SUNSET LAKE

LAKES LAY MONITORING PROGRAM

1987

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

by

Jeffrey A. Schloss

Coauthored and edited by

A.L. Baker J.F. Haney

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.

PREFACE

This report contains the findings of a water quality survey of Sunset Lake, New Hampshire, conducted jointly by the Freshwater Biology Group (FBG) of the University of New Hampshire and the Sunset Lake Association in the summer of 1987.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1987 results an "Introduction" to explain the program philosophy and a brief explanation of the various water quality tests that are taken. The description of methods and materials used by the lay monitors and the Freshwater Biology Group has been included in an appendix. While it is common practice to exclude this type of section from a "general" writing such as this, it is our goal to provide the association with a complete report which can stand on its own for comparison to past as well as future lake studies.

This is a Level I program report with a data listing and a brief summary. A more extensive report (Level II or III) is recommended after the lake has participated in the program for five years. While not generally included in reports of this level, some graphic data display has been included in the appendix to aid visual perspective. In addition, listings of data with statistical summaries appear in appendices. 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.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This was the fourth year of participation in the Lakes Lay Monitoring Program (**LLMP**) for the Sunset Lake Association. The Lay Monitors were Ralph Green and Woodbury Roderick. The Freshwater Biology Group (**FBG**) congratulates the monitors on the quality of his work, and the time and effort put forth. We encourage other interested members of the Sunset Lake Association to continue monitoring during the 1988 season. We also thank Ralph Green for the maintenance of the LLMP for Sunset Lake.

The Freshwater Biology Group (**FBG**) is co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included Jeff Schloss, Leanne Hussey Doerthe Fuhlendorf, Paul Schofield and Camilla Girgus. Jeff was responsible for arranging the field trips, training lay monitors, supervising the research team, data interpretation and report writing. Leanne and Camilla were responsible for the preparation of chemical solutions, chlorophyll analysis, and data entry. Paul was responsible for phosphorus chemistry and analysis. All team members participated in field work and chemical analyses. In the fall, Elizabeth Ferrari assisted in sample processing, data organization and data entry, Dan Helsel processed phosphorus samples and Annette Grace counted zooplankton and assisted the coordinator. The **FBG** also acknowledges Ann Meade for her time volunteered.

The **FBG** would like to thank the Institute for Marine Science and Ocean Engineering of the University of New Hampshire for the partial funding of the coordinator position. Eileen Wong of the Department Zoology provided accounting and secretarial service. The College of Life Science and Agriculture provided lab and storage facilities. 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 1987 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, Big Island Pond, Bow Lake Camp Owners, Lake Chocorua, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Mendum's Pond, Merrymeeting Lake, Moultonbouro Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pleasant Lake, Silver Lake (Madison), Squam Lake, Sunset Lake, Lake Winona, and Wentworth Lake and the towns of Alton, Amherst, Hollis, Merrimack and Strafford.

NON-TECHNICAL SUMMARY

As in previous years the general water quality of Sunset Lake was good.

1) Water transparency at the deep sites of the lake, measured by secchi disk was high, a sign of a clear, unproductive lake. The secchi disk was visible as far down as 6.8 meters (22 feet). This indicates the deepwater site on the lake is usually low in dissolved color and suspended matter such as algae and particulates. The transparency average in 1987 (5.2 meters) was slightly lower than the previous year sampled but greater than 1984 and 1985 averages. 1987 Transparency had a range of 2.6 to 6.8 meters. The very low transparency in the early season was most likely due to a flood event which caused a large amount of runoff into the lake.

2) Chlorophyll a concentrations for the surface waters of the deep site of Sunset Lake were low and similar to levels measured for previous years. Chlorophyll levels indicate the extent of algae growth in the water. Concentrations in the mixed layer of water (the upper 3.5 to 5 meters) averaged 1.5 milligrams per cubic meter (mg m^{-3}, equivalent to 1.5 parts chlorophyll per billion parts water). Generally, concentrations below 3 mg m^{-3} are indicative of less productive, clear lakes. Chlorophyll concentration approached more productive levels in early June, most likely due to nutrient loading from the flooding.

3) Total phosphorus (nutrient) levels were high early in the season. On 24 August site 5 had phosphorus concentrations above the 15 parts per billion (ppb) level, commonly thought of as the boundary between less productive and more productive lakes. Levels did drop as the summer progressed.

4) The total alkalinity, the lakes ability to buffer acid input, remains high. Last year alkalinity values averaged 0.5 alkalinity units (milligrams of calcium carbonate) higher. The alkalinity of Sunset Lake is almost twice the average of all program lakes in 1987. With higher buffering capacity, Sunset Lake is not subject to pH stress from acid precipitation or during spring melt when acid loading is high.

COMMENTS AND RECOMMENDATIONS

1) We recommend that each association, including the Sunset 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) As we approach our tenth year in this cooperative lake monitoring effort we are expanding our program options with the help of a one time allocation from the state legislature. Some older equipment will be replaced and new equipment will include rain monitors and fish condition indexing kits. These materials will be provided at no cost to the association. The association should begin to look for interested members who would like participate in these studies.

3) We recommend the continuation of alkalinity testing in 1988. Alkalinity indicates the ability of water to buffer acids, and may be more reliable than pH in predicting the effects of acidification on a lake. It is important to establish a data base for alkalinity in order to detect changes as early as possible.

INTRODUCTION

General Overview

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. 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 50 lakes throughout New Hampshire.

As a long-term research project, the LLMP is investigating the extent of lake degradation caused by perturbations such as acid rain, septic and agricultural runoff, and lakeshore development. Essentially, the volunteer 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. The long-term data base permits the detection of both short and long-term changes of the water quality of the lakes. Results from the program are presented at national and international meetings and published in international journals.

As part of its commitment to education through the University, the LLMP trains several undergraduate and graduate students each year to collect and analyze lakewater samples for physical, chemical and biological parameters, and to interpret water quality data. In addition, more than 350 "lay" monitors have been educated about lake water quality and trained to monitor their own lakes.

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 and support services provided by the University.

Program Philosophy

Frequent sampling over many years is required to resolve long-term trends and make predictions on the water quality of our lakes. Consider the hypothetical lake in Figure 1. Sampling only once a year during June from 1975 to 1981 would produce a plot (Fig. 1A) suggesting a decrease in eutrophication (the "greening" of a lake). The actual long-term trend of the lake, increasing eutrophy, can only be clearly discerned by sampling more frequently for a longer period (Fig. 1B). 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"). Intensive sampling of a number of lakes requires more labor than state agencies or universities are able to provide. Based on this premise, with much encouragement from lake associations within the state, the LLMP was conceived in 1978 and initiated in 1979.

The "grass roots approach" to volunteer water quality monitoring is readily apparent upon examination of a typical LLMP sampling kit. The quality of work that can be achieved with equipment constructed from wire, a wine or beer bottle, coffee cans, garden hose and yards of clothes-line has surprised even the most skeptical. These monitoring tools are fun to use and far less intimidating than expensive and complicated scientific apparatus. More importantly, all of the various LLMP sampling kits necessary for the monitoring of a lake can be made for less than the price of a commercially made water sampler.

A major factor in the continued success of our volunteer monitoring program is open communication between the lay monitors and the program staff. Monitors send samples and data sheets to the University on a weekly basis. Each lake has a contact person to coordinate monitoring and act as a liaison between monitors and the FBG. The FBG field team visits each full program lake at least once each summer to collect corroborative data and perform additional analyses. The site visits, along with yearly meetings/workshops held at the university, provide the monitors with program updates and allow for feedback on all aspects of the program.

The quality of work from the volunteers and the lack of constraints from outside sources enables the lay monitors to conduct a wide range of water quality tests (See Figure 2 for a breakdown of basic and optional testing by the lay monitors and the sampling conducted by the FBG field team). Expanded testing and surveys allow for a better understanding of the dynamic inter-relationships of the components of a lake system. Thus, the program provides the necessary information for the intelligent management of our lake resources at minimum cost.

Though not the first volunteer monitoring program, nor the largest in number of volunteers or lakes participating, the LLMP is the most extensive and diverse program of its kind. Through the commitment and enthusiasm of all participants the program is also one of the most long-lived, approaching ten years of operation.

EXPLANATION OF WATER TESTS

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. Secchi disk depths greater than 4 meters are typical of clear, less productive lakes. In 1987 values of water transparency at LLMP lakes were in the range 2.5 to 12 meters with a weighted average (by lake) of 6.4 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. Summer chlorophyll a concentrations average above 7 mg m^{-3} (one milligram per liter is equivalent to 1 part 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}. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll a generally between 3 mg m^{-3} and 7 mg m^{-3}. In 1987 chlorophyll a concentrations in LLMP lakes were in the range 0.1 to 7.1 mg m^{-3} with a weighted average (by lake) of 1.5 mg m^{-3}.

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. Color is commonly expressed in units of a platinum color standard (ptu). To put the color concentrations in perspective, New Hampshire Lakes studied in 1987 by the Freshwater Biology Group had a range of dissolved color of from essentially 0 ptu to 137 ptu with an unweighted average of 17 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 primarily originate from anthropogenic 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.

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 average alkalinity of New Hampshire lakes is approximately 9 mg $CaCO_3$ $liter^{-1}$ while the 1987 average alkalinity of all LLMP lakes was 6 mg $CaCO_3$ $liter^{-1}$.

pH

The pH is a way of expressing the acidic level of lake water, and is 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 an order of magnitude, ie: 10 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.

Specific Conductivity

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and de-icing salt runoff from highways can cause high conductivity values.

Stratification in the Deep Water Sites

Profiles of temperature for the deep sites studied generally show a distinct pattern of temperature stratification where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions is characterized by a sharp drop in temperature with depth and is called the **thermocline** or **metalimnion.**

Dissolved Oxygen and Free CO2

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 in the cool deep waters. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

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 and produce oxygen during the day, but respire at night along with the aquatic animals and bacteria. Carbon dioxide usually accumulates in the bottom waters of more productive systems where large amounts of organic material, produced within and around the lake, support large bacterial populations. Breakdown of organic matter, respiration and fermentation, by the bacteria in the water and sediments, consumes oxygen and releases carbon dioxide. Increases in dissolved carbon dioxide result in the decrease of the lakewater pH.

REFERENCES

American Public Health Association.(APHA) 1985. Standard Methods for the Examination of Water and Wastewater 16th edition. APHA, AWWA, WPCF. Washington, D.C.

Baker, A.L. 1973. Microstratification of phytoplankton in selected Minnesota lakes. Ph. D. thesis, University of Minnesota.

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-379.

Edmondson, W.T. 1937. Food conditions in some New Hampshire lakes. In: Biological survey of the Androscoggin, Saco and coastal watersheds. (Report of E.E. Hoover.) New Hampshire Fish and Game Commission, Concord, New Hampshire.

Forsberg, C. and S.O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish wastewater receiving lakes. Arch. Hydrobiol. 89:189-207

Gallup, D.N. 1969. Zooplankton distributions and zooplankton-phytoplankton relationships in a mesotrophic lake. Ph.D. Thesis, University of New Hampshire.

Haney, J.F. and D.J. Hall. 1973. Sugar-coated Daphnia: a preservation technique for Cladocera. Limnol. Oceanogr. 18:331-333.

Hoover, E.E. 1936. Preliminary biological survey of some New Hampshire lakes. Survey report no. 1. New Hampshire Fish and Game Department, Concord, New Hampshire.

Hoover, E.E. 1937. Biological survey of the Androscoggin, Saco, and coastal watersheds. Survey report no. 2. New Hampshire Fish and Game Department, Concord, New Hampshire.

Hoover, E.E. 1938. Biological Survey of the Merrimack watershed. Survey report no. 3. New Hampshire Fish and Game Department, Concord, New Hampshire.

Hutchinson, G.E. 1967. A treatise on limnology, vol. 2. John Wiley and Sons, New York.

Lind, O.T. 1979. Handbook of common methods in limnology. C.V. Mosby, St. Louis.

Lorenzen, M.W. 1980. Use of chlorophyll-Secchi disk relationships. Limnol. Oceanogr. 25:371-372.

New Hampshire Water Supply and Pollution Control Commission. 1981. Classification and priority listing of New Hampshire lakes. Staff report no. 121. Concord, New Hampshire.

Newell, A.E. 1970. Biological survey of the lakes and ponds in Cheshire, Hillsborough and Rockingham Counties. Survey report no. 8c. New Hampshire Fish and Game Department, Concord, New Hampshire.

Newell, A.E. 1972. Biological survey of the lakes and ponds in Coos, Grafton and Carroll Counties. Survey report no. 8a. New Hampshire Fish and Game Department, Concord, New Hampshire.

Newell, A.E. 1977. Biological survey of the lakes and ponds in Sullivan, Merrimack, Belknap and Strafford Counties. Survey report no. 8b. New Hampshire Fish and Game Department, Concord, New Hampshire.

Schindler, D.W., et al. 1985. Long-term ecosystem stress: Effects of years of experimental acidification on a small lake. Science. 228:1395-1400.

Sprules, W.G. 1980. Zoogeographic patterns in size structure of zooplankton communities with possible applications to lake ecosystem modeling and management. in W.C. Kerfoot ed. Evolution and Ecology of Zooplankton Communities. University Press of New England. Dartmouth. pp642-656.

U.S. Environmental Protection Agency. 1979. A manual of methods for chemical analysis of water and wastes. Office of Technology Transfer, Cincinnati. PA-600/4-79-020.

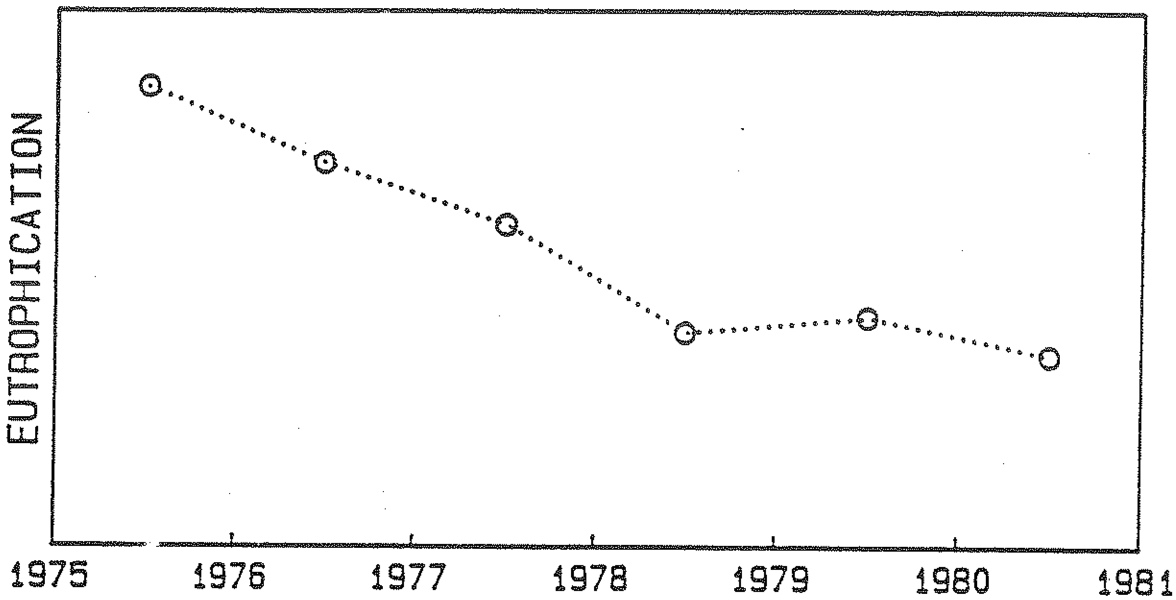
Vollenweider, R.A. 1969. A manual on methods for measuring primary productivity in aquatic environments. International Biological Programme. Blackwell Scientific Publications, Oxford.

Wetzel, R.G. 1983. Limnology. Saunders College Publishing, Philadelphia.

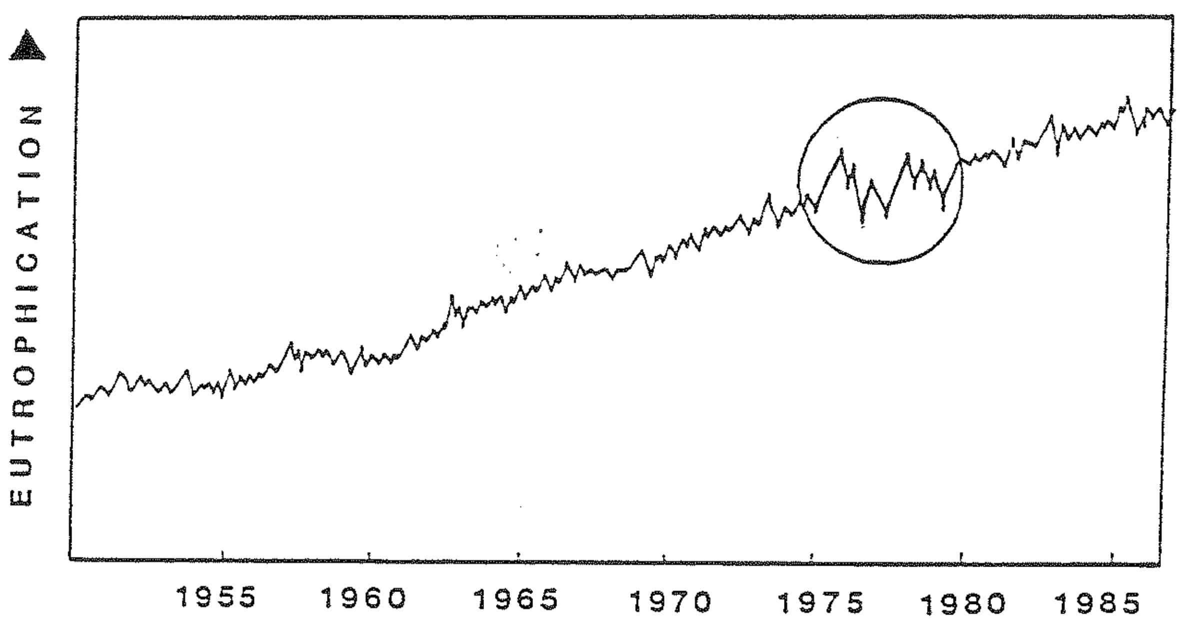
FIGURES

Figure 1. Hypothetical example where a limited sampling of a lake can be very deceptive. The upper graph (A) depicts the results of sampling only once a year in June. The indicated trend seems to be that of decreasing eutrophy. However, weekly sampling of the same lake over a longer period of time would produce the lower graph (B). The actual long-term trend is that of increasing eutrophy. The circled area in the lower graph is an enlargement of the data-set used to produce the upper graph.

RESOLUTION OF LONG-TERM TREND



A



B

Figure 2. Diagram indicating the water quality parameters tested by participants in the New Hampshire Lakes Lay Monitoring Program. Sampling is conducted by two groups: Volunteer monitors and the Freshwater Biology Group summer field team. Each test is coded as to the type of sample collected and which group does the processing (see key).

LAKES LAY MONITORING PROGRAM - PARAMETERS SAMPLED

LAY MONITORS

BASIC PROGRAM

- SECCHI DISK TRANSPARENCY
- TEMPERATURE PROFILE
- CHLOROPHYLL a *^{I}
- DISSOLVED COLOR *^{I,T}

ADVANCED OPTIONS

- TOTAL PHOSPHORUS *^{I,T}
- TOTAL ALKALINITY ^{I,T}
- pH ^{I,T}
- METALIMNETIC CHLOROPHYLL a *^{P}
- FISH CONDITION
  - Length/Weight Index
  - Age Classification *
- MOTORBOAT EFFECTS
- AQUATIC VEGETATION SURVEY

DATA CORROBORATION ⟷ (Lay Monitors: SECCHI DISK TRANSPARENCY through METALIMNETIC CHLOROPHYLL a; Freshwater Biology Group: SECCHI DISK TRANSPARENCY through pH)

FRESHWATER BIOLOGY GROUP

- SECCHI DISK TRANSPARENCY
- TEMPERATURE PROFILE
- CHLOROPHYLL a ^{I}
- DISSOLVED COLOR ^{I,T}
- TOTAL PHOSPHORUS ^{I,P,T}
- TOTAL ALKALINITY ^{I,M,T}
- pH ^{I,M,T}
- METALIMNETIC CHLOROPHYLL a ^{P}
- UNDERWATER LIGHT PROFILE
- DISSOLVED OXYGEN PROFILE
- FREE CARBON DIOXIDE ^{M}
- SPECIFIC CONDUCTIVITY ^{M,T}
- PHYTOPLANKTON ^{I,M}
- ZOOPLANKTON ^{V}
- ^BACTERIA ^{P,T}
  - Total Coliform
  - Fecal Coliform
  - Fecal Strep.
- ^FISH CONDITION
- ^AQUATIC VEGETATION SURVEY

KEY

*- Sample collected by Lay Monitor, processed by FBG.

I- Integrated epilimnetic sample.

P- Point sample, single depth.

M- Point samples, multiple depths.

T- Tributary samples.

V- Vertical tow through oxygenated depths.

^- Optional parameters, sampled if requested.

Figure 3. - Seasonal trends for secchi disk depth (water transparency) for sites 6 Center Sunset Lake. Solid lines on the plots border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

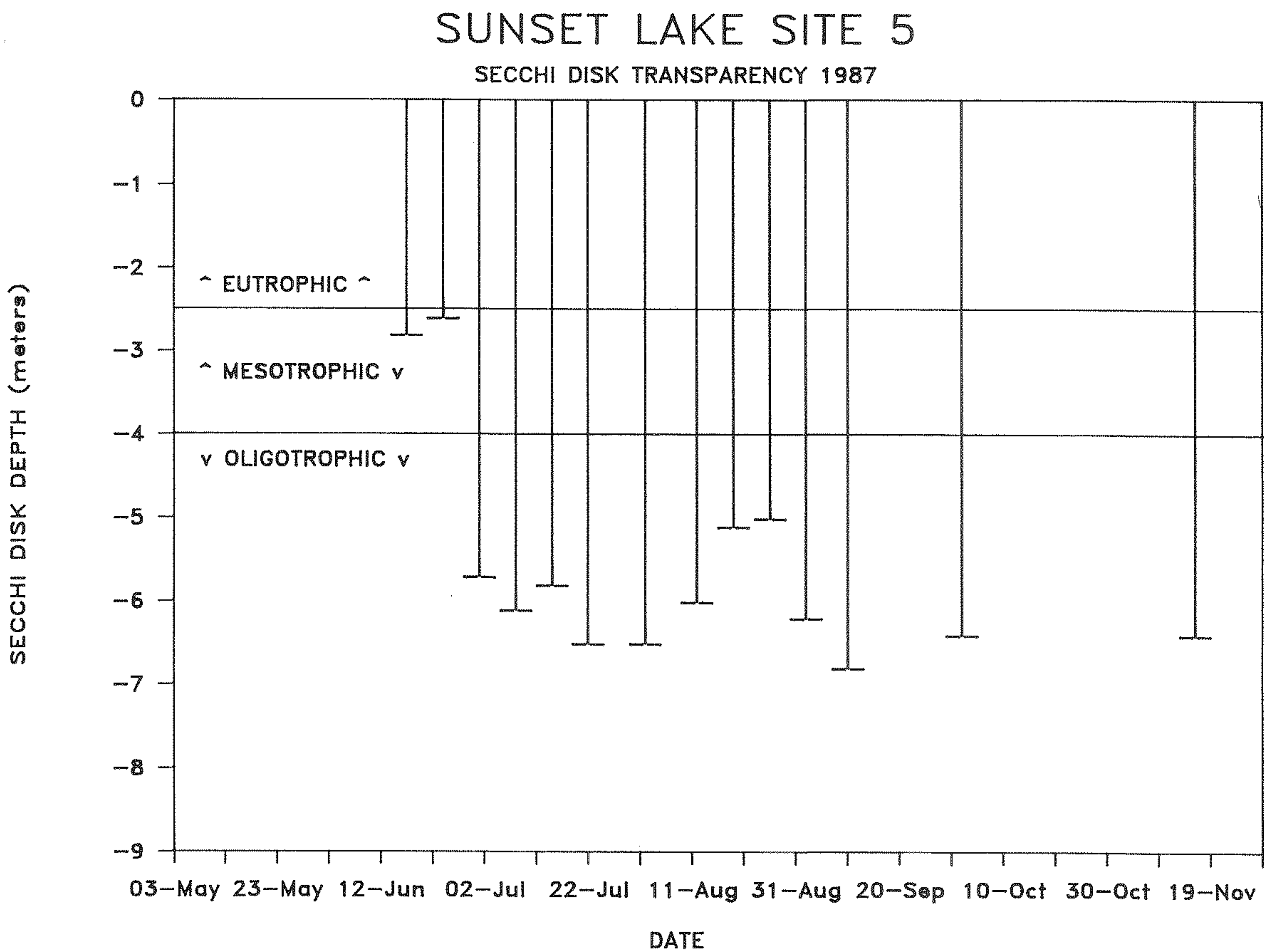
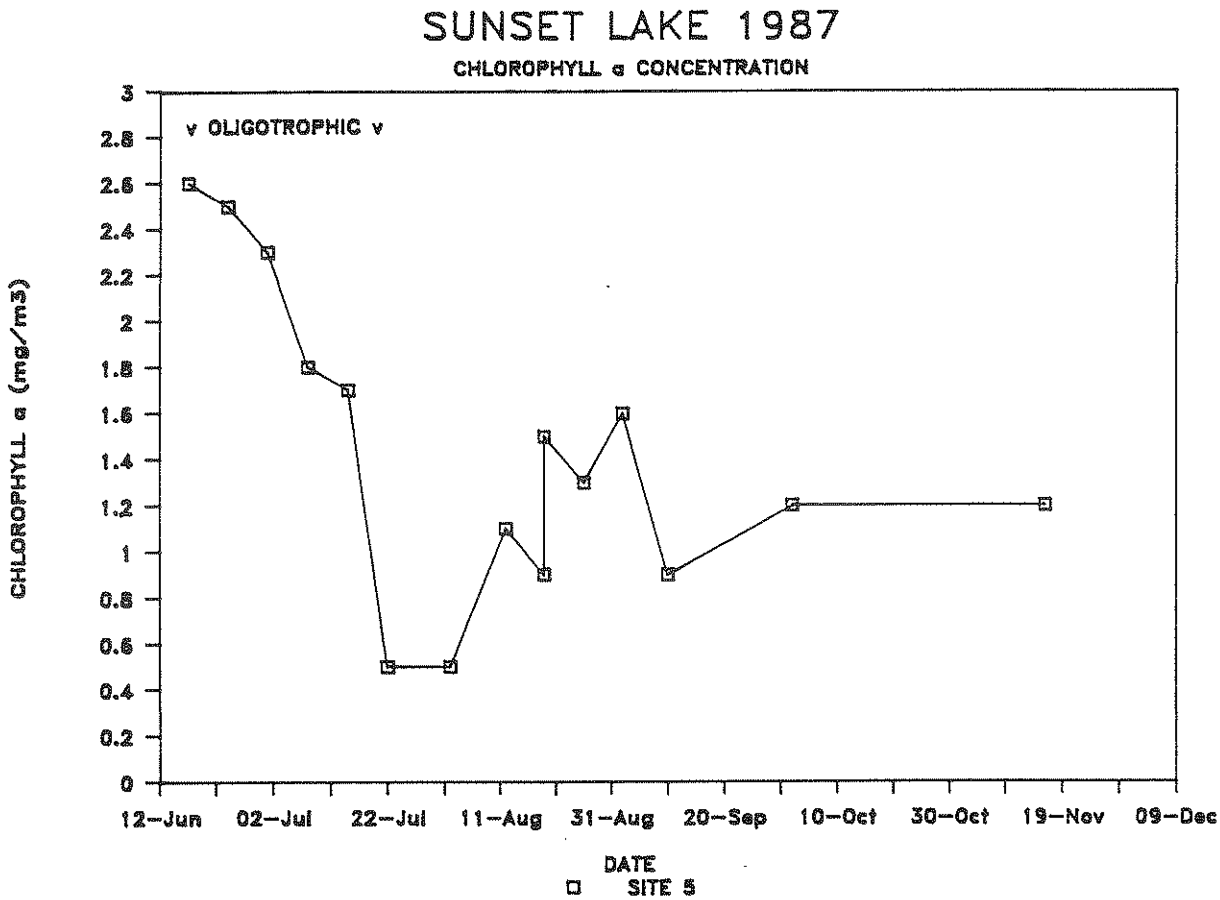
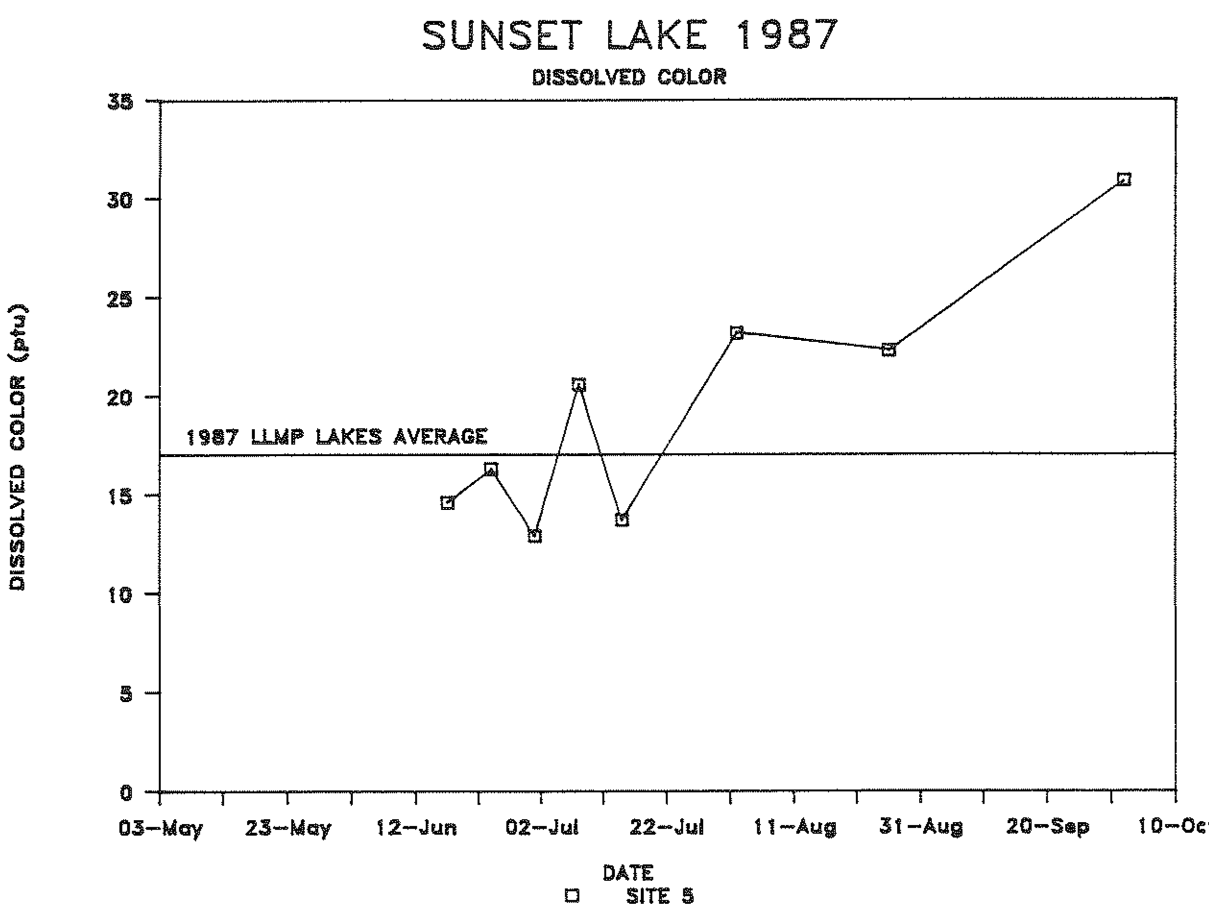
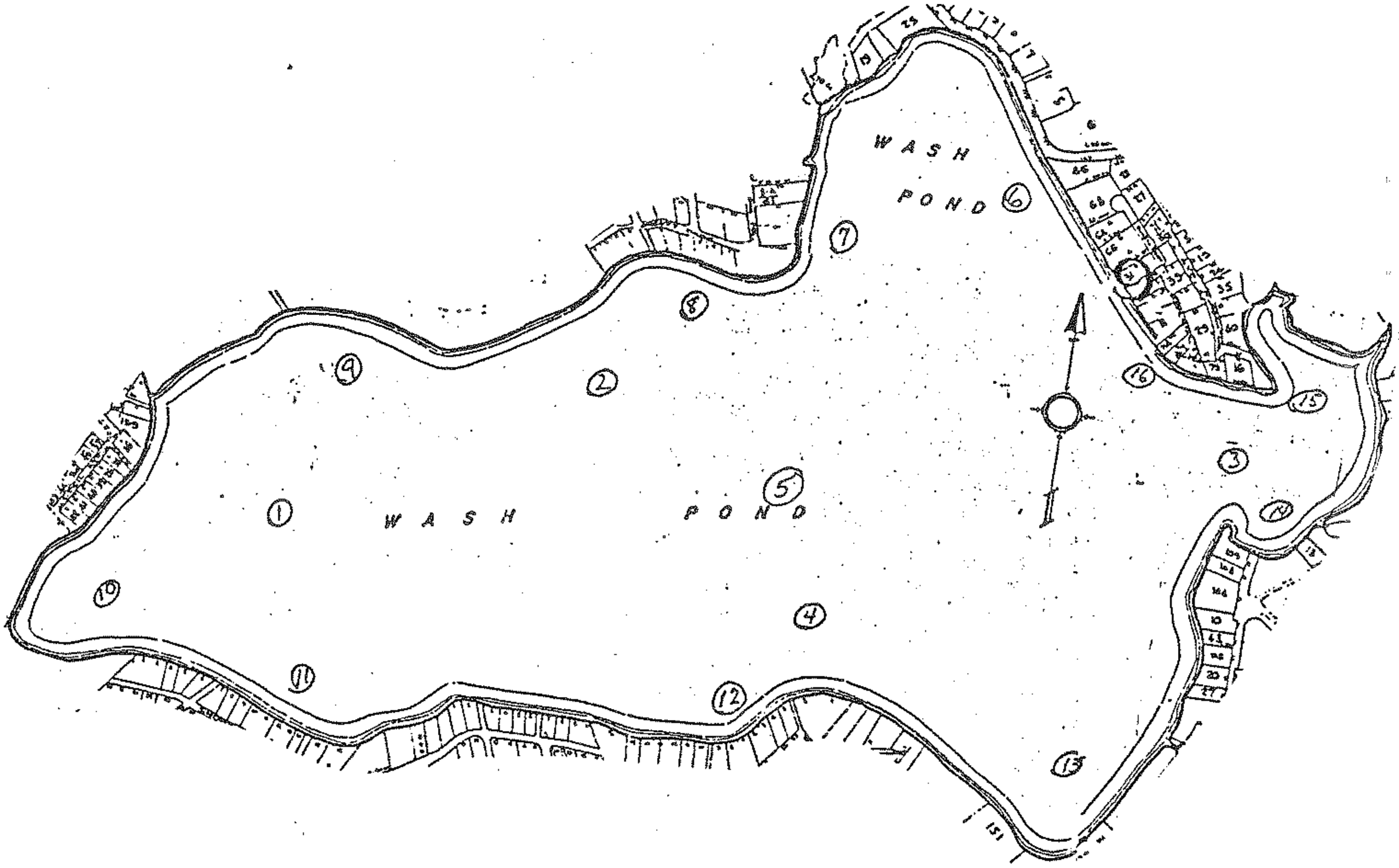

SUNSET LAKE SITE 5
SECCHI DISK TRANSPARENCY 1987
SECCHI DISK DEPTH (meters)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
^ EUTROPHIC ^
^ MESOTROPHIC v
v OLIGOTROPHIC v
03-May 23-May 12-Jun 02-Jul 22-Jul 11-Aug 31-Aug 20-Sep 10-Oct 30-Oct 19-Nov
DATE

Figure 4. Seasonal trends for chlorophyll a concentration for the lake site sampled on Sunset Lake. determined from lay monitor data. Solid lines on the plots border the ranges common to oligotrophic and mesotrophic lakes.

Figure 5. Seasonal trends for dissolved color concentration for site sampled on Sunset Lake determined from lay monitor data. Solid line indicates the average dissolved color for all LLMP lakes in 1987, weighted by lake.


SUNSET LAKE 1987
CHLOROPHYLL a CONCENTRATION
v OLIGOTROPHIC v
CHLOROPHYLL a (mg/m3)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12-Jun
02-Jul
22-Jul
11-Aug
31-Aug
20-Sep
10-Oct
30-Oct
19-Nov
09-Dec
DATE
SITE 5


SUNSET LAKE 1987
DISSOLVED COLOR
DISSOLVED COLOR (ptu)
35
30
25
20
15
10
5
0
1987 LLMP LAKES AVERAGE
03-May
23-May
12-Jun
02-Jul
22-Jul
11-Aug
31-Aug
20-Sep
10-Oct
DATE
SITE 5


WASH POND
WASH POND
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Sunset Lake Data on file as of 04/16/1988

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Sunset Lake
-- subset of trophic indicators, all sites, 1984

1984 SUMMARY

Average transparency: 4.1 (1984: 13 values)
Average chlorophyll: 1.5 (1984: 8 values)

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	05/21/1984	3.0	---	---	---	---	---
5 Center	06/08/1984	3.6	---	---	---	---	---
5 Center	06/22/1984	3.0	---	---	---	---	---
5 Center	07/02/1984	3.9	---	---	---	---	---
5 Center	07/10/1984	4.5	1.2	---	---	---	---
5 Center	07/20/1984	4.5	1.5	---	---	---	---
5 Center	08/03/1984	4.3	1.8	---	---	---	---
5 Center	08/10/1984	3.5	---	---	---	---	---
5 Center	08/17/1984	3.5	2.9	---	---	---	---
5 Center	08/26/1984	4.5	1.2	---	---	---	---
5 Center	09/08/1984	4.5	1.1	---	---	---	---
5 Center	09/18/1984	4.5	1.9	---	---	---	---
5 Center	09/30/1984	5.5	0.1	---	---	---	---

<< End of 1984 listing, 13 records >>

Sunset Lake Data on file as of 04/16/1988

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Sunset Lake
-- subset of trophic indicators, all sites, 1985

1985 SUMMARY

Average transparency:	5.2	(1985:	15 values)
Average chlorophyll:	2.2	(1985:	12 values)
Average phosphorus:	5.0	(1985:	8 values)
Average alk (gray):	12.6	(1985:	7 values)
Average alk (pink):	13.4	(1985:	7 values)
Average color, 440:	5.6	(1985:	7 values)

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	07/01/1985	5.0	7.4	---	---	---	---
5 Center	07/07/1985	5.0	4.4	---	---	---	---
5 Center	07/13/1985	5.0	1.6	---	---	---	---
5 Center	07/18/1985	5.0	1.6	2.2	---	---	---
5 Center	07/27/1985	4.5	1.2	---	---	---	8.3
5 Center	08/02/1985	4.8	1.9	5.3	---	---	8.3
5 Center	08/08/1985	4.5	2.1	5.8	13.0	13.5	6.6
5 Center	08/17/1985	4.6	2.5	7.1	12.2	12.6	2.3
5 Center	08/23/1985	4.6	0.9	6.6	12.2	12.8	5.8
5 Center	09/01/1985	4.8	1.1	4.1	12.8	13.4	6.6
5 Center	09/08/1985	5.8	1.1	4.1	---	---	---
5 Center	09/13/1985	5.2	1.1	4.6	12.9	13.5	1.5
5 Center	09/29/1985	6.0	---	---	---	---	---
5 Center	10/08/1985	6.5	---	---	12.8	14.1	---
5 Center	11/16/1985	7.0	---	---	12.5	13.7	---

<< End of 1985 listing, 15 records >>

Sunset Lake Data on file as of 04/16/1988

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Sunset Lake
-- subset of trophic indicators, all sites, 1986

1986 SUMMARY

Average transparency:	5.6	(1986: 17	values)
Average chlorophyll:	1.7	(1986: 15	values)
Average phosphorus:	6.7	(1986: 12	values)
Average alk (gray):	12.1	(1986: 19	values)
Average alk (pink):	12.8	(1986: 19	values)
Average color, 440:	11.6	(1986: 13	values)

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	02/17/1986	---	---	---	11.4	12.2	---
5 Center	04/19/1986	6.5	---	---	10.3	11.1	10.9
5 Center	05/11/1986	5.5	1.4	---	10.6	11.5	12.6
5 Center	06/17/1986	7.6	2.4	---	11.8	12.4	11.8
5 Center	07/07/1986	6.1	---	---	11.9	12.5	5.8
5 Center	07/14/1986	6.4	2.4	---	12.5	13.1	6.6
5 Center	07/18/1986	---	---	6.0	---	---	---
5 Center	07/24/1986	6.7	0.9	14.0	12.4	13.1	10.1
5 Center	08/02/1986	5.0	2.0	13.0	13.5	14.2	9.2
5 Center	08/08/1986	4.8	2.5	17.0	12.0	12.8	11.8
5 Center	08/17/1986	4.1	2.4	---	12.5	13.0	26.4
5 Center	08/29/1986	4.3	1.9	3.4	12.4	12.9	6.6
5 Center	08/30/1986	5.5	1.9	5.4	12.6	13.2	---
5 Center	08/31/1986	5.5	1.3	1.4	13.0	13.6	8.3
5 Center	09/01/1986	5.1	1.6	3.4	12.9	13.5	16.9
5 Center	09/02/1986	4.9	1.5	4.1	12.4	12.9	14.3
5 Center	09/27/1986	5.4	1.1	4.1	12.4	13.1	---
5 Center	10/22/1986	5.4	1.1	4.1	12.2	12.8	---
5 Center	11/22/1986	6.4	1.0	4.1	12.5	13.6	---
6 Winter	02/17/1986	---	---	---	11.4	12.2	---

<< End of 1986 listing, 20 records >>

Sunset Lake Data on file as of 04/16/1988

Lakes Lay Monitoring Program, U.N.H.

[Lay Monitor Data]

Sunset Lake
-- subset of trophic indicators, all sites, 1987

1987 SUMMARY

Average transparency:	5.4	(1987:	12	values)
Average chlorophyll:	1.5	(1987:	13	values)
Average phosphorus:	7.1	(1987:	10	values)
Average alk (gray):	10.9	(1987:	12	values)
Average alk (pink):	11.6	(1987:	12	values)
Average color, 440:	14.0	(1987:	7	values)

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	06/17/1987	2.8	2.6	---	11.0	11.6	10.9
5 Center	06/24/1987	2.6	2.5	18.0	11.2	11.9	12.6
5 Center	07/01/1987	5.7	2.3	10.6	10.6	11.2	9.2
5 Center	07/08/1987	6.1	1.8	13.0	10.5	11.2	16.9
5 Center	07/15/1987	5.8	1.7	---	10.6	11.3	10.1
5 Center	07/22/1987	6.5	0.5	5.3	10.8	11.4	---
5 Center	08/02/1987	6.5	0.5	4.7	11.0	11.8	19.5
5 Center	08/12/1987	6.0	1.1	3.7	10.8	11.5	---
5 Center	08/19/1987	5.1	0.9	4.7	11.2	11.8	---
5 Center	08/19/1987	---	1.5	---	---	---	---
5 Center	08/26/1987	5.0	1.3	6.3	11.4	12.0	18.6
5 Center	09/02/1987	6.2	1.6	2.0	11.0	11.8	---
5 Center	09/10/1987	6.8	0.9	2.3	11.0	12.2	---

<< End of 1987 listing, 13 records >>

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 five parameters: thermal stratification, water clarity (secchi disk depth), chlorophyll a concentration, dissolved color and total alkalinity. 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).

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 metalimnion 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 15 minutes, in the dark, to prevent decomposition or bleaching of the chlorophyll on the filter. A sample of the filtrate was poured into a 60 ml plastic bottle for the determination of dissolved water color. These filters and bottles were delivered to UNH where members of the FBG analyzed them for chlorophyll a and dissolved water color (see Methods of the Freshwater Biology Group).

METHODS OF THE FRESHWATER BIOLOGY GROUP

The **FBG** processed chlorophyll a, dissolved color, and phosphorus samples provided by the lay monitors. The input, storage and analysis of all **LLMP** data is also the responsibility of the **FBG**.

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 Baush and Lomb model 710 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 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) in a 50mm light path. 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 preserved with 1.0 milliliter of concentrated sulphuric acid and 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 thirty minutes at 250 to 260 degrees C. Reagents included potassium antimony tartrate, ammonium molybdate, and a solution of ascorbic acid mixed fresh before each sample run (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 (ppb).

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 concentrations, alkalinity, and color measurements, are filed and stored on the FBG computerized data-management system that utilizes a mainframe DEC VAX-8650 computer and an IBM compatible microcomputer (Zenith Data Systems 158). With full use of relational data bases, such as S1032 and Dbase III+ data can be easily retrieved by lake, date, station or by parameter and used for individual reports and program summaries 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 can be performed. Such analyses may identify trends and help explain variations in the data (eg. secchi disk depth, chlorophyll a, color). In addition, data from a lake may be compared with other lakes in the program, other computerized data bases (New Hampshire Water Supply and Pollution Control, New Hampshire Fish and Game, EPA Surface Water Survey and others) and to published water quality classifications.

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 program lakes. Phytoplankton are reported both as species and classes. Crustacean zooplankton were 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.