# NEWFOUND LAKE

# LAKES LAY MONITORING PROGRAM

# 1986

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

by

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LAKES LAY MONITORING PROGRAM

To obtain more information about the Lakes Lay Monitoring Program (LLMP) contact the LLMP Coordinator (J. Schloss) at (603) 862-3848, Dr. Baker at 862-3845 or Dr. Haney at 862-2106.

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## ACKNOWLEDGEMENTS

This was the first year of participation in the Lakes Lay Monitoring Program (**LLMP**) for the Newfound Lake Region Association. Lay Monitors were Peter Brown, Milt Radimer, Ken O'Neil, Ann Worthen, George Park, Verna Spaeth, and Gwyn Linton. The Freshwater Biology Group (**FBG**) congratulates the monitors on the quality of their work, and the time and effort put fourth. We would also like to acknowledge Peter Brown for his dedication to the organization and maintenance of the **LLMP** for the lake. We encourage these and other interested members of the Newfound Lake Region Association to continue monitoring during the 1987 season.

The Freshwater Biology Group (**FBG**) is co-supervised by Dr. Alan Baker and Dr. James Haney. Members of the **FBG** summer field team included Tracy Kenealy, Jeff Schloss, Patricia McCarthy, Lori Sommer, Steve Thomas and Zhanyang Guo. Tracy and Jeff shared coordination of the program and were responsible for arranging the field trips, training lay monitors, and supervising the research team. Patricia and Lori were responsible for the preparation of chemical solutions, chlorophyll analysis and data entry. Steve was responsible for phosphorus chemistry and analysis. All team members participated in field work and chemical analyses. In the fall, Alice Hibberd assisted in data organization and data entry and Jeff continued as **LLMP** Coordinator responsible for data interpretation and report writing.

The **FBG** would like to thank the University of New Hampshire Undesignated Gifts Committee for the partial funding of the coordinator position. Eileen Wong of the Department Zoology provided accounting and secretarial service. The Department of Botany and Plant Pathology provided lab and storage space. We would also like to recognize the UNH Office of Computer Services for the provision of computer time and data storage space.

Participating groups in the **LLMP** for 1986 included: The New Hampshire Audubon Society, Derry Conservation Commission, 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 associations of Baboosic Lake, Beaver Lake, Berry Bay, Bow Lake Camp Owners, Lake Chocorua, Flint Pond, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Scruton Pond, Silver Lake (Hollis), Silver Lake (Madison), Squam Lake, Sunset Lake, Lake Winona, and Lake Wentworth and the towns of Hollis and Stratham.

# COMMENTS AND RECOMMENDATIONS

1) We recommend that each association, including the Newfound Lake Association continue to develop their 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 eventually will enable more reliable predictions of water quality trends.

2) We suggest that lay monitors initiate dissolved color testing on a weekly basis. There is no aditional expense for this test. It requires the collection of filtrate from the chlorophyll processing, in small bottles that will be provided. The Freshwater Biology Group will analyse the filtrate spectrophotometrically.

3) Shallow secchi disk readings after severe precipitation events suggest that silt from construction site washouts directly caused low transparency. The association might want to survey the lakeshore for open sites and ask contractors or developers to try to use methods that restrict sediment and soil loss. The monitors can locate problem areas next season by taking a series of secchi disk measurements around the lake after a storm. This is a good, low cost method for preliminary investigations.

4) Weekly alkalinity measurements at both sites is important because the lake has low alkalinity. The 1986 data suggest that alkalinity is lower at the northern end of the lake.

5) We recommend the initiation of total phosphorus testing as early as possible after spring melt. Early spring phosphorus data combined with summer sampling can provide information on the amount and sources of phosphrus loading into the lake.

6) The **FBG** trip provided a more in-depth analysis of the lake during early stratification conditions. We recommend two trips or, if limited to one, that it take place mid- or late summer to provide information on conditions after the lake has been stratified for a longer period of time. This will also allow sampling of the metalimnion of the lake to see if any stratification of blue-green bacteria is present. The trip also showed that the data the lay monitors are collecting compares well to data collected by the **FBG**.

7) As a general addition to our Lakes Lay Monitoring Program, we recommend that each lake in the Program begin monitoring the condition of the fish taken from the lake. The "Fish Monitoring" will require at least one lay monitor to record the species, length and weight and collect a sample of fish scales for each fish examined. In most lakes this will involve periodic creel census of sport fishermen on the lake. The required equipment, supplies and

analitical costs will be approximately $100. Explaination of procedures and fish identification will be given to monitors who decide to measure this parameter.

Length-to-weight ratios give a measure of the nutritional condition of the fish. Age analysis of the fish scales (to be done at UNH) will tell how old each fish is. Together, these variables can help to track changes in the condition of the fish populations in the lake, and, of course, the "health" of the lake.

Since Newfound lake has both warm water and cold water fish populations, the fish indexing could provide needed data on both communities. It could also involve more residents in the monitoring program.

# PROGRAM DESCRIPTION

## The Lakes Lay Monitoring Program

The New Hampshire Lakes Lay Monitoring Program (**LLMP**) is a research and educational function of the Freshwater Biology Group (**FBG**) at the University of New Hampshire co-directed by Professors Alan Baker, Department of Botany and Plant Pathology, and James Haney, Department of Zoology and coordinated by Jeffrey Schloss. The program involves the cooperative participation of lake residents, lake associations, conservation and planning commissions and local governments with University faculty and students. Developed in 1978 around Squam Lake, the program has grown to include more than 30 lakes throughout New Hampshire.

As a **research** project, the LLMP has investigated the extent of lake degradation caused by perturbations such as acid rain, septic and agricultural runoff, and lakeshore development. Essentially the monitors in the program collect data once each week. The data are stored on a computer, the results are analyzed periodically, and interpretive reports are written that include graphics and statistical analyses. A major goal is to detect any short or long-term changes in the water quality of the lakes. To that end a long-term data base has been established.

As an **educational** tool, several students are trained each year to collect and analyze lakewater samples for physical, chemical and biological parameters, and to interpret water quality data. In addition, more than 200 "lay" monitors have been trained to monitor their own lakes and educated about lake water quality.

As a **service** to the state and to local communities, the reports of the **LLMP** are available at cost, and should prove useful to lake residents, conservationists, developers and land-use planners. Also, **LLMP** staff members conduct workshops, lectures and informal talks on various lake related topics and hold advisory positions on many municipal and private conservation and planning boards. The **LLMP** is a not-for-profit organization with funding derived primarily from the participating groups.

# INTRODUCTION

## Importance of long term monitoring

A major goal of this program is to identify any short or long-term changes in the water quality of the lakes. Of major concern, is the detection of cultural eutrophication; increases in the productivity of the lake 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 since New Hampshire receives large amounts of acid precipitation. Weekly sampling of a lake during a single summer provides information only on the variation that occurs. Short-term differences may be due to variations in weather or lake activity, or other chance events. The resulting short-term fluctuations may be unrelated to the actual long-term trend.

As an example, a 30 year study of a lake may indicate a long-term trend toward eutrophy (Fig. 1). Yet if only the data from a five year period (ie: Fig 1, years 1975-80) are examined, no apparent trends can be seen. If only two years are examined, the data suggest a decrease in eutrophy! Monitoring carried out weekly 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, each lake must establish a long-term data base.

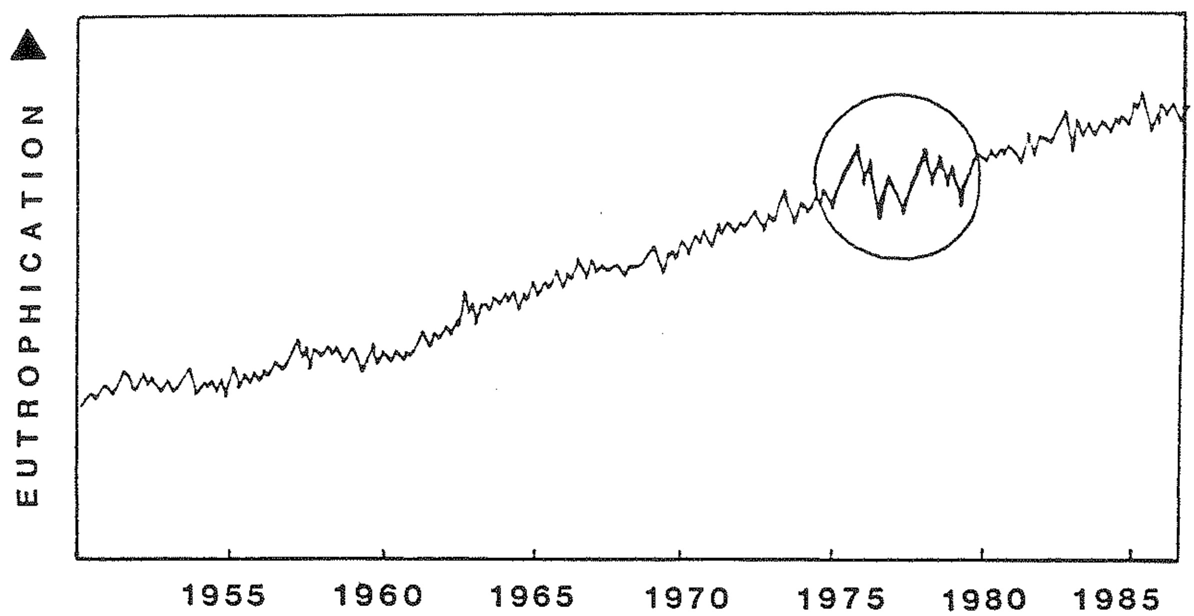



Figure 1. Eutrophication of a hypothetical lake over time. Circled area is enlarged for comparison between short and long-term trends.

The number of seasons it takes to discern 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. 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 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. 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.

Every data sheet the **LLMP** receives is significant to further the understanding of the lakes in the program. We are pleased with the interest and commitment of our lay monitors and are proud that their work is what makes the **LLMP** the most extensive, and we believe, the best volunteer program of its kind.

# METHODS OF 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 six parameters: thermal stratification, water clarity (secchi disk depth), chlorophyll a concentration, total phosphorus, specific conductivity and dissolved water 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, empty bottle with a stopper 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 Celsius. 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 Celsius per meter) and at one meter intervals through the hypolimnion (depths below the metalimnion).

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. Damp filters, containing chlorophyll-bearing algae, were air-dried for at least 15 minutes, 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).

To determine the alkalinity, a two-endpoint titration using the indicator methyl red/bromocresol green was done with 0.002 N sulfuric acid to a pH of 5.1 (grey) and 4.5 (pink). The amount of titrant used (dilute sulfuric acid) was recorded to the nearest 0.1 ml, representing the equivalent milligrams of calcium carbonate per liter.

Samples for total phosphorus analysis were collected in two ways. For determination of epilimnetic phosphorus, water was taken from the integrated sample collected with the tube-sampler. On parts of the lake where it was suspected that phosphorus might be high (ie: sites along the shoreline, inlets or outlets), sub-surface samples were taken by dipping a bottle into the water and letting it fill. All samples were collected in acid-washed 250 ml bottles, fixed with 1.0 ml of concentrated sulfuric acid, and stored frozen until analysis by the FBG team. (see Methods of the Freshwater Biology Group).

# METHODS OF THE FRESHWATER BIOLOGY GROUP

The Freshwater Biology Group (**FBG**) research team took 1 trip to Newfound Lake and conducted several tests which included measurements of sunlight penetration into the water, dissolved oxygen, alkalinity, free (unbound) carbon dioxide, pH, specific conductivity, chlorophyll a, dissolved color, total phosphorus, and a survey of the microscopic plants (phytoplankton) and animals (zooplankton) present. The **FBG** also processed chlorophyll a, and phosphorus samples provided by the lay monitors. The input, storage and analysis of all **LLMP** data is also the responsibility of the **FBG**.

## Field and Laboratory Methods

On the lake, a dissolved oxygen and temperature profile was taken using a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at one-meter intervals throughout the epilimnion and hypolimnion, and at one-half meter intervals through the metalimnion.

Sunlight and skylight penetration into the water was measured with a Whitney submersible photometer model LMA-8A, off the sunny side of the boat. From the relative light intensities which were recorded, the coefficient of light extinction was later determined.

Samples for water chemistry (dissolved oxygen, alkalinity, free (unbound) carbon dioxide, pH, and specific conductivity) were collected with a 3-liter Van Dorn bottle at depths which represented the surface, mid-epilimnion, metalimnion, and hypolimnion. Alkalinity, free carbon dioxide, and pH samples were stored on ice in 250 milliliter polyethylene bottles and were analyzed in the field within 1 to 2 hours of sampling. Specific conductivity samples were analyzed in the FBG lab at room temperature.

In addition to the oxygen profile taken, the dissolved oxygen (DO) concentration of specific lakewater samples (epilimnetic and hypolimnetic) were determined chemically using the Winkler method with the azide modification for dissolved oxygen (EPA 1979). The precision of the method allows us to to check the accuracy of the electronic probe, so that adjustments could be made in the probe readings if necessary. In the Winkler method, water is collected in 350 ml biological oxygen demand (BOD) bottles and fixed with manganese sulfate and alkali-iodine-azide. A loose precipitate (floc) of manganous hydroxide is formed that will absorb any dissolved oxygen present. The sample is then acidified with concentrated sulfuric acid in the presence of of iodide, and iodine is released in a quantity equal to the amount of dissolved oxygen present. A known quantity of sample is then titrated to an equivalence point using .0250N phenylarsine oxide titrant and a starch indicator solution.

To determine the alkalinity, a two-endpoint titration using the indicator methyl red/bromocresol green was done with 0.002 N sulfuric acid to a pH of 5.1 (grey) and 4.5 (pink). The amount of titrant used (dilute sulfuric acid) was recorded to the nearest 0.1 ml, representing the equivalent milligrams of calcium carbonate per liter.

Free carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N Sodium Hydroxide to a final pH of 8.3, using the dye phenolphthalein as the end-point indicator.

Lakewater pH was measured with a digital pH meter (Beckman model phi 44 ) equipped with a combination probe (Orion Co.) and an automatic temperature compensating probe.

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB , with a model B-10 probe (cell constant = 1.0). Corrections were made for sample temperatures with a standard curve of potassium chloride solution conductivity vs temperature. Results are reported as micro-Siemens (uS; where 1 uS equals 1 umho $cm^{-2}$) standardized to $18^{o}$ Centigrade.

Samples to be analyzed for chlorophyll a, total phosphorus, and phytoplankton were collected with a vertical tube sampler into a 2.5 liter dark plastic bottle. 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). An absorptivity value of 84 gm liter$^{-1}$ cm$^{-1}$ (Vollenweider 1969) was used for calculating the concentrations.

Dissolved color samples of the filtrate from **FBG** and lay monitor chlorophyll filtrations was determined by reading the absorbance of the samples at two different wavelengths (440 and 493 nanometers). The two readings were converted to the more widely used platinum cobalt color values (ptu) using standard curves of the absorbance of chloroplatinate.

Phosphorus samples were fixed with 1.0 milliliter of concentrated sulfuric acid and stored refrigerated until analysis. Also, phosphorus samples from lay monitors were received by the **FBG** in a refrigerated or frozen state, and stored cold until analysis. To determine the total phosphorus content, ammonium persulfate and 11 N sulfuric acid was added to digest the total phosphorus, and the samples were autoclaved for one hour. A double reagent method was employed using potassium antimony tartrate, ammonium molybdate, and a fresh solution of ascorbic acid (E.P.A. 1979). Absorbance of the blue phosphorus complex was measured with a spectrophotometer at 650 nanometers. A standard curve of the absorbance of a potassium phosphate (monobasic) solution to convert the readings to total phosphorus concentrations. Each sample was analyzed twice and an average of the two values taken as the phosphorus content in parts per billion.

Phytoplankton samples were fixed with iodine (Lugol's solution) immediately after collection. The preserved samples were later counted with an inverted microscope after settling for 24 hours in counting chambers. At least 200 individual algal "units" were counted with a modified scan technique (Baker, 1973).

Zooplankton samples were collected with a plankton net (30 centimeter diameter, 150 micron porosity) towed vertically through the oxygenated portion of the water (>0.5 ppm oxygen). Samples were immediately preserved in a 4% formalin-sucrose solution (Haney and Hall, 1973). Organisms were keyed to species whenever possible. Subsampling, whenever necessary, was done with a 1 ml Hensen-Stemple pipette. Repeated subsamples were analyzed until at least 100 zooplankters were counted.

Crustacean zooplankton were classified into one of four categories depending on their size (large or small) and their feeding preferences (herbivore or predator) using a modified version of criteria from Sprules (1980). The differences in abundance between the different groups allow for a more standardized description of the crustacean zooplankton community and may be helpful in trophic classification of lakes.

## Data analysis

Incoming data are received through the mail during the sampling season and are first filed in an "incoming data" book. This provides temporary storage until the corresponding chlorophyll and/or phosphorus sample for each data sheet is analyzed. All data, including date, lake, site, secchi disk depth, chlorophyll a and phosphorus content, alkalinity, and color measurements, are filed and stored on a computerized data-management system of the University of New Hampshire. Data can be easily retrieved by lake, sampling station or date, and used for individual reports and for each year.

Statistical treatment of the data from each lake, produced for level III reports, includes a comparison of seasonal tendencies found throughout the year, monthly means for the different parameters tested, and confidence levels for each site. The same comparisons are made on a yearly basis if the lake has been in the program for two years or more. Where sufficient data are available from several years, regression analyses and other statistical tests are performed. Such analyses may identify trends and help explain variations in the data (eg. secchi disk depth, chlorophyll a, color). In addition, data is compared with other lakes in the program and to published water quality classifications. Trophic boundaries of Forsberg and Ryding (1980) are used to classify each lake.

## RESULTS AND DISCUSSION OF LAY MONITOR DATA

Monitoring of Newfound Lake was done at two locations, site 2 Mayhew with a maximum depth of about 18 meters and site 3 Pasquaney with a maximum depth of 20 meters. This year, sampling for temperature, secchi disk depth, chlorophyll a, and alkalinity took place weekly from 26 June through 2 September. Another site, 1 Deep (maximum depth of 54 meters) was sampled on 26 June. See figure 2 for the sampling site locations and tributary phosphorus sites, and Appendix A for the 1985-86 Lay Monitor data.

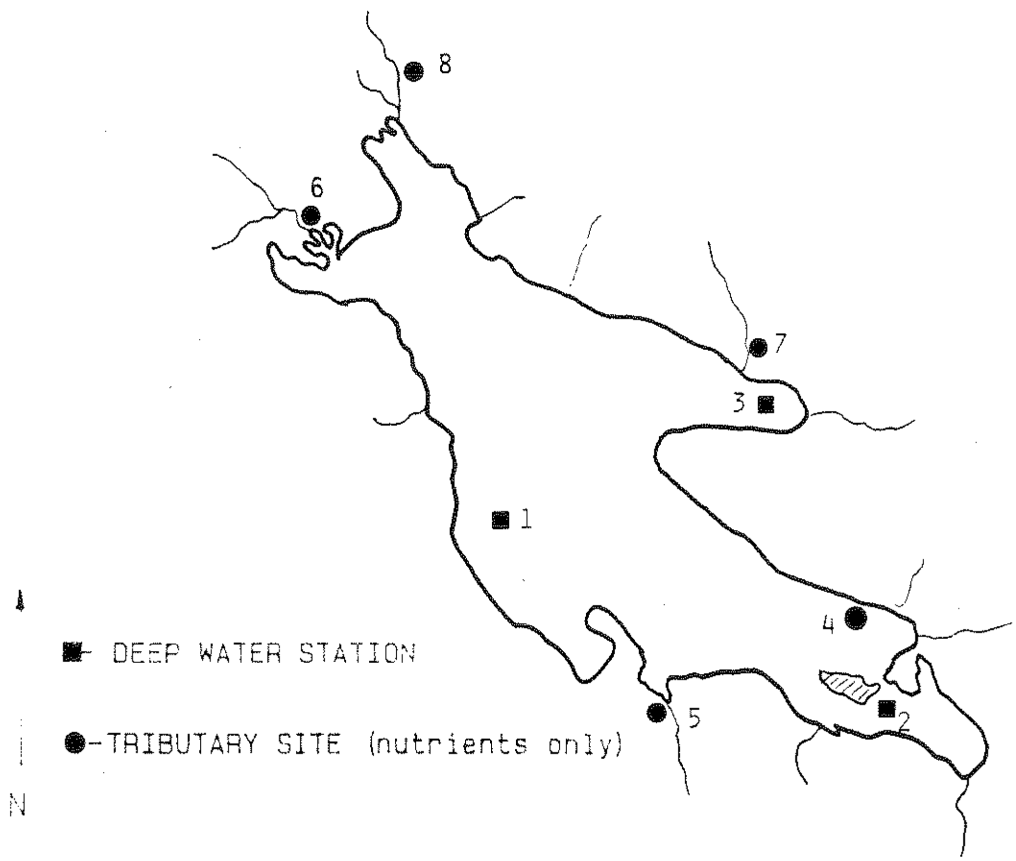



Figure 2. Location of sampling sites on Newfound Lake, Grafton County, New Hampshire.

**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. An average secchi disk depth greater than 4.0 meters generally indicates a clear lake.

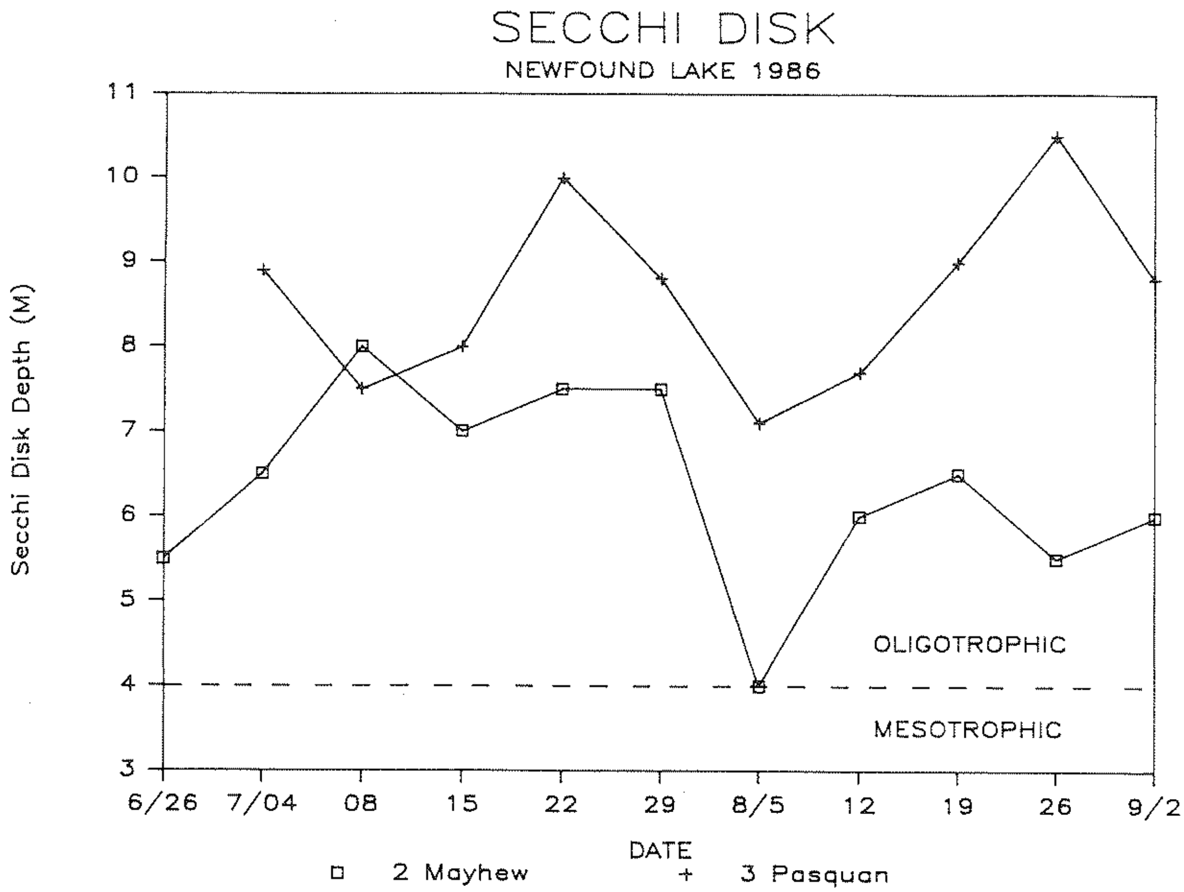
Generally Newfound Lake has a high water transparency. The average secchi disk depth at 3 Pasquaney was 8.6 meters with a range of 7.1 to 10.5 meters. This site had the highest transparency values measured in all the **LLMP** lakes for the months of July (10.0 meters) and August (10.5 meters). Site 2 Mayhew had lower transparency values with an average of 6.4 meters and a range of 4.0 to 8.0 meters. The minimum secchi disk depths (indicating low transparency) for both sites occurred 5 August, after a large storm event that lasted about 3 weeks. Monitors reported that there were large amounts of sediments in the waters possibly coming into the lake from construction site washouts. Secchi disk depth fluctuated throughout the sampling season and no distinct seasonal trends at either site are apparent (see Fig.3).

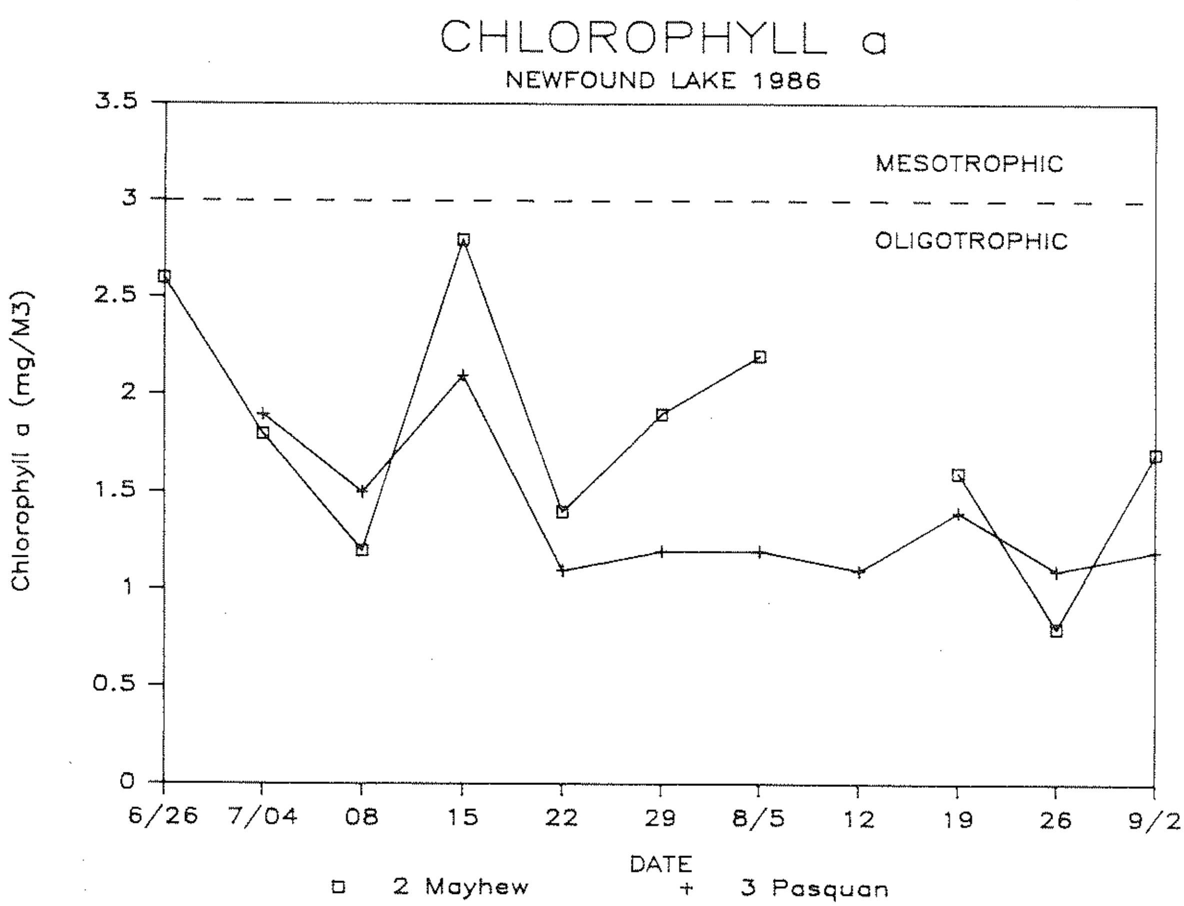
## Chlorophyll *a*

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 amounts of algae and aquatic plants due to nutrient enrichment. **Oligotrophic** lakes have low productivity and low nutrient levels and **mesotrophic** lakes are intermediate in productivity.

The average chlorophyll *a* concentration at 2 Mayhew was 1.8 mg $m^{-3}$ with a range of 0.8 to 2.8 mg $m^{-3}$. Concentrations at 3 Pasquaney were slightly lower averaging 1.4 mg $m^{-3}$ with a range of 1.1 to 2.1 mg $m^{-3}$. The average chlorophyll *a* concentration for all lakes in the **LLMP** in 1986 was 2.0 mg $m^{-3}$ with a range of 0.5 to 19.7 mg $m^{-3}$. As with secchi disk depth, concentrations of chlorophyll fluctuated throughout the summer but the pattern of weekly change is similar between sites (Fig. 3). The chlorophyll concentrations at both sites fell within the range of oligotrophic lakes although concentrations approached mesotrophic levels at Mayhew on 26 June and 15 August. That there is no consistent relationship between weekly values of chlorophyll and the water transparency supports the observation discussed above that suspended sediment was an important factor affecting the water transparency of Newfound Lake this year.

**Figure 3**- Seasonal trends for Secchi Disk depth and Chlorophyll _a_ at Newfound Lake sites 2 Mayhew (squares) and 3 Pasquaney (crosses) determined from the lay monitor data. Dotted lines on the plots border the ranges common to oligotrophic and mesotrophic lakes.


SECCHI DISK
NEWFOUND LAKE 1986
Secchi Disk Depth (M)
11
10
9
8
7
6
5
4
3
OLIGOTROPHIC
MESOTROPHIC
6/26
7/04
08
15
22
29
8/5
12
19
26
9/2
DATE
2 Mayhew
3 Pasquan


CHLOROPHYLL a
NEWFOUND LAKE 1986
Chlorophyll a (mg/M3)
3.5
3
2.5
2
1.5
1
0.5
0
MESOTROPHIC
OLIGOTROPHIC
6/26
7/04
08
15
22
29
8/5
12
19
26
9/2
DATE
2 Mayhew
3 Pasquan

## RESULTS AND DISCUSSION OF FBG DATA

Chlorophyll a and water transparency values measured during the **FBG** field team visit on 18 June at site 1 Deep compare well with the lay monitor results from the same site on 26 June (Table 1).

Table 1. **COMPARISON OF FBG AND LAY MONITOR RESULTS**

| Site/Date/Group | Secchi Disk | Chlorophyll |
|---|---|---|
| **1 Deep** 18 JUNE **FBG** | 9.1m | 1.7 mg $m^{-3}$ |
| **1 Deep** 26 JUNE **Lay Monitor** | 9.0 | 1.9 |

### pH

The pH reflects the acidity of the lake water as measured by the hydrogen ion concentration. The scale ranges from 1 to 14 and is logarithmic (ie: changes in 1 pH unit reflect a 10 time change in hydrogen ion concentration) and inverse, so a pH of 1 reflects high acidity, a pH of 7 indicates neutrality and a pH of 14 indicates an extremely basic condition. Most aquatic organisms can only tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Surface pH at Newfound Lake was 7.1 to 7.2, within the upper range of all **LLMP** lakes. The range of surface water pH for all **LLMP** lakes was 5.2 to 7.2.. The pH values at site 1 Deep decreased with depth to a minimum of 6.3 at 20 meters as would be expected in a lake with higher $CO_2$ concentrations in the lower waters (see Fig. 4). Presently the pH throughout the whole water column is well above levels which damage fish condition 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 of lake watersheds.

The epilimnetic alkalinity at site 1 Deep was 2.5 mg $CaCO_3$ liter$^{-1}$ . Lay monitor alkalinity testing at sites Mayhew and Pasquaney yielded average values of 3.6 and 1.5 mg liter$^{-1}$ respectively. These results suggest that Newfound Lake alkalinities increase as the water moves from the north to the south. All three averages are low and below the New Hampshire state average of 9.0 mg liter$^{-1}$. The average alkalinity of all **LLMP** lakes in 1986 was 6.8 mg liter$^{-1}$ with a range of 0.7 to 14.7 mg liter$^{-1}$. The low buffering capacity in Newfound Lake indicates that changes in pH will occur more readily during spring melt and precipitation events.

## Dissolved Color

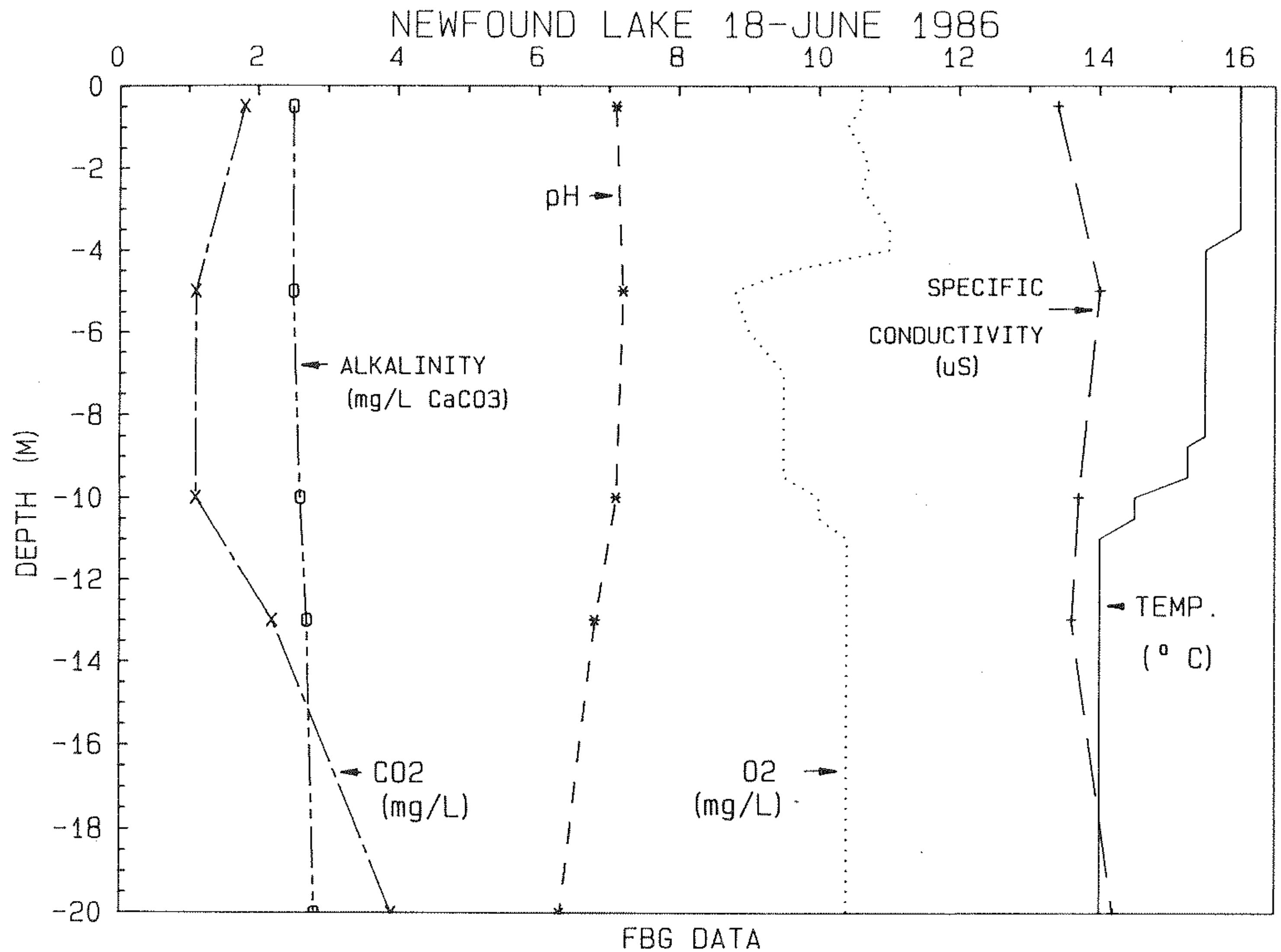
The dissolved color of lakes is generally due to dissolved organic matter from humic substances (a natural polyphenolic breakdown product from decayed vegetation) and from plants within and surrounding the lake. Highly colored or "stained" lakes have a brown color.

The dissolved color in Newfound Lake is very low with a value of less than 1 ptu. The average dissolved color in **LLMP** lakes this year was 19 ptu with a range of less than 1 to 117 ptu. The low color of the water along with low chlorophyll concentrations is responsible for the high water transparency of the lake.

## Dissolved Oxygen and Temperature

Profiles of temperature and dissolved oxygen for the Deep site indicate multiple stratifications were starting to form in the lake (Fig. 4). A thermocline was developing from 9 to 11 meters and there seemed to be a temperature discontinuity forming around 4 meters. High winds made staying on station for the profile difficult and the roughness of the thermocline and the discontinuity may just be a result of the probe not being at the indicated depth. More importantly, the dissolved oxygen profile indicates a

**Figure 4-** Profiles of temperature, dissolved oxygen, free carbon dioxide, total alkalinity, pH, and specific conductivity at Newfound Lake on 18 June 1986. Units of measurement are as indicated. Temperature and oxygen was measured continuously at 0.25, 0.5 or 1 meter intervals. The other parameters were sampled at discrete depths of 0.5, 5.0, 10.0, 13.0 and 20.0 meters.


NEWFOUND LAKE 18-JUNE 1986
DEPTH (M)
0
2
4
6
8
10
12
14
16
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
ALKALINITY
(mg/L CaCO3)
CO2
(mg/L)
pH
O2
(mg/L)
SPECIFIC
CONDUCTIVITY
(uS)
TEMP.
(° C)
FBG DATA

good supply of oxygen in the lake all the way down to the bottom. This is important for the lake in many ways. The cold water fish species such as trout and salmon which are found in the deeper waters require high levels of oxygen to develop and reproduce. Oxygen in the lower waters also allows for more efficient decomposition processes to occur and prevents the accumulation of large amounts of organic matter. Oxygen over the bottom sediments also allows for the complexing of excessive nutrients to the lake bottom. As the summer progresses the oxygen in the bottom waters will decrease. To what extent this occurs at Newfound Lake is not presently known.

## Free Carbon Dioxide

Carbon dioxide is generated and can accumulate in aquatic systems as a result of the respiration of a wide variety of organisms in the water. Plants (including the phytoplankton) take up free carbon dioxide during the day but respire at night along with the aquatic animals and bacteria. Carbon dioxide usually accumulates in the bottom waters of productive systems where large amounts of organic material, produced within and around the lake, support large bacterial respiration and fermentation. Breakdown of organic matter by the bacteria in the water and sediments consumes oxygen and releases carbon dioxide. Increases in dissolved carbon dioxide result in decreses of the lakewater pH.

The concentration of free carbon dioxide in Newfound Lake had a range of 1.8 mg $liter^{-1}$ at the surface to 3.9 mg $liter^{-1}$ at 20 meters at the Deep site (note the relationship between pH and $CO_2$ discussed above and shown in Fig. 3). These values are low and common to clear, oligotrophic lakes with low productivity.

## Specific Conductivity

Surface and deep water conductivity at site 1 Deep were very low with a range of 13.4 uS to 14.2 uS. The average conductivity for all of the **LLMP** lakes was 88 uS with a range of 13.4 to 249.3 uS. Low conductivity suggests that there is no direct sewage input and there is minimal effect of de-icing salt runoff from the roads near this site.

## Total Phosphorus

The **FBG** sampled four sites for phosphorus on 18 June and the lay monitors sampled four sites in August with the following results:

**TABLE 2**- Total Phosphorus Concentration (ppb) for Newfound Lake
Numbers in parentheses indicate site location (See Fig. 2)

| DATE | SITE | TP | DATE | SITE | TP |
|---|---|---|---|---|---|
| 18 June | 1 Deep | 11.0 | 5 Aug | Fowler River(5) | 1.7 |
| 18 June | 2 Mayhew | 9.5 | 27 Aug | Cockermouth R.(6) | 2.4 |
| 18 June | Lovejoy Pt (4) | 8.5 | 27 Aug | Whitmore Brook(7) | 1.4 |
| 18 June | Fowler R. Marina(5) | 11.5 | 27 Aug | Georges Brook(8) | 8.4 |

Most lakes receive the highest input of phosphorus and other nutrients after spring melt which means higher values should occur early in the season. Higher values later in the season might indicate nutrient input from cultural sources. All of the values above are within the average range for oligotrophic lakes (less than 15 ppb). Higher values at Georges Brook might indicate some nutrient loading occurring in that area.

**Phytoplankton**

Counts from site 1 Deep of the integrated sample 0 to 9.5 meters indicate a concentration of 4032 cells per milliliter (ml). Although the cell number are moderate, about 1500 cells per ml were of the very small blue green bacteria Aphanothecae so counts still indicate low phytoplankton productivity. No other nuisance forms of phytoplankton were present in the sample. Historical data on Newfound Lake has suggested an occasional presence of a dense population of phytoplankton occurring at the thermocline. The high numbers of Aphanothecae might have resulted from sampling too far down into the metalimnion where these organisms can occur in higher numbers. Future sampling on the lake should include a further investigation into this possibility.

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# Appendix A

Data Listing

## Lay Monitor Data

| SITE | DA | SDD | CHL | ALK_GRAY | ALK_PINK |
|---|---|---|---|---|---|
| 1 Deep | 06/26/1986 | 9.0 | 1.9 | --- | --- |
| 2 Mayhew | 06/26/1986 | 5.5 | 2.6 | --- | --- |
| 2 Mayhew | 07/04/1986 | 6.5 | 1.8 | --- | --- |
| 2 Mayhew | 07/08/1986 | 8.0 | 1.2 | --- | --- |
| 2 Mayhew | 07/15/1986 | 7.0 | 2.8 | --- | --- |
| 2 Mayhew | 07/22/1986 | 7.5 | 1.4 | --- | --- |
| 2 Mayhew | 07/29/1986 | 7.5 | 1.9 | 3.1 | 3.3 |
| 2 Mayhew | 08/05/1986 | 4.0 | 2.2 | 3.0 | 3.4 |
| 2 Mayhew | 08/12/1986 | 6.0 | --- | 3.1 | 3.6 |
| 2 Mayhew | 08/19/1986 | 6.5 | 1.6 | 3.0 | 3.2 |
| 2 Mayhew | 08/26/1986 | 5.5 | 0.8 | 3.6 | 4.6 |
| 2 Mayhew | 09/02/1986 | 6.0 | 1.7 | 3.1 | 3.4 |
| 3 Pasquan | 07/04/1986 | 8.9 | 1.9 | --- | --- |
| 3 Pasquan | 07/09/1986 | 7.5 | 1.5 | --- | --- |
| 3 Pasquan | 07/16/1986 | 8.0 | 2.1 | --- | --- |
| 3 Pasquan | 07/22/1986 | 10.0 | 1.1 | --- | --- |
| 3 Pasquan | 07/29/1986 | 8.8 | 1.2 | --- | --- |
| 3 Pasquan | 08/06/1986 | 7.1 | 1.2 | --- | --- |
| 3 Pasquan | 08/13/1986 | 7.7 | 1.1 | 1.5 | 1.7 |
| 3 Pasquan | 08/19/1986 | 9.0 | 1.4 | 1.7 | 2.4 |
| 3 Pasquan | 08/26/1986 | 10.5 | 1.1 | 1.4 | 2.1 |
| 3 Pasquan | 09/02/1986 | 8.8 | 1.2 | 1.3 | 1.8 |

## FBG Data

| SITE | DA | SDD_METERS | CHL_PPB | TP_PPB | COLOR(ptu) |
|---|---|---|---|---|---|
| 1 Deep | 06/18/1986 | 9.1 | 1.7 | 11.0 | <1 |