SUNSET LAKE (WASH POND)
1989
LAKES LAY MONITORING PROGRAM
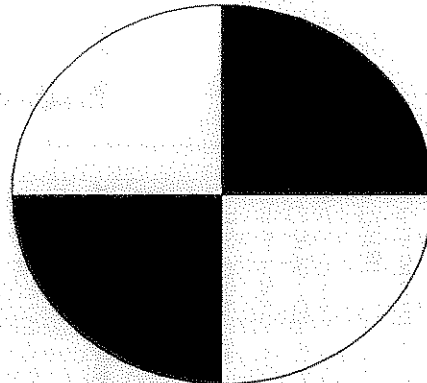
by

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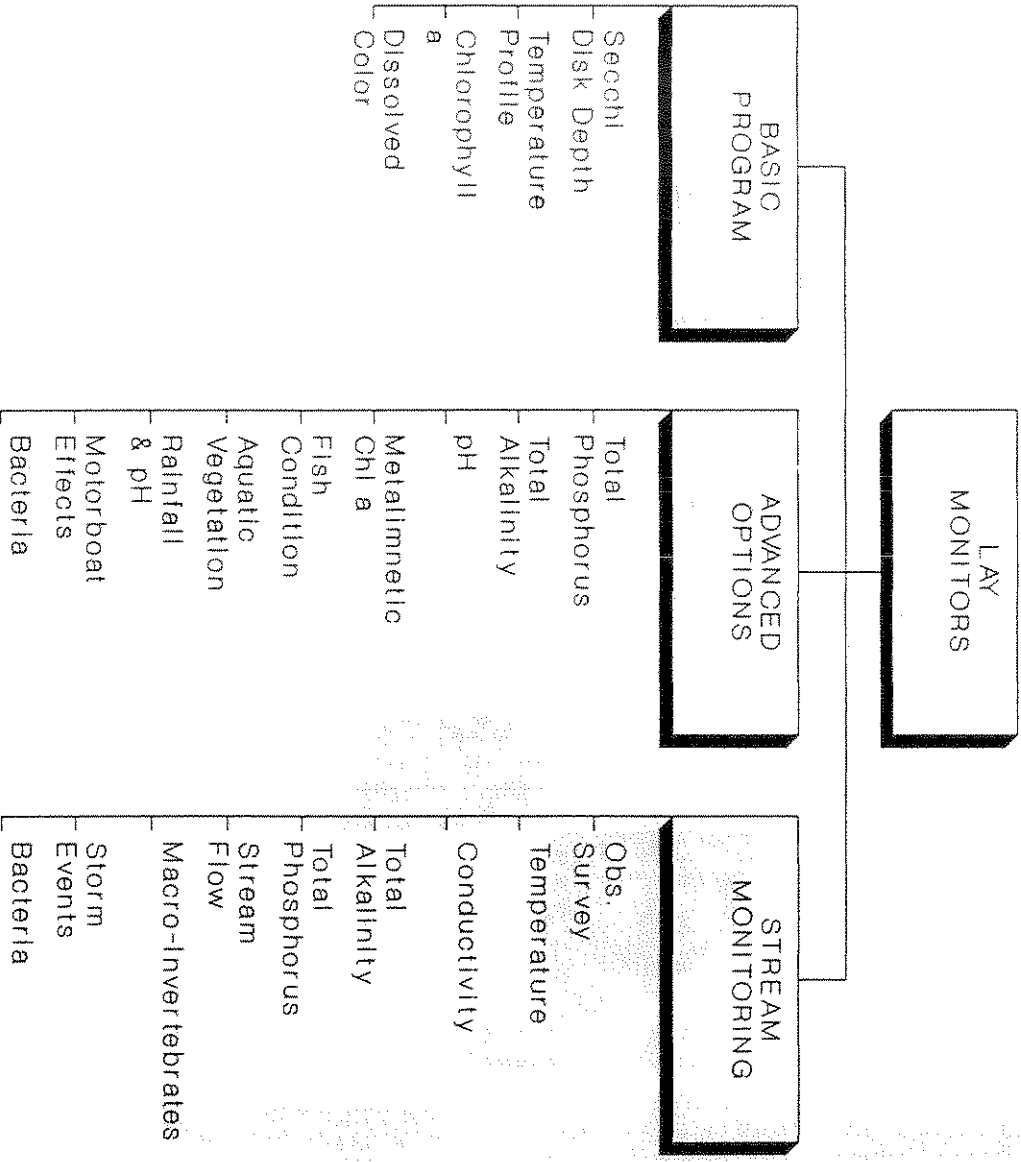NEW HAMPSHIRE LAKES LAY MONITORING PROGRAM

NH LLMP

PARAMETERS SAMPLED
NH LAKES LAY MONITORING PROGRAM

LAY MONITORS

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 Sunset Lake, New Hampshire, conducted in the summer of and 1989 by the Freshwater Biology Group (**FBG**) of the University of New Hampshire and the Sunset Lake Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1989 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. A Glossary of terms and concepts is also included. The more adventurous reader is referred to these last sections, as well as the materials cited in the references section, if there is interest in learning more about the dynamics of fresh water systems.

ACKNOWLEDGEMENTS

Participating groups in the **LLMP** include: The New Hampshire Audubon Society, Derry Conservation Commission, Dublin Garden Club, Nashua Regional Planning Commission, Center Harbor Bay Conservation Commission, Governor's Island Club Inc., Little Island Pond Rod and Gun Club, Walker's Pond Conservation Society, United Associations of Alton, the Pemaquid Watershed Study Group, the associations of Baboosic Lake, Beaver Lake, Berry Bay, Big Island Pond, Bow Lake Camp Owners, Lake

Chocorua, Crystal Lake, Dublin Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mascoma Lake, Mendum's Pond, Merrymeeting Lake, Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Perkins Pond, Pleasant Lake, Silver Lake (Hollis), Silver Lake (Harrisville), Silver Lake (Madison), Squam Lakes, Lake Sunapee, Sunset Lake, Swains Lake, Lake Winona, and Wentworth Lake and the towns of Alton, Amherst, Enfield, Hollis, Madison, Merrimack, Strafford and Wolfeboro.

SUNSET LAKE

1989 NON-TECHNICAL SUMMARY

Weekly monitoring was undertaken at Sunset Lake by the volunteer monitors.

1)   Water transparency at Sunset Lake was high, the sign of a clear and unproductive lake. The secchi disk was visible as far down as 7.1 meters (23.3 feet) in 1989. This indicates the deepwater sites on the lake are relatively low in dissolved color and suspended matter such as algae and particulates. The transparency average was 5.6 meters in 1989 compared to 5.1 meters in 1988. In 1988 the highest transparency for the lake recorded since 1984 occurred (8.1 meters) although 1988 average transparency was slightly lower than previous years averages.

2)   Chlorophyll $\underline{a}$ concentrations for the surface waters of Sunset Lake were low. Chlorophyll levels indicate the extent of algae growth in the water. Concentrations in the mixed layer of water averaged 2.2 milligrams per cubic meter (mg m^{-3}, equivalent to about 2.2 parts chlorophyll per billion parts water) in 1989.   Generally, concentrations below 3 mg m^{-3} are common to less productive, clear lakes and values above 7 mg m^{-3} are common in productive lakes. The 1988 and 1989 chlorophyll averages were slightly greater than averages of previous years thus algal levels are slowly increasing.

3)   Dissolved lakewater color levels for Sunset Lake in 1989 were low (10 ptu average) and less than the average levels of 28 ptu (platinate color units) in other 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.

4) Total phosphorus (nutrient) levels were low in the open waters of Sunset Lake and at the dam site. Lake samples were in the range of 2 to 6 parts per billion (ppb) phosphorus. Phosphorus levels at the tributary site was 17 ppb a more moderate level. A concentration of 15 ppb is commonly thought of as the boundary between less productive and more productive lakes.

5) The alkalinity of the lake, the lakes ability to buffer acid input, is at moderate levels but high in comparison with other program lakes. The alkalinity of Sunset Lake averaged 13.5 units in 1989, considerably higher than the average of 6 units alkalinity for the other LLMP lakes. The data indicate that the lake has adequate buffering capacity at this time to resist fluctuations in pH due to acid precipitation.

6) For all measurements considered and averaged for the season, Sunset Lake would be classified as having low productivity, a clear, oligotrophic lake.

INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

During the past decade the NH Lakes Lay Monitoring Program has grown from a university class project on Chocorua Lake to a comprehensive state-wide program with over 500 volunteer monitors and more than 75 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. Current projects include: use of volunteer generated data for non-point pollution studies using a geographic based information system (GIS) in conjunction with the NH Office of State Planning, intensive watershed monitoring for the development of lake nutrient budgets, investigations of water quality and indicator organisms (fish condition, and stream invertebrates), and ground-truthing for remote sensing studies. Key ingredients responsible for the success of the program include innovative funding and cost reduction, assurance of credibility of data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

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 over a decade, 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 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.

ALGAL STANDING CROP 1980–1989
A MEASUREMENT OF EUTROPHICATION

TREND=>INCREASING EUTROPHY

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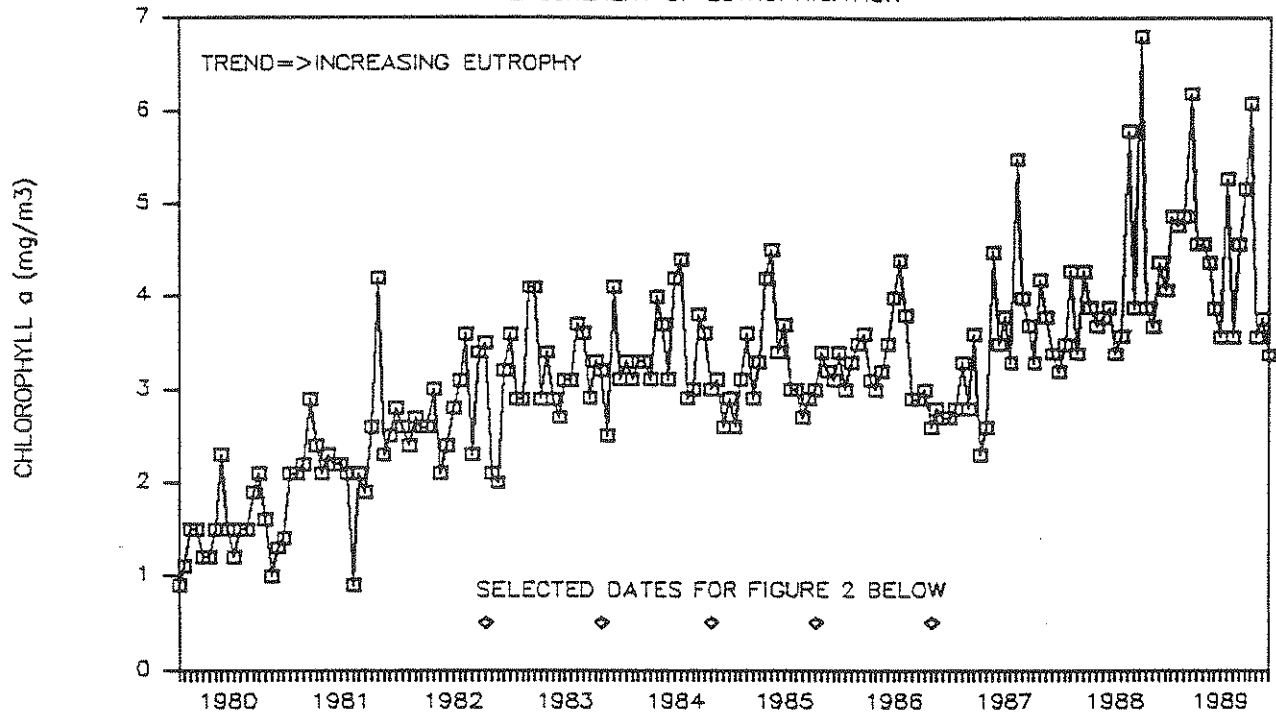
Figure 1. The upper graph depicts weekly chlorophyll concentrations of a model lake measured weekly during ice-free conditions. The long-term trend is that of increased eutrophication (lake has become "greener"). Diamonds below the curve represent late summer (August) dates the data set was subsampled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

ALGAL STANDING CROP 1982–1986
LATE SEASON SAMPLE FROM FIG.1 ABOVE

TREND=>DECREASING EUTROPHY

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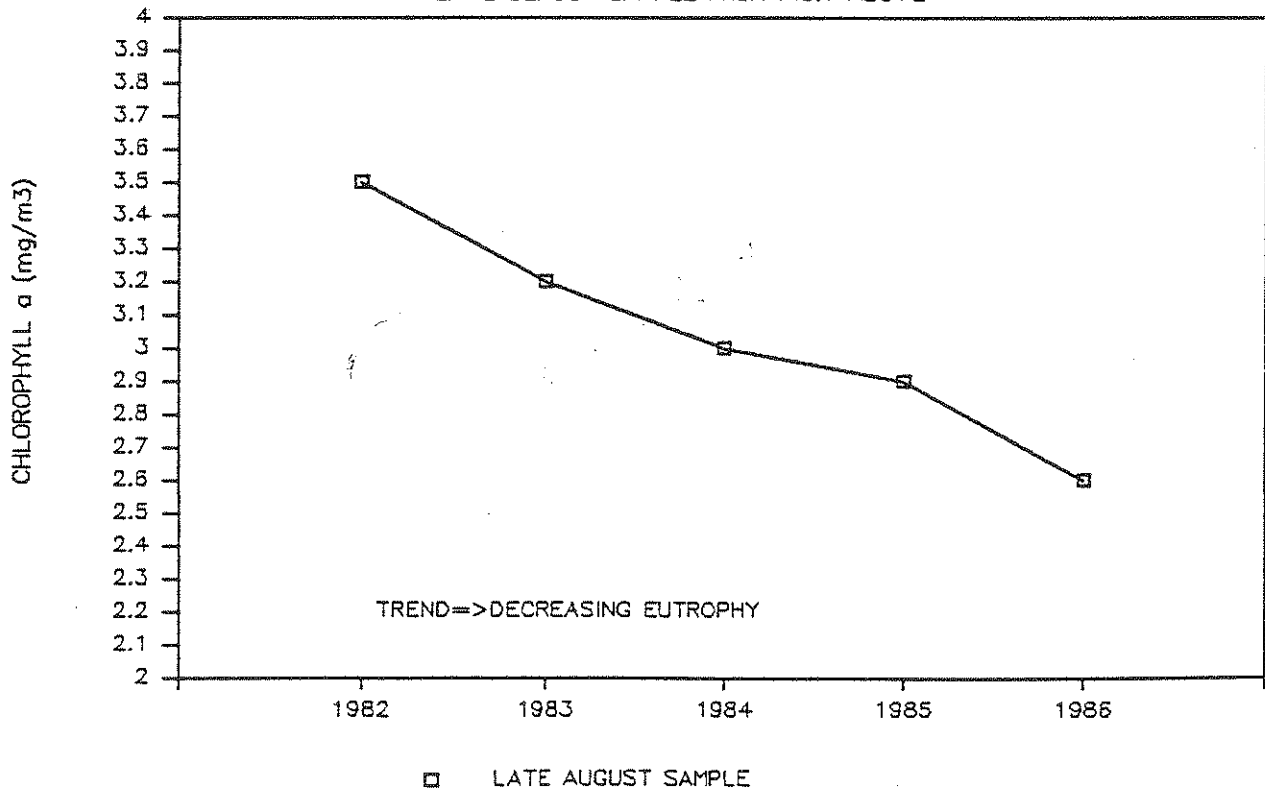
Figure 2.   The lower graph depicts late summer chlorophyll data of the model lake in Figure 1. Note how limited sampling over a five year period suggests a much different trend, that of decreasing eutrophy. Thus, limited sampling can mislead the investigator of long-term trends.

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

This was the sixth year that monitoring of Sunset Lake was undertaken by the Freshwater Biology Group and the Sunset Lake Association. The program of sampling was designed to continue adding to

the long-term data base. Sampling emphasis was placed on one open water deep station.

The primary purpose of this report is to discuss results of the 1989 monitoring with emphasis on current conditions of Sunset 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 and 1970'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 done by other groups. 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 1988 and 1989 results from Sunset Lake and 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 (*). No FBG trip to Sunset Lake was undertaken in 1988 or 1989.

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** (see figures at the end of report. Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

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 1989 the average transparency for lakes participating in the NH LLMP was 6.2 meters with a range of 1.4 to 12.5 meters. Sunset Lake transparency was in the range of 3.0 to 7.1 meters with an average of 5.6 meters.

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 1989 the average chlorophyll for lakes participating in the NH LLMP was 2.8 mg m^{-3} with a range of 0.1 to 54.4 mg m^{-3}. The Sunset Lake average was 2.2 mg m^{-3} with a range of 1.2 to 3.1 mg m^{-3}.

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. **Sunset monitors should consider late summer testing for any stratifications. A sample collected from within the metalimnion using the bottle sampler should be filtered in the same manner as the integrated sample.** Contact the **NH LLMP** coordinator for more information.

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. Sunset Lake dissolved color was in the range of 4 to 17 units.

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.

In lake levels were in the range of 2 to 6 ppb, the outlet water (dam) measured 4 ppb in July and the inlet site 9.5 had a mid-August concentration of 17 ppb.

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.

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 6.0 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.

Sunset Lake alkalinity was high for a New Hampshire lake, 13.5 units (mg per liter $CaCO_3$) average with a range of 12.6 to 14.5 units.

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. Conductivity samples at Sunset Lake tributaries did not indicate any substantial water quality problems.

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.

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.

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. Desirable levels for a Class A water body is less than 50 total coliform organisms per 100 milliliters. If the total coliform level rises above 150 organisms per 100ml swimming should be prohibited.

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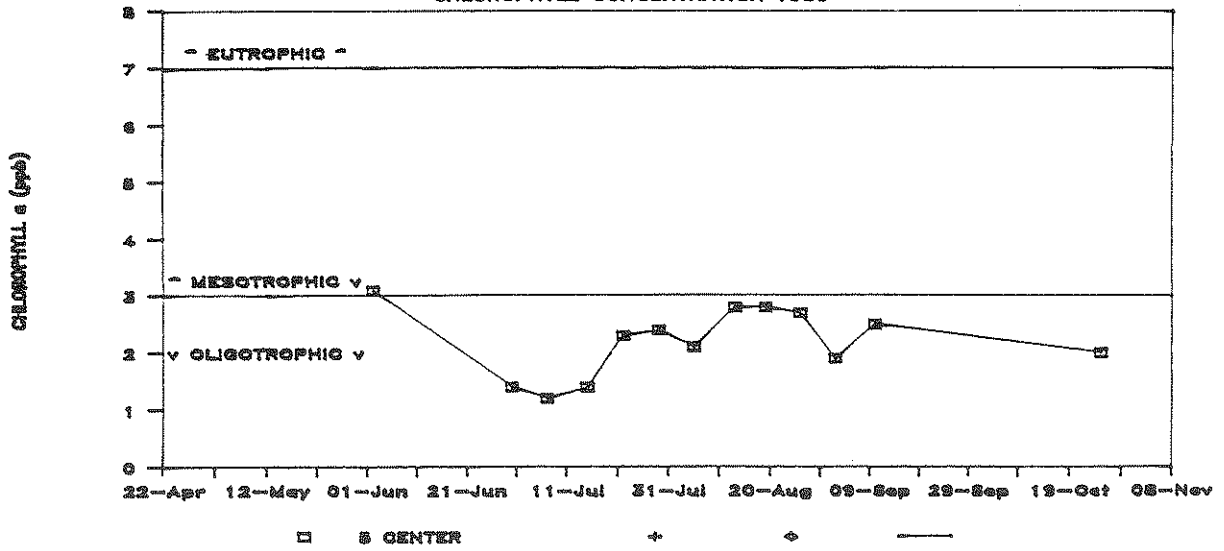
As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

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.

To assess the lake's health through the use of a **bio-indicator** such as fish, a substantial number of fish samples are required. Thus, it is important for **NH LLMP** participants interested in monitoring fish populations to provide at least 30 to 50 fish readings per species of fish. Many lakes have designated a separate coordinator for the fish condition program and have received participatory support from fishing clubs and bait and tackle shops. For more information on the NH LLMP Fish Condition Program call Kelly Gestring at 862-2100.

SUNSET LAKE
CHLOROPHYLL CONCENTRATION 1989

CHLOROPHYLL a (ppb)

- EUTROPHIC -

- MESOTROPHIC v

v OLIGOTROPHIC v

22-Apr 12-May 01-Jun 21-Jun 11-Jul 31-Jul 20-Aug 09-Sep 29-Sep 19-Oct 08-Nov

□   5 CENTER   +   ◇   ———

SUNSET LAKE
DISSOLVED COLOR 1989

DISSOLVED COLOR (pku)

1989 NH LLMP AVERAGE

22-Apr 12-May 01-Jun 21-Jun 11-Jul 31-Jul 20-Aug 09-Sep 29-Sep 19-Oct 08-Nov
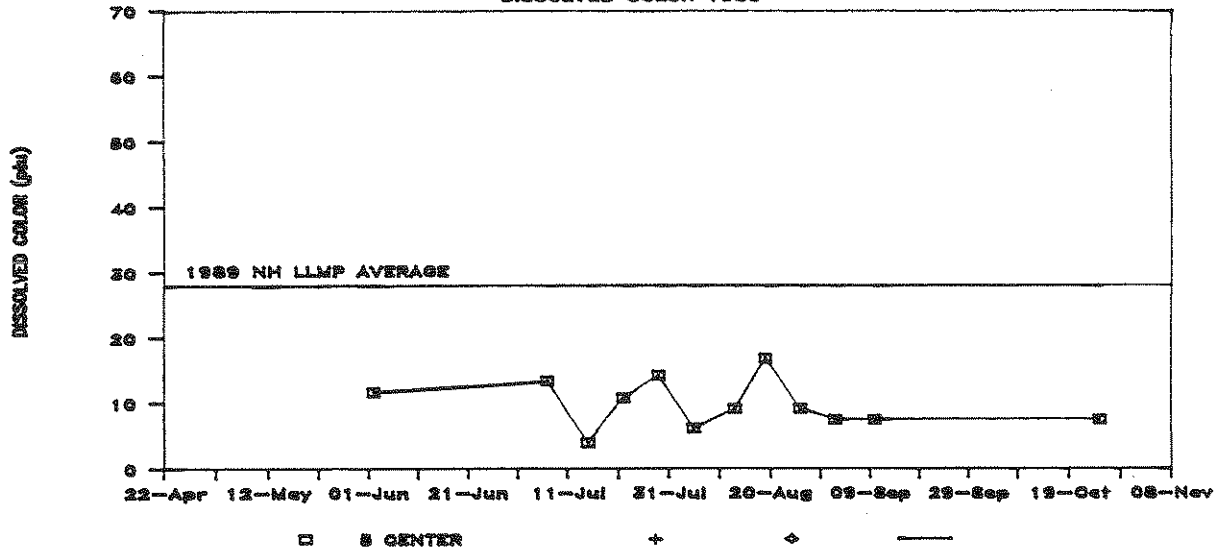
□   5 CENTER   +   ◇   ———

SUNSET LAKE 5 CENTER
SECCHI DISK TRANSPARENCY 1989

SECCHI DISK DEPTH (meters)

- EUTROPHIC -

- MESOTROPHIC v

v OLIGOTROPHIC v

22-Apr 12-May 01-Jun 21-Jun 11-Jul 31-Jul 20-Aug 09-Sep 29-Sep 19-Oct 08-Nov

DATE
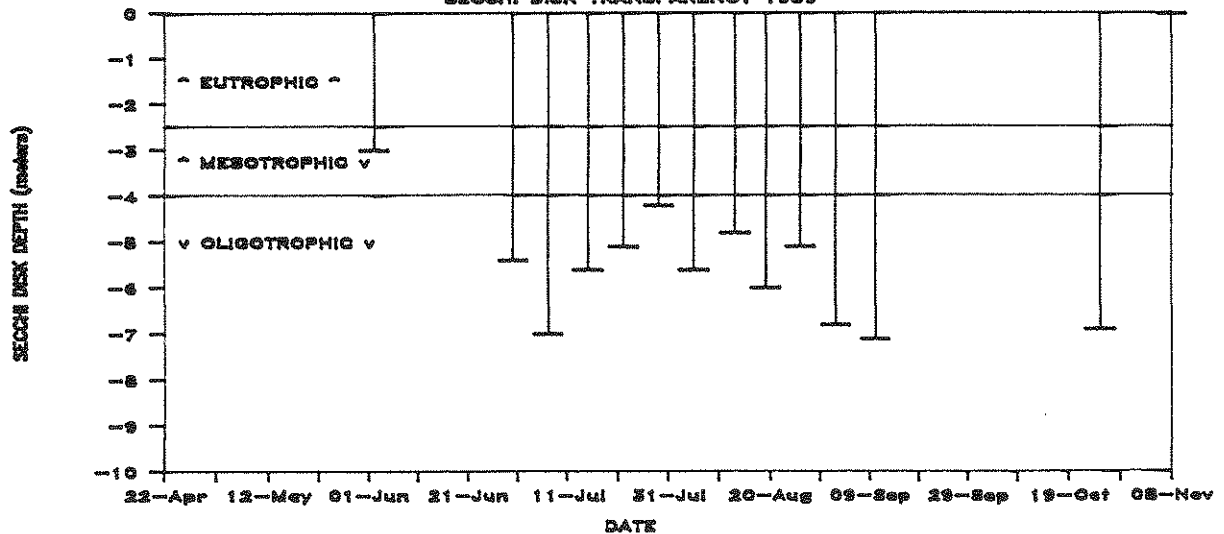
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Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

SUNSET LAKE, N.H.   -- subset of trophic indicators, all sites, 1989

1989 SUMMARY
Average transparency: 5.6   (1989:   13   values;   3.0 -   7.1 range)
Average chlorophyll: 2.2   (1989:   13   values;   1.2 -   3.1 range)
Average phosphorus: 6.6   (1989:   5   values;   2.2 -   17.4 range)
Average alk (gray):   13.5   (1989:   13   values;   12.6 -   14.5 range)
Average alk (pink):   14.1   (1989:   13   values;   13.3 -   15.4 range)
Average color, 440:   9.9   (1989:   12   values;   4.0 -   16.9 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
5 Center	06/02/1989	3.0	3.1	5.9	13.0	13.6	11.8
5 Center	06/30/1989	5.4	1.4	---	12.6	13.3	---
5 Center	07/07/1989	7.0	1.2	---	13.8	14.1	13.5
5 Center	07/15/1989	5.6	1.4	---	13.8	14.4	4.0
5 Center	07/22/1989	5.1	2.3	---	13.2	13.8	10.9
5 Center	07/29/1989	4.2	2.4	3.9	13.6	14.0	14.3
5 Center	08/05/1989	5.6	2.1	---	13.4	13.9	6.2
5 Center	08/13/1989	4.8	2.8	---	13.3	13.8	9.2
5 Center	08/19/1989	6.0	2.8	---	13.5	14.0	16.9
5 Center	08/26/1989	5.1	2.7	---	13.9	14.6	9.2
5 Center	09/02/1989	6.8	1.9	---	13.4	14.6	7.5
5 Center	09/10/1989	7.1	2.5	---	13.7	14.2	7.5
5 Center	10/25/1989	6.9	2.0	2.2	14.5	15.4	7.5
9.5	08/12/1989	---	---	17.4	---	---	---
Dam	07/06/1989	---	---	3.7	---	---	---

<< End of 1989 listing,   15   records >>

METHODS OF THE LAY MONITORS

Lay monitors receive their initial training either on-site or on campus from a member of the FBG. Workshops covering new techniques are usually offered on a yearly basis and updates may be held on-site during an FBG sampling trip.

This year data were collected on five parameters: thermal stratification, water clarity (secchi disk depth), total phosphorus, chlorophyll a concentration and dissolved color. Whenever possible, testing was done weekly between the hours of 9 am and 3 pm, the period of maximum sunlight penetration into the water. All samples and data were mailed or hand delivered to the FBG at UNH for analysis.

Thermal (temperature) profiles were obtained by collecting lakewater samples at several successive depths using a modified Meyer bottle (Lind, 1979). A weighted, stoppered, empty bottle was lowered to a specific depth. At that depth, the stopper was pulled, allowing the bottle to be filled with water. The bottle was quickly pulled back up to the surface where the temperature of the sample was taken with a Taylor pocket thermometer, and recorded in degrees C. This procedure was repeated at one meter intervals through the epilimnion (upper water column), at one-half meter intervals throughout the metalimnion (depths at which the temperature change is greater than 1 degree C per meter) and at one meter intervals through the hypolimnion (depths below the metalimnion). An alternative procedure uses an electronic thermocouple thermometer instead of the bottle and pocket thermometer to obtain the temperature profile.

Water clarity was measured by lowering a secchi disk (approximately 20 cm. or 8 inches) through the water off the shaded side of the boat, and noting the average of the depths at which it disappeared upon lowering and reappeared when being raised (the cord attached to the secchi disk is marked in one tenth of a meter for the first half

meter and in one-half meters thereafter). Water clarity was determined while holding a view-scope just below the surface to eliminate effects of surface reflection and wave action. This was repeated two or three times, and an average to the nearest one-tenth of a meter was recorded.

Chlorophyll a concentration was used as an index of algal biomass that is useful in determining the trophic state of the lake. A weighted plastic tube (10 meters in length) was lowered through the epilimnion to the top of the metalimnion (the depths of the epilimnion and metalinmion are determined from the temperature profile). The end of the tube above water is folded to shut off the water flow into or out of the tube. The weighted end of the tube is pulled up out of the water with an attached cord, trapping an integrated sample of water representing the "upper lake" in the tube. This sample is poured into a blue plastic 2.5 liter bottle and stored in the shade until chlorophyll filtration could be done.

Water samples for chlorophyll a filtration were filtered through a 0.45 micron membrane filter under low vacuum. Damp filters, containing chlorophyll-bearing algae, were air-dried for at least 1 hour, in the dark, to prevent decomposition or bleaching of the chlorophyll on the filter. These filters were sent to UNH where members of the FBG analyzed them for chlorophyll a (see Methods of the Freshwater Biology Group).

Dissolved water color was determined by saving the filtrate from the the chlorophyll filtration and storing it frozen in a 50 ml plastic bottle. The bottles were sent to UNH and the color was analyzed by the FBG team (see Methods of the Freshwater Biology Group).

METHODS OF THE FRESHWATER BIOLOGY GROUP

Laboratory Methods

Chlorophyll samples were filtered through a 0.45 micron membrane filter and air-dried in the dark until analysis. The chlorophyll a content was analyzed by extracting the chlorophyll with a 95% acetone solution saturated with magnesium carbonate. The samples were then centrifuged and their light absorbance read at two standard wavelengths (663 and 750 nanometers) with a Milton Roy model 1001+ spectrophotometer equipped with 50mm cuvettes. An absorptivity value of 84 gm liter^{-1} cm^{-1} (Vollenweider 1969) was used for calculating the concentrations.
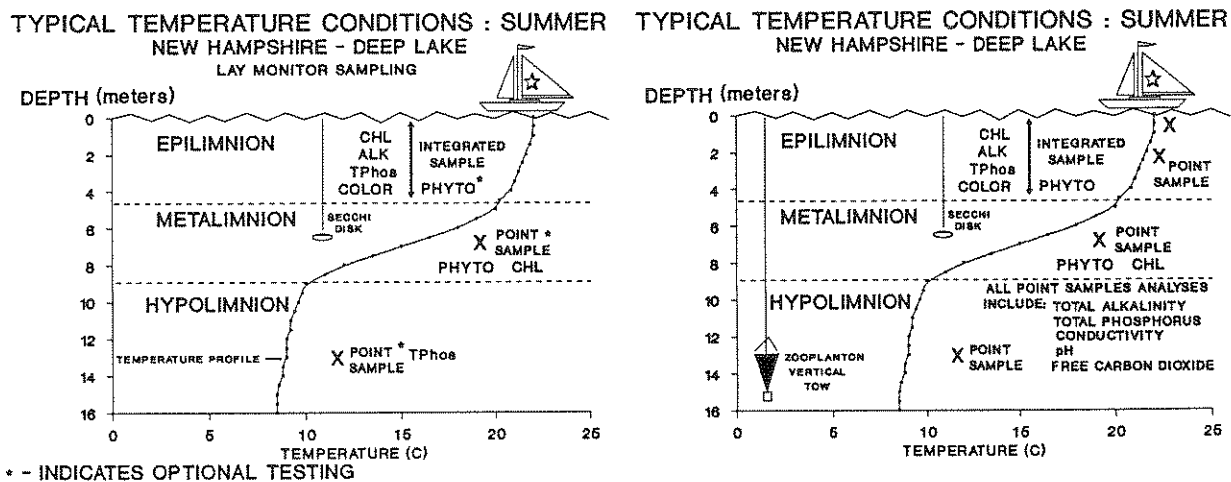
Dissolved color of the filtrate from chlorophyll filtrations was determined by reading the absorbance of the samples at two different wavelengths (440 and 493 nanometers) in a 50mm light path. The two readings were converted to the more widely used platinum cobalt color values with our standard curves of the absorbance of chloroplatinate.

Phosphorus samples were preserved with 1.0 milliliter of concentrated sulphuric acid and refrigerated until analysis. To determine the total phosphorus content, ammonium persulfate and 11 N sulphuric acid was added to digest the total phosphorus, and the samples were autoclaved for thirty minutes at 120 to 130 degrees C. Reagents included potassium antimony tartrate, ammonium molybdate, and a solution of ascorbic acid mixed fresh before each sample run (APHA 1985, EPA 1979). Absorbance of the blue phosphorus complex was measured with the spectrophotometer at 660 nanometers. A standard curve of the absorbance of a potassium phosphate (monobasic) solution was used to convert the readings to total phosphorus concentrations. Each sample was analyzed twice and an average of the two values was recorded as the phosphorus content in parts per billion (ppb).

Data Analysis

All field and laboratory data was filed and stored on the FBG computerized data management system that utilizes a mainframe DEC VAX-8650 computer and an IBM compatible micro-computer (Zenith Data Systems 158). With full use of relational data bases, such as S1032 and Dbase III+, data can be retrieved easily by date, station, or by parameter for within-lake comparison, or between-lake comparisons with other lake data bases (Lakes Lay Monitoring Program, New Hampshire Water Supply and Pollution Control, N.H. Fish and Game, EPA Surface Water Survey and others). Spreadsheet, statistics and graphics packages on both the mainframe and micro-computer enable data analysis and presentation.

Trophic boundaries of Forsberg and Ryding (1980) of transparency, chlorophyll a, and total phosphorus are used as criteria in discussions of the trophic state of the lakes. Phytoplankton are reported both as species and classes. Crustacean zooplankton were identified to genus or species and classified into one of four categories depending on their size (large or small) and their feeding preferences (herbivore or predator) with a modified version of criteria from Sprules (1980). The differences in abundance between the different groups allow for a more complete description of the zooplankton community and the trophic classification of lakes.

TYPICAL TEMPERATURE CONDITIONS : SUMMER
NEW HAMPSHIRE – DEEP LAKE
LAY MONITOR SAMPLING

* – INDICATES OPTIONAL TESTING

TYPICAL TEMPERATURE CONDITIONS : SUMMER
NEW HAMPSHIRE – DEEP LAKE

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 euthrophy is low Secchi disk depth, high chlorophyll a, and low 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 repiration, 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 nearlu 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, lochs, 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 <u>a</u> 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.

<u>Overturn</u>-   See circulation or mixis

<u>pH</u>-   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.

<u>Photosynthesis</u>-   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.

<u>Phytoplankton</u>-   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.

<u>Parts per million</u>-   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.

<u>Parts per billion</u>-   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!

<u>Plankton</u>-   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" (mocrocrustaceans and rotifers).

<u>Saturated</u>-   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.

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

<u>Stratum</u>-   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.

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

<u>Thermocline</u>- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissoved), 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.

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)