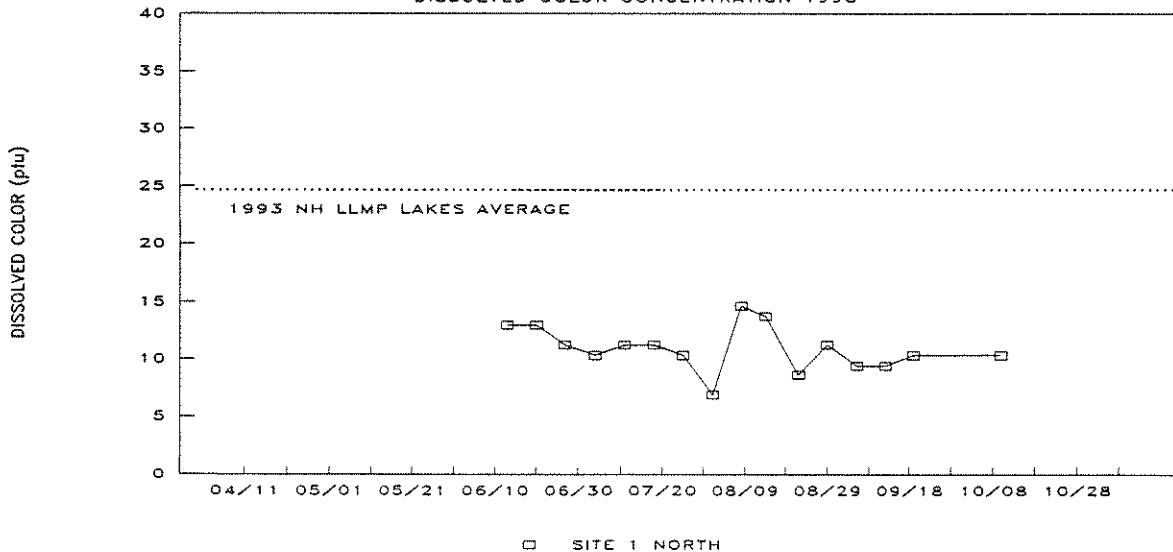# LOVELL LAKE
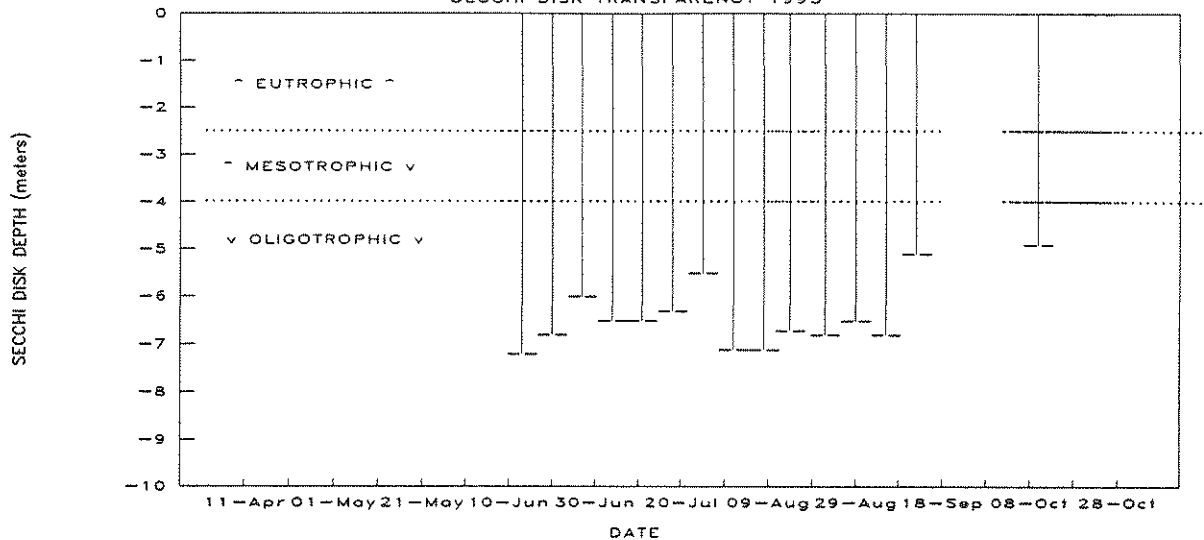## DISSOLVED COLOR CONCENTRATION 1993
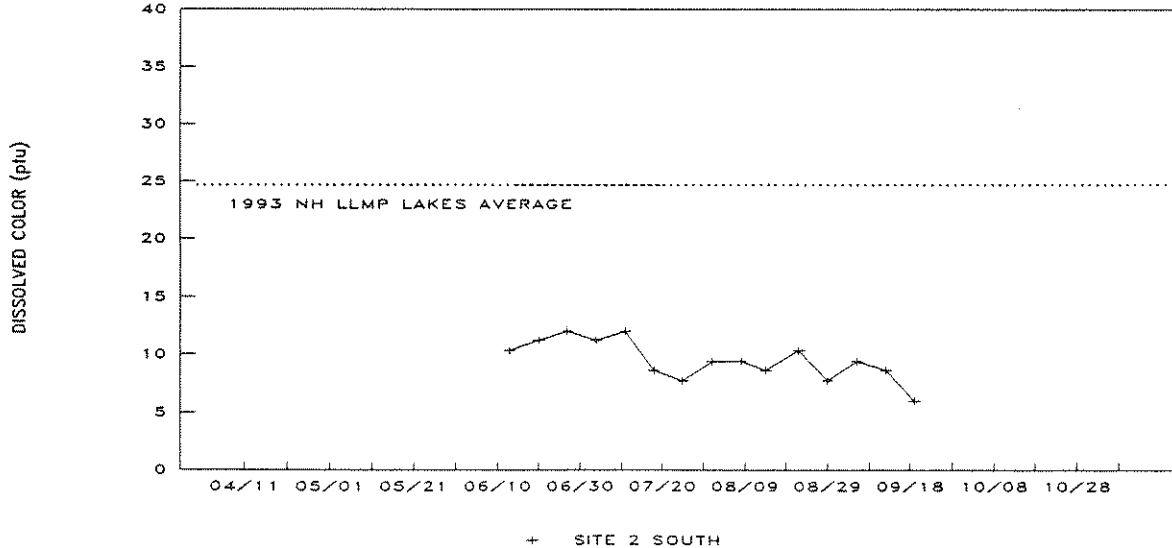
Figure 10. Lovell Lake, 1993. Seasonal trends for chlorophyll *a* concentration of lay monitor Sites 1 North (squares) and 2 South (crosses). Chlorophyll *a* concentrations in parts per billion (ppb) of chlorophyll *a*. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

Figure 11. Lovell Lake, 1993. Seasonal trends for dissolved color concentration of lay monitor Sites 1 North (squares) and 2 South (crosses). Color expressed as platinum-cobalt units (ptu). The dotted horizontal line represents the dissolved color average for participating **LLMP** lakes.

LOVELL LAKE
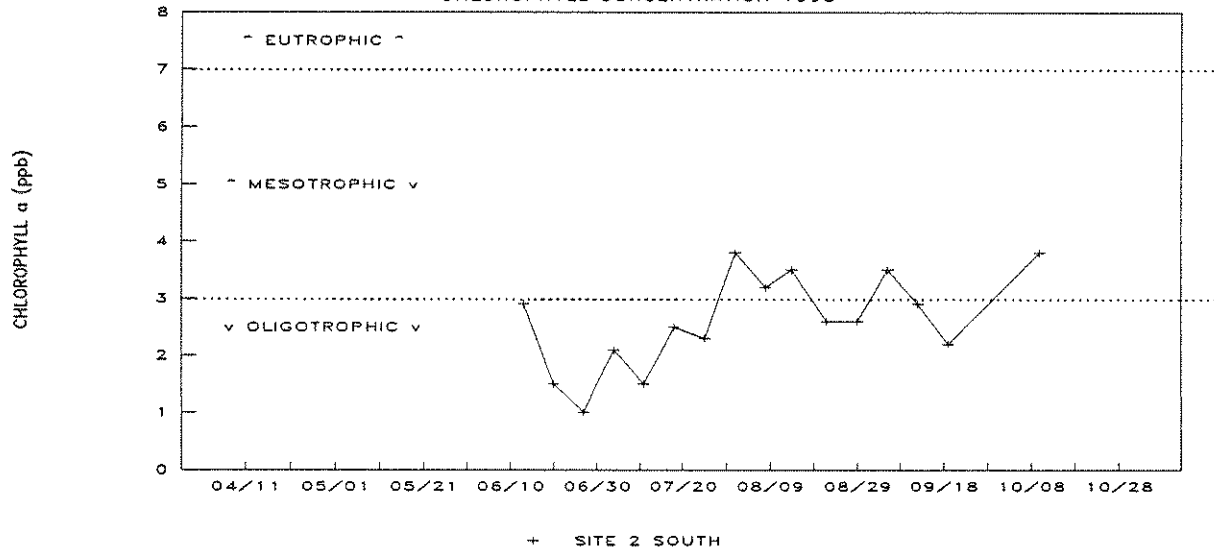
CHLOROPHYLL CONCENTRATION 1993

^ EUTROPHIC ^

^ MESOTROPHIC v

v OLIGOTROPHIC v

□ SITE 1 NORTH   +   SITE 2 SOUTH

LOVELL LAKE

DISSOLVED COLOR CONCENTRATION 1993

1993 NH LLMP LAKES AVERAGE

□ SITE 1 NORTH   +   SITE 2 SOUTH

Figure 12. Comparison of the 1993 Lovell Lake, Site 1 North, Lay Monitor Secchi Disk data with previous yearly data. Minimum, Mean and Maximum values are indicated as shown in the first bar. Secchi Disk readings are taken to the nearest 0.1 meter.

Figure 13. Comparison of the 1993 Lovell Lake, Site 1 North, Lay Monitor Chlorophyll *a* data with previous yearly data. Minimum, Mean and Maximum values are indicated as shown in the first bar. The Chlorophyll *a* Concentration is measured in parts per billion (ppb) which is equivalent to milligrams per cubic meter.

LAY MONITOR SECCHI DISK DATA
LOVELL LAKE - SITE 1 NORTH
YEARLY COMPARISONS (1989-1993)

YEAR

LEGEND:

KEY:

MINIMUM   AVERAGE   MAXIMUM

1989

1990

1991

1992

1993

LOW   MODERATE   HIGH

0   2   4   6   8   10   12

SECCHI DISK DEPTH (meters)

The higher value = clearer water

LAY MONITOR CHLOROPHYLL *a* DATA
LOVELL LAKE - SITE 1 NORTH
YEARLY COMPARISONS (1989-1993)

YEAR

LEGEND:

KEY:

MINIMUM   AVERAGE   MAXIMUM

1989

1990

1991

1992

1993

LOW   MODERATE   HIGH

0   2   4   6   8   10

Chlorophyll *a* concentration (ppb)
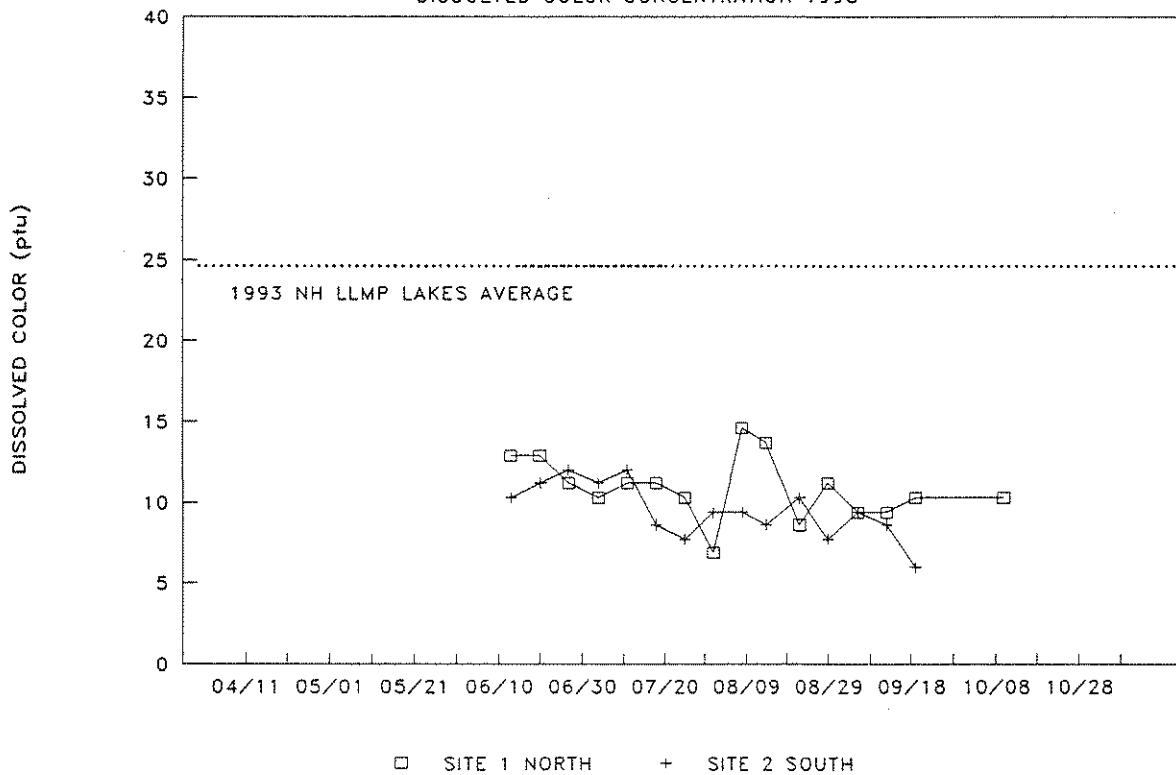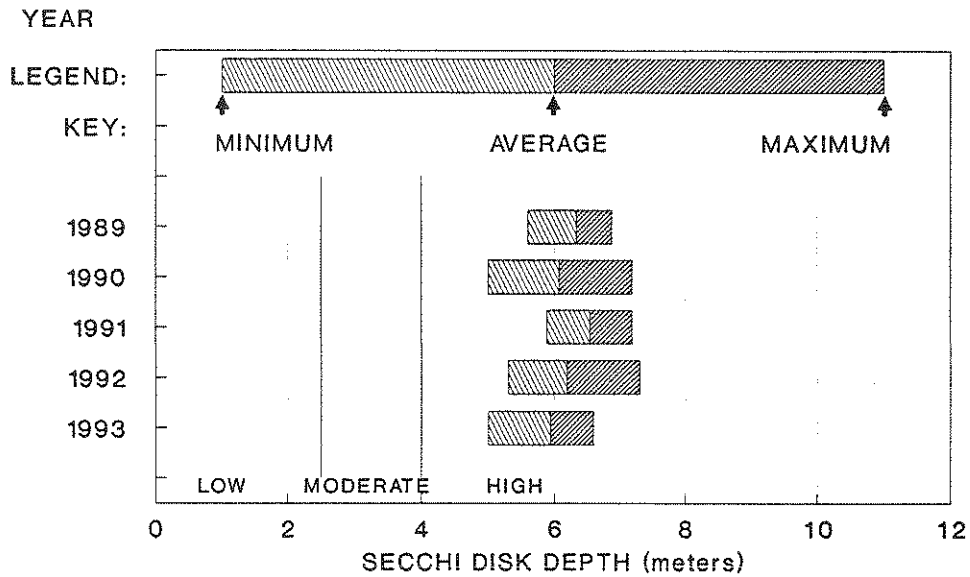
The higher value = more algal growth

Figure 14. Comparison of the 1993 Lovell Lake, Site 2 South, Lay Monitor Secchi Disk data with previous yearly data. Minimum, Mean and Maximum values are indicated as shown in the first bar. Secchi Disk readings are taken to the nearest 0.1 meter.
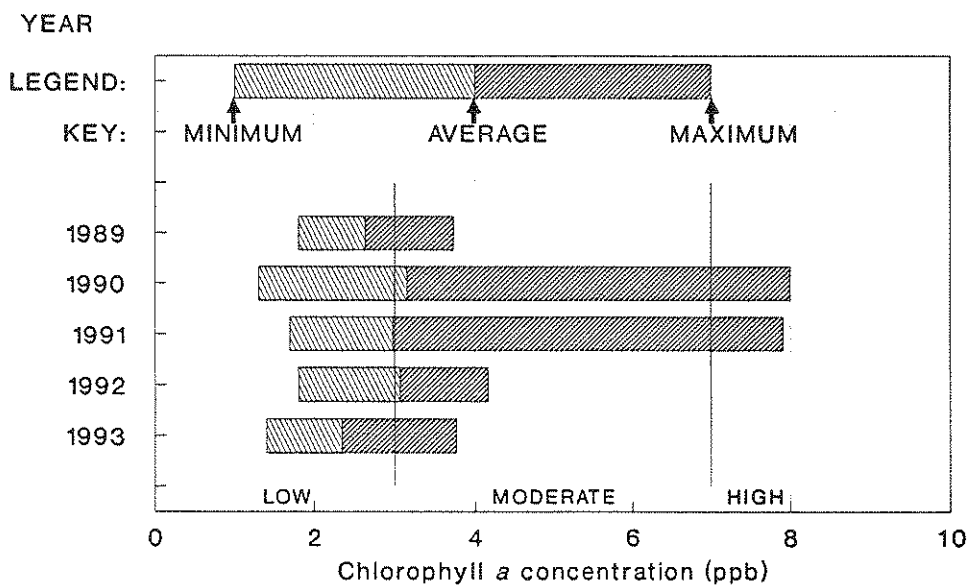
Figure 15. Comparison of the 1993 Lovell Lake, Site 2 South, Lay Monitor Chlorophyll *a* data with previous yearly data. Minimum, Mean and Maximum values are indicated as shown in the first bar. The Chlorophyll *a* Concentration is measured in parts per billion (ppb) which is equivalent to milligrams per cubic meter.

LAY MONITOR SECCHI DISK DATA
LOVELL LAKE - SITE 2 SOUTH
YEARLY COMPARISONS (1989-1993)
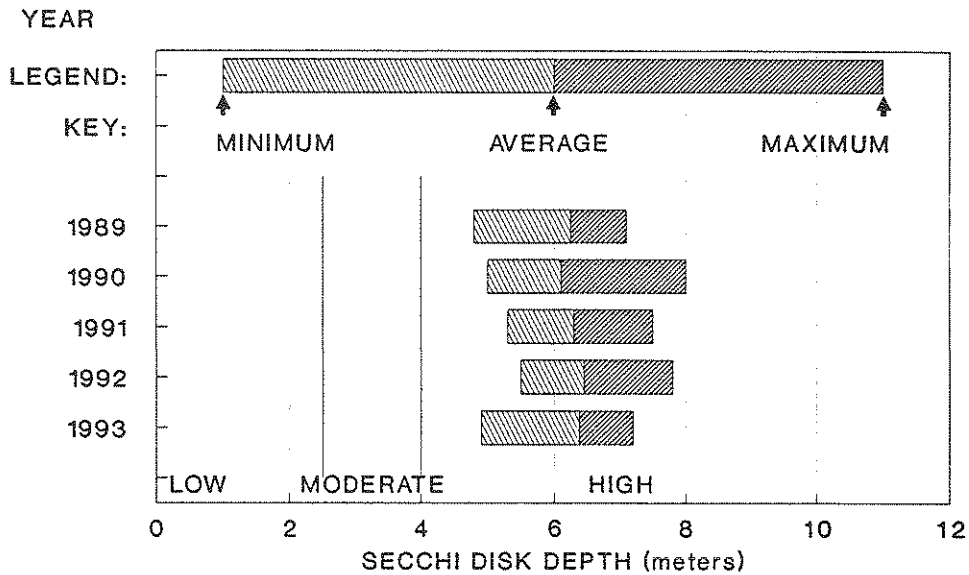
The higher value = clearer water

LAY MONITOR CHLOROPHYLL *a* DATA
LOVELL LAKE - SITE 2 SOUTH
YEARLY COMPARISONS (1989-1993)
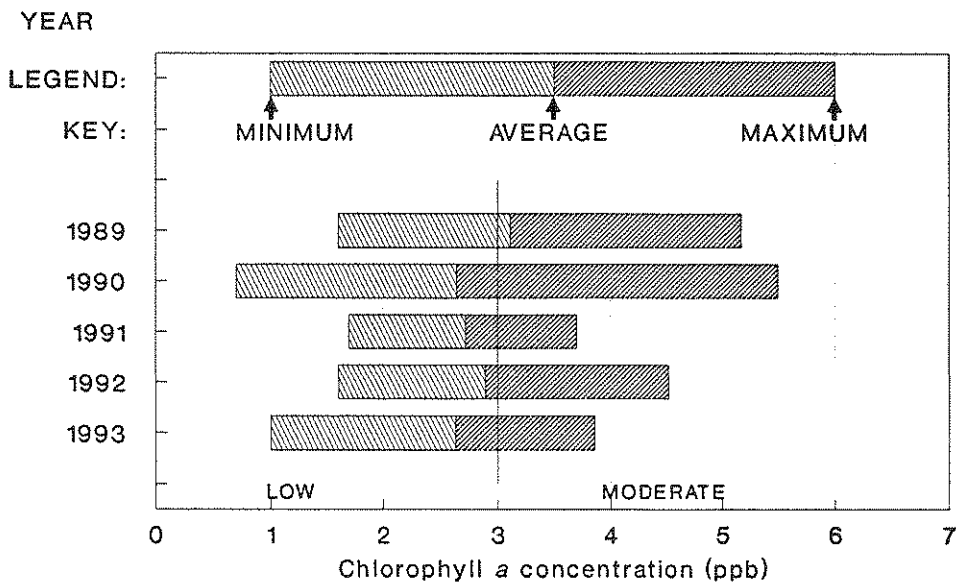
The higher value = more algal growth

Figure 16. Profiles of temperature and dissolved oxygen collected at the Lovell Lake deep sampling stations: (A) Site 1 North and (B) Site 2 South. The temperature and dissolved oxygen profiles were collected on August 3 at one-half meter intervals. Notice the low dissolved oxygen concentrations in the deeper waters (see text).

TEMPERATURE/DISSOLVED OXYGEN PROFILE
LOVELL LAKE - SITE 1 NORTH
AUGUST 3, 1993

OXYGEN (mg/l)

DEPTH

TEMPERATURE

DISSOLVED OXYGEN

TEMPERATURE (C)

—— TEMPERATURE   —+— DISSOLVED OXYGEN
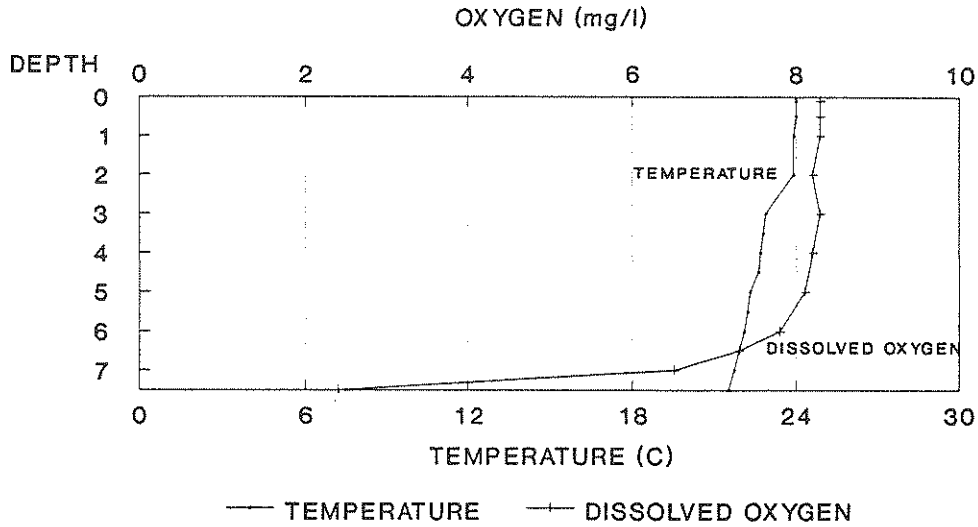
TEMPERATURE/DISSOLVED OXYGEN PROFILE
LOVELL LAKE - SITE 2 SOUTH
AUGUST 3, 1993

OXYGEN (mg/l)

DEPTH

Note:Low dissolved oxygen concentrations

TEMPERATURE

DISSOLVED OXYGEN

TEMPERATURE (C)

—— TEMPERATURE   —+— DISSOLVED OXYGEN
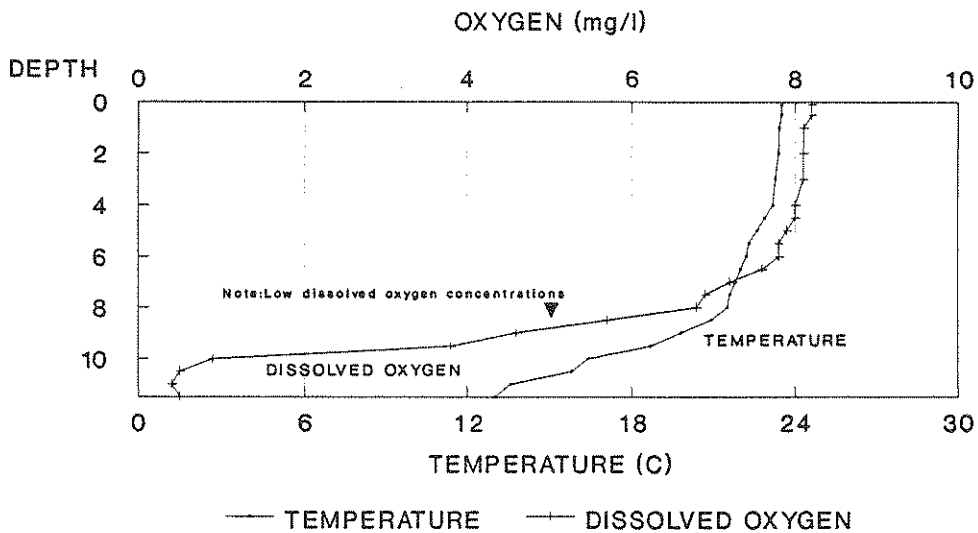
Figure 17. Pie diagrams of macro-zooplankton abundance collected at the Lovell Lake deep sampling stations: (A) Site 1 North and (B) Site 2 South. The macro-zooplankton samples were collected by pulling a fine mesh net (80 microns) vertically through the water column on the August 3 sampling date. The macro-zooplankton densities are presented as the number of animals per liter.

LOVELL LAKE
August 3, 1993

SITE 1 NORTH
DEPTH OF TOW 0 - 6.5m

Diaptomus 11.8

Daphnia sp. 0.58
Diaphanosoma 1.64
Bosmina 0.38
Cyclopoid 3.76
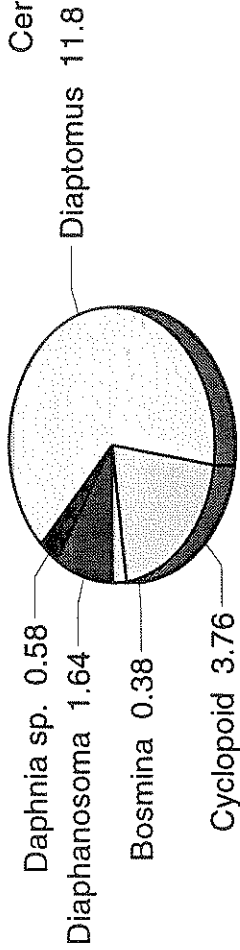
SITE 2 SOUTH
DEPTH OF TOW 0 - 10.5m

Bosmina 0.13
Diaphanosoma 1.42
Daphnia sp. 0.8
Holopedium 0.05

Cyclopoid 2.24
Ceriodaphnia 0.02

Diaptomus 7.22
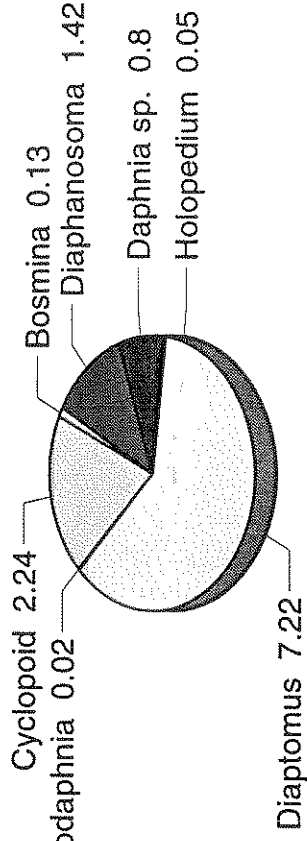
Macrozooplankton densities are presented as # animals per liter.

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Lovell Lake, NH
-- subset of trophic indicators, all sites, 1993

1993 SUMMARY
Average transparency: 6.2 (1993: 31 values;   4.9 - 7.2 range)
Average chlorophyll: 2.5 (1993: 32 values;   1.0 - 3.8 range)
Average Lake phos.:   6.5 (1993: 12 values;   4.4 - 9.9 range)
Average alk (gray): 13.5 (1993: 32 values; 11.3 - 15.6 range)
Average alk (pink): 15.6 (1993: 32 values; 13.5 - 18.0 range)
Average color, 440: 10.2 (1993: 31 values;   6.0 - 14.6 range)

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units	SPCD uSiemans
1 North	06/13/1993	6.0	1.6	6.0	12.3	13.6	12.9	----
1 North	06/20/1993	5.5	1.6	----	13.5	17.0	12.9	----
1 North	06/27/1993	6.0	1.4	----	14.7	18.0	11.2	----
1 North	07/04/1993	6.0	1.9	----	14.5	18.0	10.3	----
1 North	07/11/1993	6.2	1.6	----	12.7	15.7	11.2	----
1 North	07/18/1993	5.8	1.9	----	15.6	18.0	11.2	----
1 North	07/25/1993	5.5	1.7	6.0	14.1	17.8	10.3	----
1 North	08/01/1993	6.6	2.6	----	14.0	15.7	6.9	----
1 North	08/08/1993	6.6	2.2	----	13.2	14.4	14.6	----
1 North	08/14/1993	6.2	2.9	----	13.8	14.8	13.7	91.5
1 North	08/22/1993	5.0	3.3	----	14.4	16.0	8.6	89.4
1 North	08/29/1993	6.4	2.8	----	13.3	14.7	11.2	88.3
1 North	09/05/1993	5.1	3.8	----	13.5	14.7	9.4	89.8
1 North	09/12/1993	5.5	2.2	----	13.4	15.0	9.4	89.5
1 North	09/19/1993	6.6	3.3	----	13.5	15.4	10.3	----
1 North	10/10/1993	6.1	2.9	4.9	12.4	13.5	10.3	86.6
2 South	06/13/1993	7.2	2.9	4.4	11.3	14.0	10.3	----
2 South	06/20/1993	6.8	1.5	----	13.5	15.5	11.2	----
2 South	06/27/1993	6.0	1.0	----	12.9	16.0	12.0	----
2 South	07/04/1993	6.5	2.1	----	15.3	18.0	11.2	----
2 South	07/11/1993	6.5	1.5	----	12.7	15.1	12.0	----
2 South	07/18/1993	6.3	2.5	----	14.0	18.0	8.6	----
2 South	07/25/1993	5.5	2.3	9.9	14.3	17.0	7.7	----
2 South	08/01/1993	7.1	3.8	----	12.5	15.2	9.4	----
2 South	08/08/1993	7.1	3.2	----	13.2	14.1	9.4	----
2 South	08/14/1993	6.7	3.5	----	13.0	14.3	8.6	----
2 South	08/22/1993	6.8	2.6	----	14.7	16.4	10.3	----
2 South	08/29/1993	6.5	2.6	----	13.1	15.4	7.7	----
2 South	09/05/1993	6.8	3.5	----	13.3	14.6	9.4	----
2 South	09/12/1993	5.1	2.9	----	13.4	15.2	8.6	----
2 South	09/19/1993	----	2.2	----	12.5	14.6	6.0	----

Lovell Lake Data on file as of 06/27/1994

Site	Date	Trans-parency (m)	Chl a (ppb)	Total Phos (ppb)	Alk. (gray) ph 5.1	Alk. (pink) ph 4.6	Color Pt-Co units	SPCD uSiemans
2 South	10/10/1993	4.9	3.8	6.2	12.8	14.5	----	----
3 Mid	06/13/1993	----	----	6.0	----	----	----	----
3 Mid	07/25/1993	----	----	6.0	----	----	----	----
3 Mid	10/10/1993	----	----	5.7	----	----	----	----
Beach	06/13/1993	----	----	7.9	----	----	----	87.6
Beach	06/27/1993	----	----	----	----	----	----	86.5
Beach	07/11/1993	----	----	----	----	----	----	82.6
Beach	07/25/1993	----	----	9.5	----	----	----	94.1
Beach	08/08/1993	----	----	----	----	----	----	86.7
Beach	08/14/1993	----	----	----	----	----	----	82.0
Beach	08/22/1993	----	----	----	----	----	----	86.4
Beach	08/29/1993	----	----	----	----	----	----	91.5
Beach	09/05/1993	----	----	----	----	----	----	88.3
Beach	09/12/1993	----	----	----	----	----	----	89.9
Beach	09/19/1993	----	----	----	----	----	----	90.8
Beach	10/10/1993	----	----	4.9	----	----	----	88.7

<< End of 1993 listing, 38 records >>

Depth (m)	pH	CO2 mg/l	Alk Gray end pt.	Alk Pink end pt.	Spec. Cond. (umho)	T-Phos (ppb)	Chloro- phyll a (ppb)	Diss. Color (ptu)
0-7.0	----	----	12.2	12.7	88.9	5.3	1.7	6.9
0.5	7.3	1.7	10.7	11.2	87.1	----	1.7	6.9
3.5	7.2	1.8	10.8	11.3	87.2	----	----	----
6.5	7.2	2.9	10.8	11.3	88.2	4.2	----	----

Depth (m)	Tem- pera- ture (C°)	Diss. oxygen (mg/l)
0.10	24.0	8.3
0.50	24.0	8.3
1.00	23.9	8.3
2.00	23.9	8.2
3.00	22.9	8.3
3.50	22.8	----
4.00	22.7	8.2
4.50	22.6	----
5.00	22.3	8.1
5.50	22.2	----
6.00	22.1	7.8
6.50	21.9	7.3
7.00	21.7	6.5
7.50	21.5	2.4

Secchi Disk Depth   6.6 meters

Results of Additional FBG sampling:

Site	Date	T-Phos (ppb)
3 Mid	8-03-93	7.1
Beach	7-22-93	10.8
Beach	8-03-93	7.7

Lovell Lake - Site 2 South (FBG Data)   August 3, 1993

Depth (m)	pH	CO2 mg/l	Alk Gray end pt.	Alk Pink end pt.	Spec. Cond. (umho)	T-Phos (ppb)	Chloro-phyll a (ppb)	Diss. Color (ptu)
0-8.0	----	----	10.8	11.4	87.7	5.3	3.1	7.7
0.5	7.3	2.0	11.9	12.5	87.6	----	1.2	6.9
4.0	7.2	1.3	11.0	11.5	86.8	----	----	----
9.0	6.9	5.1	12.3	12.7	89.3	----	3.1	9.4
11.0	6.7	12.6	15.5	16.0	93.9	15.9	----	----

Depth (m)	Tem-pera-ture (C^O)	Diss. oxygen (mg/l)	DLS visit no.
0.10	23.5	8.2	1675
0.50	23.5	8.2	1675
1.00	23.4	8.1	1675
2.00	23.4	8.1	1675
3.00	23.3	8.1	1675
4.00	23.2	8.0	1675
4.50	22.9	8.0	1675
5.00	22.6	7.9	1675
5.50	22.3	7.8	1675
6.00	22.2	7.8	1675
6.50	22.0	7.6	1675
7.00	21.8	7.2	1675
7.50	21.6	6.9	1675
8.00	21.5	6.8	1675
8.50	20.9	5.7	1675
9.00	19.8	4.6	1675
9.50	18.7	3.8	1675
10.00	16.4	0.9	1675
10.50	15.8	0.5	1675
11.00	13.6	0.4	1675
11.50	13.0	0.5	1675

Secchi Disk Depth   7.0 meters

A - 4

TYPICAL TEMPERATURE CONDITIONS : SUMMER
NEW HAMPSHIRE - DEEP LAKE

DEPTH (meters)

EPILIMNION
UPPER - WARM WATER LAYER - WIND MIXED

METALIMNION
SHARP DROP IN TEMPERATURE
(THERMOCLINE)

HYPOLIMNION
BOTTOM COLD WATER LAYER

TEMPERATURE (C)
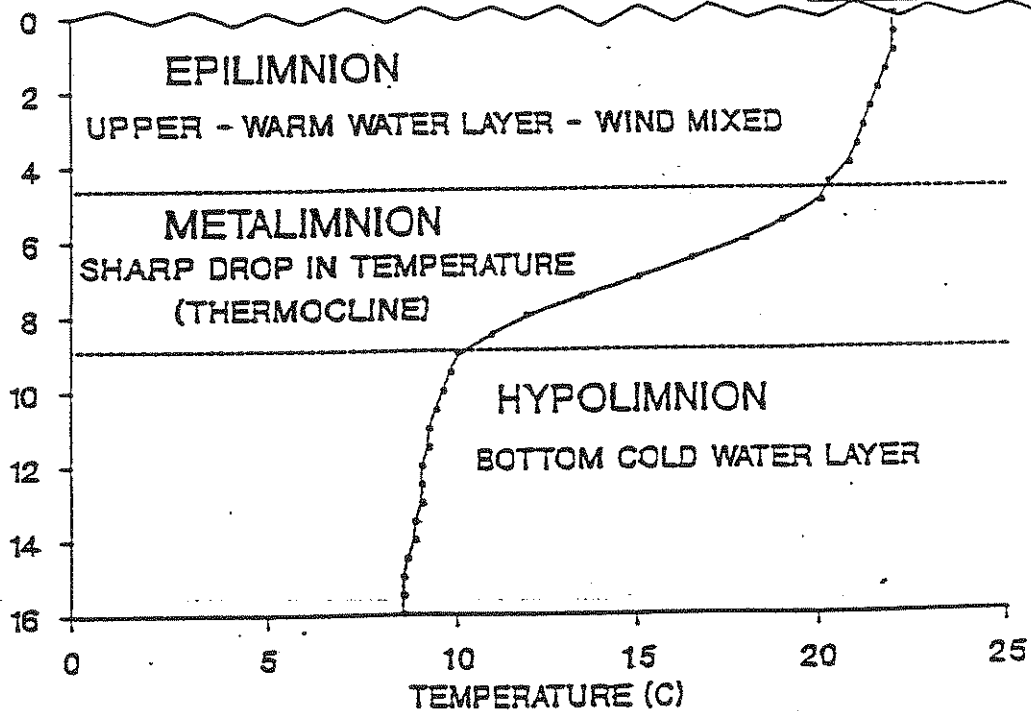
APPENDIX C

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy-   The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity.   Chlorophyll *a* concentration may be low or high.

Epilimnion-   The uppermost layer of water during periods of thermal stratification.   (See lake diagram).

Eutrophy-   The lake trophic state in which algal production is high.   Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus.   From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present.   A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2-   Carbon dioxide that is not combined chemically with lake water or any other substances.   It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis-   The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems.   Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire.   Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion-   The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments.   The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification.   (See lake diagram)

Lake-   Any "inland" body of relatively "standing" water.   Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology-   The shape and size of a lake and its basin.

Littoral-   The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis-   The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate.   These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification.   Usually defined as the region where the water temperature changes at least

one degree per meter depth. Also called the thermocline.

Mixis-   Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn-   See circulation or mixis

pH-   A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis-   The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton-   Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million-   Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion-   Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton-   Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated-   When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater,

gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.