COOPERATIVE LAKES MONITORING PROGRAM

Michigan's Citizen Volunteer Lakes Monitoring Program

ANNUAL SUMMARY REPORT

2000

a partnership for Michigan's lakes

Michigan's Citizen Volunteers
Michigan Lake & Stream Associations, Inc.
Michigan Department of Environmental Quality
Department of Fisheries and Wildlife – Michigan State University

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INTRODUCTION

Michigan's unique geographical location provides its citizens with a wealth of freshwater resources including over 11,000 inland lakes. In addition to being valuable ecological resources, lakes provide aesthetic and recreational value for the people of Michigan and neighboring states. An ideal Michigan summer pastime is going to a cottage on an inland lake to fish, water-ski, swim, and relax.

As more and more people use the lakes and surrounding watersheds, the potential for pollution problems and use impairment increases dramatically. Although many of Michigan's inland lakes have a capacity to accommodate the burden of man's activities in the short term, continuing stress on the lakes and lake watersheds over time will ultimately lead to adverse water quality and recreational impacts.

Reliable information including water quality data, levels of use, and use impairment are essential for determining the health of a lake and for developing a management plan to protect the lake. As the users and primary beneficiaries of Michigan's lake resources, citizens must take an active role in obtaining this information and managing their lakes.

Michigan's abundant water resources...

...include over 11,000 inland lakes.

To meet this need, the Department of Environmental Quality's (DEQ) Land and Water Management Division and Michigan Lake and Stream Associations, Inc. (ML&SA) have partnered to implement the Cooperative Lakes Monitoring Program (CLMP). The purpose of this effort is to help citizen volunteers monitor indicators of water quality in their lake and document changes in lake quality. The CLMP provides sampling methods, training, workshops, technical support, quality control, and laboratory assistance to the volunteer monitors. Michigan State University's Department of Fisheries and Wildlife supports the partnership with technical assistance.

THE SELF-HELP LEGACY

Originally known as the Self-Help Program, the CLMP continues a long tradition of citizen volunteer monitoring. Michigan has maintained a volunteer lake monitoring program since 1974, making it the second oldest volunteer monitoring program for lakes in the nation. The original program was designed for lake property owners to monitor water quality by measuring water clarity with a Secchi disk. In 1992, the DEQ Land and Water Management Division (then part of the Department of Natural Resources) and the ML&SA entered into a cooperative agreement to expand the basic program. An advanced Self-Help program was

"working together to protect lakes"

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initiated in 1993 that included a monitoring component for the plant nutrient phosphorus. In 1994, a side-by-side sampling component was added to the program to assure the quality of the data being collected.

The CLMP continues the "self-help" legacy by providing Michigan's citizens an opportunity to participate in environmental management and learn more about their lakes. Currently, the CLMP supports monitoring components for basic indicators of primary productivity in lakes, including Secchi disk transparency, total phosphorus, chlorophyll *a*, dissolved oxygen and temperature.

The CLMP is a cost-effective process for the DEQ to increase the baseline data available for Michigan's inland lakes as well as to establish a continuous data record for determining water quality trends in lakes. The CLMP continues the DEQ/citizen volunteer partnership critical to lake management in Michigan.

LAKE QUALITY

A lake's condition is influenced by many factors, such as the amount of recreational use it receives, shoreline development, and water quality. Lake *water quality* is a general term covering many aspects of lake chemistry and biology. The health of a lake is determined by its water quality.

CLMP Goals

- Provide baseline information and document trends in water quality for individual lakes.
- Educate lake residents, users, and interested citizens in the collection of water quality data, lake ecology, and lake management practices.
- Build a constituency of citizens to practice sound lake management at the local level and to build public support for lake quality protection.
- Provide a cost-effective process for the DEQ to increase baseline data for lakes state-wide.

CLMP Measurements

- Secchi disk transparency
- spring total phosphorus
- summer total phosphorus
- chlorophyll *a*
- dissolved oxygen and temperature

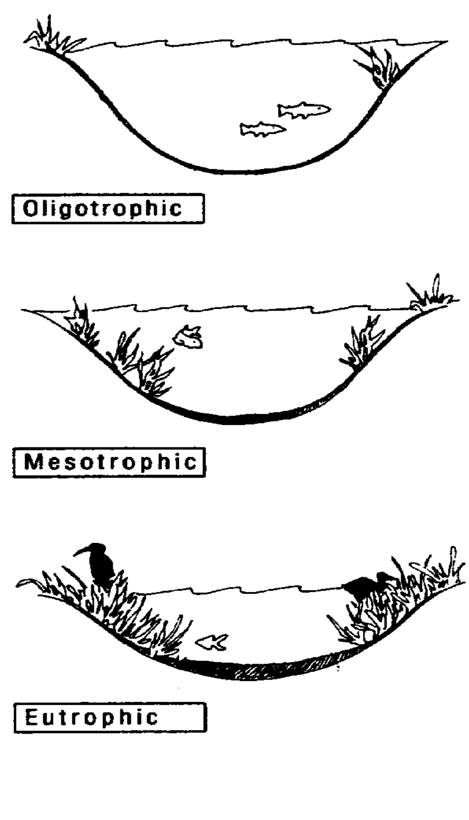
Increasing lake productivity can impact water quality and result in problems such as excessive weed growth, algal blooms, and mucky bottom sediments. *Productivity* refers to the amount of plant and animal life that can be produced within the lake.

Plant *nutrients* are a major factor that cause increased productivity in lakes. In Michigan, *phosphorus* is the nutrient most responsible for increasing lake productivity.

The CLMP is designed to specifically monitor changes in lake productivity. The current program enlists citizen volunteers to monitor water clarity, the algal plant pigment chlorophyll *a* and dissolved oxygen throughout the summer months and total phosphorus is measured during the spring and late summer. These parameters are indicators of primary productivity and, if measured over many years, may document changes in the lake.

CLASSIFYING LAKES

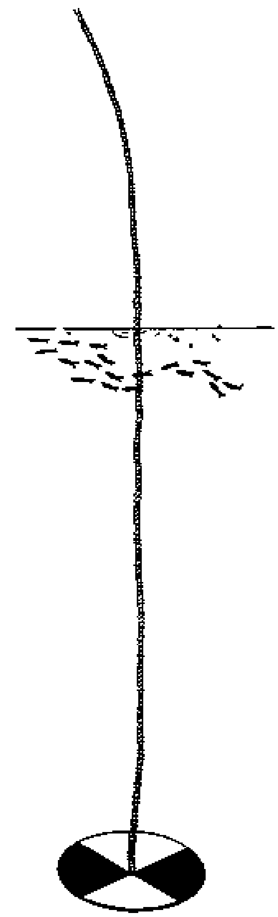
A lake's ability to support plant and animal life defines its level of productivity, or *trophic state.* Lakes are commonly classified based on their productivity. Low productive *oligotrophic* lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient *dissolved oxygen* in the cool, deep-bottom waters during late summer to support cold water fish, such as trout and whitefish. By contrast, high productive *eutrophic* lakes are generally shallow, turbid, and support abundant aquatic plant growth. In deep eutrophic lakes, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, these lakes can only support warm water fish, such as bass and pike. Lakes that fall between these two classifications are called *mesotrophic* lakes. Lakes that exhibit extremely high productivity, such as nuisance algae and weed growth are called *hypereutrophic* lakes.



(Source: Hamlin Lake Improvement Board)

EUTROPHICATION

The gradual increase of lake productivity from oligotrophy to eutrophy is called lake aging or *eutrophication*. Lake eutrophication is a natural process resulting from the gradual accumulation of nutrients, increased productivity, and a slow filling in of the lake basin with accumulated sediments, silt, and muck. Human activities can greatly speed up this process by dramatically increasing nutrient, soil, or organic matter input to the lake. This human influenced, accelerated lake aging process is known as *cultural eutrophication*. A primary objective of most lake management plans is to slow down cultural eutrophication by reducing the input of nutrients and sediments to the lake from the surrounding land.



MEASURING EUTROPHICATION

Measuring a lake's water quality and eutrophication is not an easy task. Lakes are a complex ecosystem made up of physical, chemical, and biological components in a constant state of action and interaction.

As on land, plant growth in lakes is not constant throughout the summer. Some species mature early in the season, die back, and are replaced by other species in a regular succession.

While overall population levels often reach a maximum in mid-summer, this pattern may be influenced or altered by numerous factors, such as temperature, rainfall, and aquatic animals. For the same reasons lakes are different from week to week, lake water quality can fluctuate from year to year.

Given these factors, observers of lake water quality must train themselves to recognize the difference between short-term, normal fluctuations and long-term changes in lake productivity (eutrophication). Many years of reliable data collected on a consistent and regular basis are required to separate true long-term changes in lake productivity from seasonal and annual fluctuations.

Important Measures of Eutrophication

Nutrients are the leading cause of eutrophication. Nitrogen and *phosphorus* both stimulate plant growth. Both are measured from samples of water and reported in units of ug/l (micrograms per liter), or ppb (parts per billion). *Phosphorus* is the most important nutrient, and is often used directly as a measure of eutrophication.

Plants are the primary users of nutrients. *Chlorophyll a* is a component of the cells of most plants, and can be used to measure the concentration of small plants in the water, such as algae. *Chlorophyll a* is measured from samples of water and reported in units of ug/l. Macrophytes are aquatic plants with stems and leaves. The location of different species of plants can be mapped, and the density can be measured in pounds of plants per acre of lake.

Transparency or the clarity of water is measured using a device known as a *Secchi disk*. This is an eight inch diameter target painted black and white in alternate quadrants. The disk is attached to a marked line, or measuring tape, and lowered from a boat into the lake. The distance into the water column the disk can be seen is the transparency, measured in feet or meters. A short distance of visibility means that there are suspended particles or algae cells in the water, an indication of nutrient enrichment.

Dissolved Oxygen (DO) which is oxygen dissolved in the water, is necessary to sustain fish populations. Fish, such as trout, require more DO than warm water species. Eutrophic lakes occasionally have levels of DO below the minimum for fish to survive, and fish kills can result.

Sediments can be measured to determine how fast material is depositing on the bottom. This may indicate watershed erosion, or a large die-off of aquatic plants.

Fish can be sampled using nets. In an oligotrophic lake there are likely to be cold water species, such as trout. A sample of warm water fish, such as sunfish, bass, bullheads, and carp is more typical of a eutrophic lake.

Temperature affects the growth of plants, the release of nutrients, and the mixing of layers of water in the lake. Temperature measurements can determine if mixing occurs, moving nutrients from the lake bottom up into the surface waters promoting algae blooms.

LAKE PRODUCTIVITY INDEX

The general lake classification scheme described is convenient, but somewhat misleading in that it places all lakes into a few distinct trophic categories. In reality, lake water quality is a continuum progressing from very good to very poor conditions. A more precise method of describing the productivity of a lake is to use a numerical index which can be calculated directly from water quality data. A variety of indexes are available with Carlson's (1977) *Trophic State Index*, or TSI, being the most widely used.

Carlson's TSI was developed to compare lake data on water clarity, as measured by a Secchi disk, chlorophyll *a,* and total phosphorus. These parameters are good indirect measures of a lake's productivity. The TSI expresses lake productivity on a continuous numerical scale from 0 to 100, with increasing numbers indicating more eutrophic conditions. The zero point on the TSI scale was set to correlate with a Secchi transparency of 64 meters (210 feet).

Carlson developed mathematical relationships for calculating the TSI from measurements of Secchi depth transparency, chlorophyll *a*, and total phosphorus in lakes during the summer season. The computed TSI values for an individual lake can be used to compare with other lakes, to

Carlson's TSI Equations

$$TSI_{SD} = 60 - 33.2 \log_{10} SD$$

$$TSI_{TP} = 4.2 + 33.2 \log_{10} TP$$

$$TSI_{CHL} = 30.6 + 22.6 \log_{10} CHL$$

where,
SD = Secchi depth transparency (m)
TP = total phosphorus concentration (ug/l)
CHL = chlorophyll *a* concentration (ug/l)

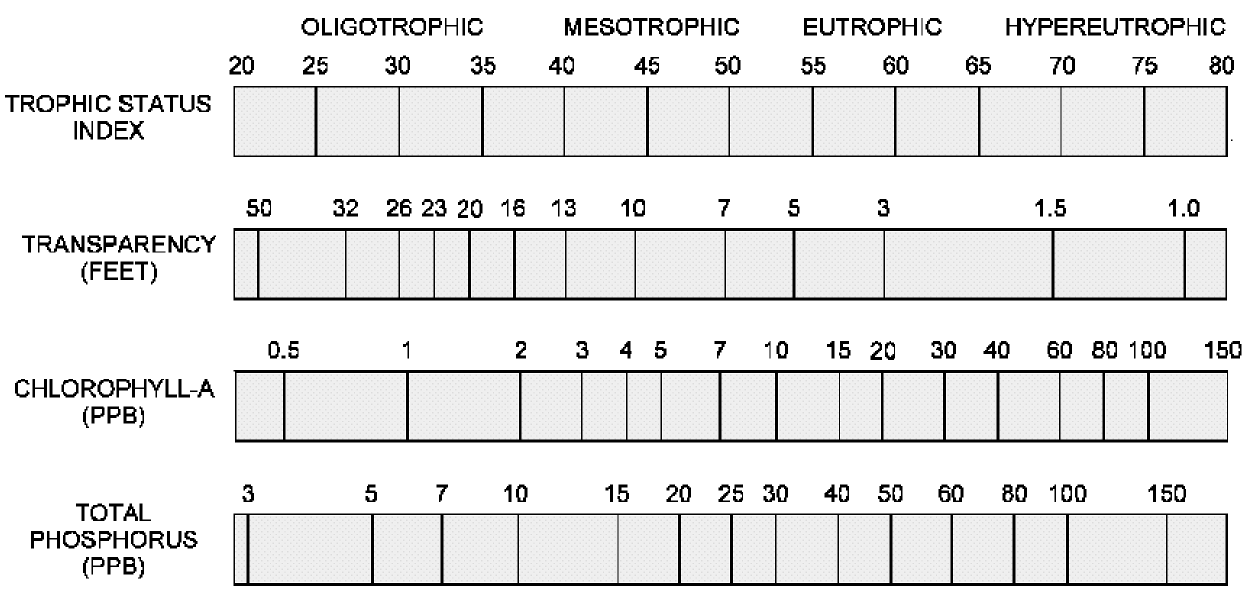
evaluate changes within the lake over time, and to estimate other water quality parameters within the lake.

For those preferring to use the general lake classification scheme, the TSI values which correspond approximately with the trophic state terms are illustrated in the figure below. However, the dividing lines between these categories are somewhat arbitrary since lake water quality is a continuum and there is no broad agreement among lake scientists as to the precise point of change between each of these classifications. For many lakes in Michigan, Carlson's TSI equations can be used to roughly predict values of one variable from measurements of another in the surface water of the lake during the summer season as shown in the figure below.

Lake scientists have also developed relationships to predict summer productivity indicators from water quality variables measured during lake turnover in the spring. One such relationship was developed by Dillon and Rigler (1974) which predicts mean (average) summer chlorophyll *a* from spring phosphorus measurements.

These relationships must be used carefully when predicting water quality variables and productivity.

CARLSON'S TROPHIC STATE INDEX



(Source: Minnesota Pollution Control Agency)

OTHER MEASURES OF LAKE PRODUCTIVITY

Dissolved Oxygen (DO) and Temperature

Dissolved oxygen and temperature are two fundamental measurements of lake productivity. The amount of dissolved oxygen in the water is an important indicator of overall lake health.

For approximately two weeks in the spring and fall, the typical lake is entirely mixed from top to bottom, with all the water in the lake being 4 degrees Centigrade. In the winter there is only a few degrees difference between the water under the ice (0 degrees Centigrade) and the water on the bottom (4 degrees Centigrade). However, in the summer most lakes with sufficient depth (greater than 30 feet) are stratified into three distinct layers of different temperatures. These layers are referred to as the epilimnion (warm surface waters) and hypolimnion (cold bottom waters) which are separated by the metalimnion, or thermocline layer, a stratum of rapidly changing temperature. The physical and chemical changes within these layers influence the cycling of nutrients and other elements within the lake.

During summer stratification the thermocline prevents dissolved oxygen produced by plant photosynthesis in the warm waters of the well-lit epilimnion from reaching the cold dark hypolimnion waters. The hypolimnion only has the dissolved oxygen it acquired during the short two-week spring overturn. This finite oxygen supply is gradually used by the bacteria in the water to decompose the dead plant and animal organic matter that rains down into the hypolimnion from the epilimnion, where it is produced. With no opportunity for re-supply the dissolved oxygen in the hypolimnion waters is gradually exhausted. The greater the supply of organic matter from the epilimnion and the smaller the volume of water in the hypolimnion the more rapid the oxygen depletion in the hypolimnion. Highly productive eutrophic lakes with small hypolimnetic volumes can lose their dissolved oxygen in a mater of a few weeks after spring overturn ends and summer stratification begins. Conversely, low productive oligotrophic lakes with large hypolimnetic volumes can retain high oxygen levels all summer long.

When a lake's hypolimnion dissolved oxygen supply is depleted, significant changes occur in the lake. Fish species like trout and whitefish that require cold water and high dissolved oxygen levels are not able to survive. With no dissolved oxygen in the water the chemistry of the bottom sediments are changed resulting in the release of the plant nutrient phosphorus into the water from the sediments. As a result the phosphorus concentrations in the hypolimnion of productive eutrophic and hypereutrophic lakes can reach extremely high levels. During major summer storms or at fall overturn, this phosphorus can be mixed into the surface waters to produce nuisance algae blooms.

Some eutrophic lakes of moderate depth (25 to 45 feet deep) can stratify, lose its hypolimnion dissolved oxygen and then destratify with each summer storm. So much phosphorus can be brought to the surface water from these temporary stratifications and destratifications that the primary source of phosphorus for the lake is not the watershed but the lake itself in the form of internal loading or recycling.

Besides the typical lake stratification pattern just described, it is now known that some Michigan lakes may not follow this pattern. Small lakes with significant depth, and situated in hilly terrain or protected from strong wind forces, may not completely circulate during spring overturn every year. Additionally, some lakes deep enough to stratify will not, if they have a long fetch oriented to the prevailing wind or are influenced by major incoming river currents. Finally, lakes with significant groundwater inflow may have low dissolved oxygen concentrations due to the influence of the groundwater instead of the lake's productivity and biological decomposition.

The dissolved oxygen and temperature regime of a lake is important to know in order to develop appropriate management plans. A lake's oxygen and temperature patterns not only influence the physical and chemical qualities of a lake but the sources and quantities of phosphorus, as well as the types of fish and animal populations.

CLMP RESULTS

Secchi Disk Transparency

Citizen volunteers measure Secchi disk transparency from late spring to the end of the summer. Ideally, 18 weekly measurements are made from mid-May through mid-September. As a minimum, eight equally spaced measurements from the end of May to the beginning of September are accepted to provide a good summer transparency mean (average) for the lake. Frequent transparency measurements are necessary throughout the growing season since algal species composition in lakes can change significantly during the spring and summer months, which can dramatically affect overall water clarity.

A summary of the transparency data collected by the lake volunteers during 2000 is included in Appendix 1. The number of measurements, or readings, made between mid-May and mid-September and the minimum and maximum Secchi disk transparency values are included for each lake that participated in the program. For those lakes with eight or more evenly spaced readings over this time period, the mean, median, standard deviation, and Carlson TSI_{SD} values were calculated and listed.

The mean, or average, is simply the sum of the measurements divided by the number of measurements. The median is the middle value when the set of measurements is ordered from lowest to highest value. The standard deviation is a common statistical determination of the dispersion, or variability, in a set of data.

The data range and standard deviation gives an indication of seasonal variability in transparency in the lake. Lakes with highly variable Secchi disk readings need to be sampled frequently to provide a representative mean summer transparency value. Few measurements and inconsistent sampling periods for these lakes will result in unreliable data for annual comparisons.

The TSI_{SD} values were calculated using Carlson's equations (see page 7) and the mean summer transparency values. (Note: the mean transparency value is converted from feet to meters for the TSI_{SD} calculation) The graphical relationship (see page 8) can be used to relate the TSI_{SD} value to the general trophic status classification for the lake (i.e., oligotrophic, mesotrophic, eutrophic) as well as to provide a rough estimate of summer chlorophyll *a* and total phosphorus levels in the lake. If the transparency measurements are made properly and consistently year after year, the annual TSI_{SD} values can be compared to evaluate changes, or trends, in trophic status of the lake over time.

During 2000, Secchi disk transparency data were reported for 157 lakes (218 basins). Over 3,000 transparency measurements were reported, ranging from 2.4 to 51 feet. For the lakes with eight or more equally spaced readings between mid-May and mid-September, the overall mean, or average, Secchi disk transparency was 12.1 feet. The median value was 11.0 feet. The Carlson TSI_{SD} values ranged from 27 to 59 for these lakes with a mean value of 42. A Carlson TSI value of 42 is generally indicative of a good quality mesotrophic lake (see page 8).

Total Phosphorus

Phosphorus is one of several essential nutrients that algae need to grow and reproduce. For most lakes in Michigan, phosphorus is the most important nutrient, the limiting factor, for algae growth. The total amount of phosphorus in the water is typically used to predict the level of productivity in a lake. An increase in phosphorus over time is a measure of nutrient enrichment in a lake.

The CLMP volunteers monitor for total phosphorus during spring overturn, when the lake is generally well mixed from top to bottom, and during late summer, when the lake is at maximum temperature stratification from the surface to the bottom. Spring overturn is an opportune time of the year to sample just the surface of a lake to obtain a representative sample for estimating the total amount of phosphorus in the lake. A surface sample collected during late summer represents only the upper water layer of the lake, the epilimnion, where most algal productivity occurs. The late summer total phosphorus results, along with the Secchi disk transparency and chlorophyll measurements, are used to determine the trophic status of the lake. The spring overturn total phosphorus data, collected year after year, are useful for evaluating nutrient enrichment in the lake.

Total phosphorus results for the 2000 CLMP are included in Appendix 2. The spring total phosphorus data are listed first, followed by the late summer data. The TSI_{TP} values were calculated using Carlson's equations (see page 7) and the late summer total phosphorus data. Results from replicate and side-by-side sampling are also provided. Approximately 10 percent of the replicate samples collected by the volunteers were analyzed as part of the data quality control process for the CLMP. Also, the DEQ participated in side-by-side sampling on approximately 10 percent of the enrolled lakes.

During 2000, samples for total phosphorus measurements were collected on 128 lakes (134 basins). The spring overturn total phosphorus results ranged from <5 to 58 ug/l with a mean (average) of 13.0 ug/l. The late summer total phosphorus results ranged from 5 to 157 ug/l with 17.9 ug/l as the mean. The Carlson TSI_{TP} values ranged from 27 to 77 for these lakes with a mean value of 44. A Carlson TSI value of 44 is generally indicative of a mesotrophic lake (see page 8).

Chlorophyll *a*

Chlorophyll is the green photosynthetic pigment in the cells of plants. The relative amount of algae in a lake can be estimated by measuring the chlorophyll *a* concentration in the water. As an algal productivity indicator, chlorophyll *a* is often used to determine the trophic status of a lake.

Chlorophyll monitoring was added to the CLMP in 1998 and expanded in subsequent years. Chlorophyll samples were collected on 66 lakes in 2000. For each lake, the volunteers collected and processed five sets of chlorophyll *a* samples, one set per month from May through September.

Results from the chlorophyll monitoring are included in Appendix 3. Results for each monthly sampling event are listed as well as the mean, median, and standard deviation of the monthly data for each lake. The TSI_{CHL} values were calculated using Carlson's equations (see page 7) and the median summer chlorophyll values. Results from the replicate and side-by-side sampling are also provided. Side-by-side and replicate samples were collected and analyzed for nearly half of the lakes.

Over 350 chlorophyll samples were collected and processed in 2000. The chlorophyll *a* levels in these lakes ranged from <1 to 51 ug/l over the five-month sampling period. The overall mean (average) was 4.9 ug/l and the median was 4 ug/l. The Carlson TSI_{CHL} values ranged from <31 to 61 with a mean value of 43.7. A Carlson TSI value of 44 is generally indicative of a mesotrophic lake (see page 8).

TSI Comparisons

The TSI_{CHL}, TSI_{SD}, and TSI_{TP} values for the individual lakes can be compared to provide useful information about the factors controlling the overall trophic status in these lakes (Carlson and Simpson, 1996). For lakes where phosphorus is the limiting factor for algae growth, all three TSI values should be nearly equal. However, this may not always be the case. For example, the TSI_{SD} may be significantly larger than the TSI_{TP} and TSI_{CHL} values for lakes that precipitate calcium carbonate, or marl, during the summer. The marl particles in the water column would scatter light and reduce transparency in these lakes, which would increase the TSI_{SD}. Also, phosphorus may adsorb to the marl and become unavailable for algae growth, which would reduce the TSI_{CHL}. For lakes where zooplankton grazing or some factor other than phosphorus limits algal biomass, the TSI_{TP} may be significantly larger than the TSI_{SD} and TSI_{CHL}.

Dissolved Oxygen and Temperature

Temperature and dissolved oxygen are typically measured as surface-to-bottom profiles over the deep part of the lake. Temperature is usually measured with a thermometer or an electronic meter called a themistor. Dissolved oxygen is either measured with an electronic meter or by a chemical test. The CLMP uses an electronic meter (YSI 95D) designed to measure both temperature, with a themistor, and dissolved oxygen. The meter is calibrated by the volunteer monitor before each sampling event.

Dissolved oxygen and temperature are measured from the surface to within 3 feet of the bottom, as a profile, in the deepest basin of the lake. Measurements are taken at 5-foot intervals in the upper part of the water column. Through the mid-depth region or thermocline (15 to 45 feet), measurements are taken at 2½ foot intervals. Below the thermocline, measurements are usually made every 5 feet. Measurements are made every two weeks from mid-May to mid-September in the same deep basin location.

During 2000, CLMP participants in a pilot program sampled 19 lakes for dissolved oxygen and temperature. The lakes involved in the pilot program are identified in Appendix 4. The results of the sampling are highly varied depending upon the size, depth, volume and productivity of the lake sampled. Because of these highly varied results and the amount of individual data collected, each lake's results are not included in this report. Each participating lake community will receive individual data graphs for their lake. Instead of individual results, representative oxygen and temperature patterns are illustrated in Appendix 4. For the most part, data collected on lakes participating in the 2000 pilot project are used to present these representative patterns. Volunteer monitors may compare the results from their lake with the patterns illustrated in Appendix 4.

While it is not possible to illustrate every conceivable temperature and dissolved oxygen scheme that may develop in a lake, five common summer patters are presented in Appendix 4. These five patterns include: an oligotrophic lake with a very large volume hypolimnion, a oligotrophic/mesotrophic lake with a large volume hypolimnion, a oligotrophic/mesotrophic lake with a small hypolimnion, a eutrophic lake with a small hypolimnion, and a mesotrophic lake which weakly stratifies during the summer. A sixth pattern not represented and not sampled for in 2000 is the very shallow lake, with a maximum depth of less than 15 feet. These lakes usually have the same temperature and dissolved oxygen concentrations from surface-to-bottom as a result of frequent mixing.

CONCLUSION

Data from the CLMP provide citizens with basic information on their lakes that can be used as indicators of the lake's productivity. If measured over many years, these data may be useful in documenting changes and trends in water quality.

More importantly these data will assist the local community with the management of their lake. Michigan's lakes are high quality resources that should be protected from nutrient and sediment inputs to keep them as the special places we use and enjoy. To do this, each lake should have its own management plan.

Although CLMP data provide very useful water quality information, for certain management programs it may be necessary to assemble more specific data or information on a lake's condition. The DEQ and the ML&SA may be able to help you obtain additional information on your lake.

REFERENCES

Carlson, R.E. 1977. A trophic state index for lakes. *Limnol. Oceanogr. 22(2):* 361-369.

Carlson, R. and Simpson, J. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. February 1996.

Dillon, P.J. and Rigler, F.H. 1974. The phosphorus-chlorophyll relationship in lakes. *Limnol. Oceanogr. 19(5):* 767-773.

Hamlin Lake Improvement Board. 1994. Protecting Hamlin Lake - a homeowners guide. Prepared by: Progressive Architecture Engineering Planning, Grand Rapids, MI. July 1994.

Michigan DNR. 1990. Protecting Inland Lakes - a watershed management guidebook. Prepared by: Planning and Zoning Center, Inc., Lansing, MI. February 1990.

Minnesota PCA. 1991. Citizen Lake-Monitoring Program - 1990 report on the transparency of Minnesota lakes. Minnesota Pollution Control Agency, Division of Water Quality. St. Paul, MN. June 1991.

ACKNOWLEDGMENTS

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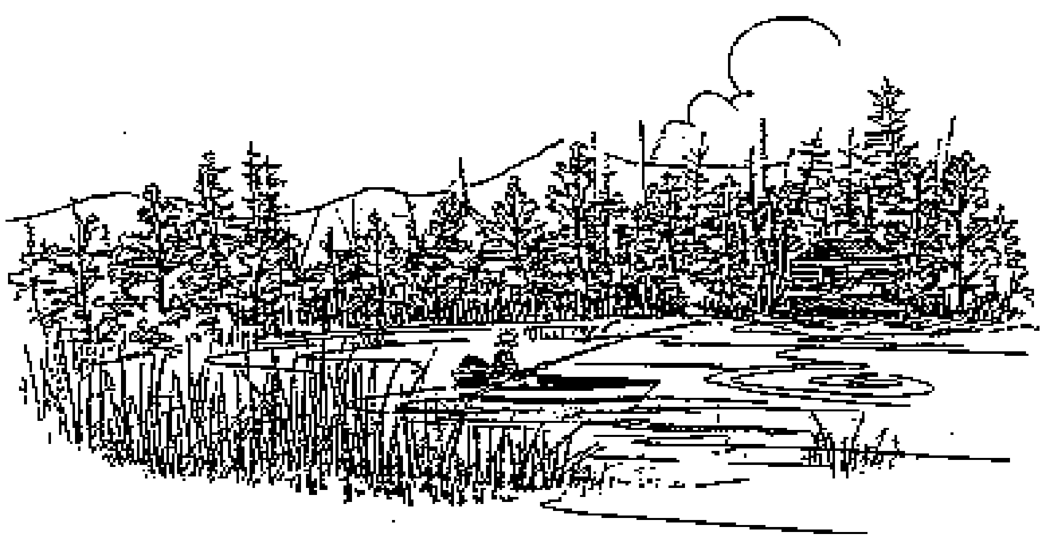
Thank you to the dedicated volunteers who have made the CLMP one of the nations most successful citizen volunteer lakes monitoring programs. Special thank you is extended to Niles Kevern and Joe Landis for their help in building the chlorophyll sampling and filtering equipment and to Ralph Vogel for constructing the Secchi disks for the CLMP.



APPENDIXES

Appendix 1

2000 Secchi Disk Transparency Results

Appendix 2

2000 Total Phosphorus Results

Appendix 3

2000 Chlorophyll Results

Appendix 4

2000 Dissolved Oxygen and Temperature Participating Lakes and Example Results

APPENDIX 1
2000 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min.	Range Max.	Mean	Median	Standard Deviation	Carlson TSI_{SD} (transparency)
Arbutus 1	Grand Traverse	18	8.0	12.5	11.9	12.5	1.38	41
Arbutus 2	Grand Traverse	18	12.0	20.0	15.2	15.0	1.87	38
Arbutus 3	Grand Traverse	18	13.0	20.0	15.3	15.0	1.90	38
Arbutus 4	Grand Traverse	18	12.0	19.0	14.6	14.0	1.92	38
Arbutus 5	Grand Traverse	18	12.0	16.0	14.1	14.0	1.46	39
Arnold	Clare	17	14.0	25.3	20.0	20.0	3.49	34
Avalon	Montmorency	10	17.0	31.0	21.5	21.0	4.70	33
Baldwin	Montcalm	17	9.0	16.0	11.9	11.0	2.01	41
Baldwin 1	Cass	13	5.7	11.2	9.3	9.5	1.61	45
Baldwin 2	Cass	13	6.3	11.6	9.8	10.1	1.47	44
Baldwin 3	Cass	13	4.5	12.0	9.4	10.0	1.92	45
Baldwin 4	Cass	13	6.0	11.6	9.3	9.1	1.43	45
Barlow	Barry	12	6.0	15.5	10.8	10.8	3.25	43
Baseline	Livingston	18	11.0	15.0	12.9	13.0	1.36	40
Bass	Livingston	11	6.4	11.3	9.3	9.6	1.43	45
Bass	Kent	18	6.0	9.3	7.7	7.8	1.22	48
Bear	Manistee	12	7.0	11.0	7.9	7.5	1.10	47
Bear 1	Kalkaska	16	23.0	46.0	31.3	30.3	6.99	27
Bear 2	Kalkaska	16	22.5	45.0	30.7	29.0	6.92	28
Beaton	Gogebic	10	13.0	28.0	18.3	15.5	5.10	35
Beaver	Alpena	17	9.0	14.0	11.1	11.5	1.68	42
Big Bear	Otsego	13	14.0	26.0	21.6	24.0	4.48	33
Big Pine Island	Kent	18	7.0	16.0	9.3	9.0	2.50	45
Big Platte	Benzie	18	5.5	14.0	10.0	10.5	2.71	44
Big Pleasant	St. Joseph	11	9.0	17.0	12.2	10.5	2.90	41
Big Twin North	Cass	17	11.0	20.0	13.8	12.0	3.37	39
Bills	Newaygo	16	8.0	22.0	13.0	11.0	4.60	40
Birch	Cass	18	14.0	24.0	18.4	18.3	2.96	35
Blue	Mason	13	22.0	38.0	28.6	27.0	5.13	29
Blue 1	Mecosta	18	10.0	24.0	14.6	13.5	3.97	38
Blue 2	Mecosta	14	10.0	25.0	14.6	13.0	4.26	38
Bradford	Otsego	18	14.0	21.4	18.8	19.2	1.91	35
Burkhart	Washtenaw	18	10.4	22.3	14.4	14.2	2.73	39
Byram 1	Genesee	18	6.0	19.0	11.3	11.0	3.16	42
Byram 3	Genesee	18	6.0	19.0	11.3	11.0	3.16	42
Camp	Kent	15	9.5	19.0	12.9	13.0	2.32	40
Cedar	Van Buren	18	10.0	24.5	15.2	13.5	4.94	38
Chain	Iosco	11	8.2	12.0	10.6	11.0	1.18	43
Christiana	Cass	18	6.0	10.5	8.0	7.5	1.32	47
Clear	Berrien	17	8.5	19.0	13.9	14.0	2.91	39

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSI_{SD}
		Readings	Min.	Max.	Mean	Median	Deviation	(transparency)
Clear	Jackson	12	8.0	10.0	9.2	9.3	0.69	45
Clear 1	St. Joseph	6	13.5	15.5				
Clifford 1	Montcalm	18	9.5	16.0	11.6	11.5	1.28	42
Clifford 2	Montcalm	18	11.0	17.0	12.6	12.5	1.31	41
Coldwater	Branch	13	6.0	22.0	11.3	8.5	5.53	42
Coon (M)	Livingston	11	5.0	10.5	7.0	6.5	1.53	49
Coon (N)	Livingston	11	5.5	10.0	7.0	6.5	1.19	49
Coon (S)	Livingston	11	5.5	10.0	7.1	7.0	1.20	49
Corey	St. Joseph	17	6.0	19.1	9.9	7.5	4.13	44
Cowan	Kent	18	2.5	4.5	3.4	3.5	0.68	59
Cranberry	Kent	3	2.4	3.8				
Crockery	Ottawa	13	2.5	6.6	4.3	4.4	1.24	56
Crooked (Big)	Van Buren	18	11.0	18.9	14.5	13.7	2.65	39
Crooked (Little)	Van Buren	11	13.2	25.8	18.7	20.7	4.21	35
Crooked 1	Clare	10	10.8	14.0	12.6	12.9	1.11	41
Crooked 2	Clare	10	10.6	14.1	12.3	12.0	1.26	41
Crystal	Benzie	4	16.0	28.0				
Cub	Kalkaska	16	20.0	25.0	22.9	23.0	1.63	32
Dean	Kent	2	11.0	11.5				
Devils	Lenawee	13	6.0	12.0	7.7	7.5	1.84	48
Dewey	Cass	17	3.0	11.0	7.1	6.5	3.04	49
Diamond	Cass	18	6.0	28.0	12.8	11.3	5.70	40
Donnell	Cass	17	6.0	14.0	10.2	11.0	2.06	44
Duck 1	Grand Traverse	17	8.0	14.0	10.2	10.0	1.67	44
Duck 2	Grand Traverse	17	8.0	15.0	10.2	10.0	1.78	44
Eagle	Allegan	18	9.0	17.5	13.8	14.0	2.29	39
East Twin	Montmorency	18	9.0	15.0	12.1	12.0	1.72	41
Emerald	Newaygo	16	8.0	13.0	9.9	10.0	1.54	44
Evans	Lenawee	15	9.5	16.0	12.4	12.5	2.02	41
Fair	Barry	13	8.7	14.6	10.5	10.2	1.61	43
Fenton	Genesee	5	15.0	16.5				
Fish	Van Buren	16	4.0	10.0	6.8	7.0	1.61	50
Fishhawk	Gogebic	5	8.0	9.0				
Ford	Mason	18	14.9	19.3	17.3	17.5	1.30	36
Forest	Oakland	18	7.0	22.0	12.5	13.0	3.67	41
George 1	Clare	18	7.0	17.5	11.7	12.0	3.13	42
George 2	Clare	18	7.0	17.0	11.3	11.0	2.79	42
George 3	Clare	18	7.0	17.0	11.4	11.5	2.91	42
Gill/Gut	Livingston	10	9.9	11.0	10.2	10.0	0.36	44
Glen (Big)	Leelanau	13	12.5	26.0	18.8	17.0	4.54	35

APPENDIX 1
2000 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of Readings	Range Min.	Max.	Mean	Median	Standard Deviation	TSI_{SD} (transparency)
Glen (Little)	Leelanau	17	3.0	7.0	5.3	5.5	1.09	53
Gratiot	Keweenaw	17	11.0	18.7	14.2	14.5	2.35	39
Gunn	Mason	16	12.0	16.0	13.2	12.5	1.40	40
Hackert	Mason	14	6.0	15.0	10.1	10.0	2.21	44
Hamburg	Livingston	18	9.0	19.0	13.3	13.5	3.04	40
Hamilton	Dickinson	16	12.5	16.5	14.3	14.3	1.51	39
Harper	Lake	13	8.0	20.0	12.9	12.5	3.46	40
Hawk	Oakland	17	6.3	13.3	9.5	10.0	2.46	45
Higgins 1	Roscommon	6	23.0	51.0				
Higgins 2	Roscommon	2	21.0	27.0				
Horsehead	Mecosta	11	8.5	18.3	13.1	13.2	3.53	40
Hubbard	Alcona	15	9.5	20.0	14.8	15.0	2.96	38
Hunter 1	Gladwin	16	10.0	18.0	12.5	11.0	2.79	41
Hunter 2	Gladwin	16	9.0	16.5	11.8	11.8	1.92	42
Hunter's 1	Alcona	12	16.0	20.0	18.6	18.8	1.03	35
Hunter's 2	Alcona	12	14.5	18.5	16.9	17.3	1.28	36
Hutchins	Allegan	9	6.2	8.4	7.2	7.2	0.70	49
Indiana	Cass	15	6.5	23.5	11.1	10.0	5.21	42
Island	Grand Traverse	9	16.0	35.0	23.0	19.0	6.96	32
Jeptha (Upper)	Van Buren	17	7.4	12.6	10.2	11.0	1.82	44
Juno	Cass	18	5.5	11.5	7.3	7.0	1.59	48
K.P.	Crawford	5	10.0	17.0				
Keeler 1	Van Buren	18	8.0	9.0	8.8	9.0	0.37	46
Kirkwood	Oakland	18	2.8	8.0	4.9	4.5	1.72	54
Klinger	St. Joseph	18	7.0	22.5	12.8	12.0	4.45	40
Lake Ann	Benzie	13	9.0	19.0	13.8	14.0	3.20	39
Lake Margrethe 1	Crawford	18	12.0	24.0	14.2	13.0	3.35	39
Lake Margrethe 2	Crawford	18	10.0	24.0	14.2	14.0	3.94	39
Lake Margrethe 3	Crawford	18	12.0	24.0	14.4	14.0	3.62	39
Lake Margrethe 4	Crawford	18	12.0	19.5	13.7	12.5	2.49	39
Lake Nepessing	Lapeer	13	6.0	14.0	9.1	9.0	2.47	45
Lake of the Woods	Van Buren	15	9.0	18.2	13.6	14.7	2.85	39
Lakeville	Oakland	18	6.0	16.0	10.0	9.0	2.56	44
Lancelot 1	Gladwin	4	6.0	8.0				
Lancelot 2	Gladwin	4	6.0	9.0				
Lancelot 3	Gladwin	4	5.5	9.2				
Lancer 1	Gladwin	4	7.0	8.0				
Lancer 2	Gladwin	4	7.0	10.0				
Lancer 3	Gladwin	4	7.0	8.0				
Lancer 4	Gladwin	4	5.0	7.0				

APPENDIX 1
2000 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min.	Range Max.	Mean	Median	Standard Deviation	Carlson TSI_{SD} (transparency)
Lancer 5	Gladwin	4	5.0	7.0				
Lansing	Ingham	18	5.9	8.9	7.1	7.0	0.84	49
Leelanau (North)	Leelanau	15	9.0	24.0	15.6	16.0	4.24	38
Leelanau (South)	Leelanau	14	7.5	13.0	10.5	11.0	1.72	43
Leisure	Shiawassee	17	7.3	12.4	9.5	9.6	1.44	45
Lily	Clare	18	9.0	11.4	10.1	10.0	0.63	44
Little Paw Paw 1	Berrien	17	5.0	9.6	6.5	6.5	1.11	50
Little Paw Paw 2	Berrien	17	5.3	7.8	6.4	6.3	0.79	50
Little Paw Paw 3	Berrien	17	5.3	8.3	6.3	6.2	0.86	51
Little Pine Island 1	Kent	14	8.0	13.0	9.4	9.0	1.50	45
Little Pine Island 2	Kent	14	8.0	13.0	9.4	9.0	1.28	45
Little Twin	Cass	16	5.2	14.2	8.8	8.0	2.93	46
Long	Branch	12	4.0	9.5	5.8	5.3	1.50	52
Long	Grand Traverse	18	20.0	49.0	31.3	27.5	9.79	27
Long	Iosco	8	8.0	11.0	10.1	10.6	1.20	44
Long (Sylvania)	Gogebic	11	11.0	17.0	14.1	14.0	2.12	39
Long (West)	Gogebic	12	11.0	17.0	14.4	14.3	2.13	39
Louise	Dickinson	16	13.5	19.0	15.4	15.0	1.53	38
Marl 1	Genesee	16	5.0	9.4	7.4	7.6	1.39	48
Marl 2	Genesee	16	5.1	10.9	8.1	7.7	1.94	47
Marl 3	Genesee	16	5.6	9.4	7.6	7.8	1.09	48
Mary	Dickinson	16	15.0	25.0	17.3	17.0	2.29	36
Mecosta	Mecosta	15	9.0	17.0	11.9	10.5	3.26	41
Mill	Van Buren	10	8.5	16.0	11.8	11.3	3.03	42
Moon	Gogebic	16	18.0	27.0	22.0	22.0	2.50	33
Murray	Kent	17	4.4	11.8	8.6	8.5	1.92	46
North 1	Alcona	18	13.0	18.0	15.4	15.0	1.29	38
North 2	Alcona	18	12.0	16.0	15.1	16.0	1.23	38
Oneida 1	Livingston	16	6.9	10.8	8.4	8.1	1.15	46
Oneida 2	Livingston	16	6.1	13.7	8.5	8.5	2.03	46
Ore	Livingston	18	7.0	14.0	10.4	11.0	1.61	43
Osterhout	Allegan	18	9.0	11.0	9.5	9.0	0.62	45
Oxbow	Oakland	9	10.3	11.6	11.0	11.1	0.42	43
Painter	Cass	18	3.5	10.5	5.3	5.0	1.61	53
Paw Paw 1	Berrien	15	4.2	11.4	7.2	6.7	1.71	49
Paw Paw 2	Berrien	15	4.3	10.8	7.0	6.6	1.77	49
Paw Paw 3	Berrien	15	3.7	10.0	6.7	6.6	1.80	50
Payne	Barry	9	7.0	12.0	9.2	8.5	1.56	45
Pentwater 1	Oceana	3	4.1	5.9				
Pentwater 2	Oceana	2	4.4	6.2				

APPENDIX 1
2000 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min.	Max.	Mean	Median	Standard Deviation	Carlson TSI_{SD} (transparency)
Pentwater 3	Oceana	2	5.2	5.9				
Pentwater 4	Oceana	2	6.6	6.9				
Pleasant 1	Washtenaw	18	7.7	10.9	9.4	9.8	1.14	45
Pleasant 1	Wexford	6	6.3	7.0				
Pleasant 2	Washtenaw	18	7.5	10.7	9.3	9.8	1.13	45
Pleasant 2	Wexford	6	8.5	9.3				
Pleasant 3	Washtenaw	18	7.3	10.5	9.2	9.8	1.08	45
Pratt	Kent	4	3.0	3.0				
Robinson	Newaygo	10	5.0	11.0	7.5	7.0	1.84	48
Round	Kent	11	10.0	14.0	11.8	12.0	1.47	42
Round	Lenawee	18	6.0	22.0	10.3	8.3	4.85	43
Round 1	Mecosta	17	9.0	14.0	11.6	12.0	1.62	42
Round 2	Mecosta	16	9.0	14.0	11.6	12.0	1.55	42
Sage 1	Ogemaw	18	9.5	13.0	10.7	10.5	0.89	43
Sanford	Benzie	11	13.0	30.0	21.0	22.5	5.74	33
Sapphire	Missaukee	18	7.5	9.0	8.2	8.0	0.35	47
School Section 1	Mecosta	18	12.1	14.1	13.1	13.1	0.65	40
School Section 2	Mecosta	18	11.6	14.2	12.9	12.8	0.77	40
School Section 3	Mecosta	18	11.8	14.1	13.1	13.0	0.66	40
Secord 1	Gladwin	12	9.0	10.0	9.5	9.3	0.50	45
Secord 2	Gladwin	12	8.0	9.0	8.5	8.5	0.52	46
Secord 3	Gladwin	12	6.0	7.0	6.3	6.0	0.49	51
Shan-gri-la 1	Livingston	9	5.7	6.2	5.9	5.9	0.18	51
Sherwood	Oakland	18	4.0	7.0	4.7	4.0	1.05	55
Shingle	Clare	18	12.0	17.0	14.0	13.0	1.87	39
Silver 1	Genesee	18	7.6	13.5	11.1	11.7	1.83	42
Silver 2	Genesee	18	8.0	12.5	10.7	11.0	1.49	43
Silver 3	Genesee	18	8.5	12.5	10.5	10.7	1.57	43
Spider 1	Grand Traverse	17	12.0	31.0	19.3	18.0	5.49	34
Spider 2	Grand Traverse	17	13.0	27.0	17.7	16.0	4.73	36
Spider 3	Grand Traverse	17	11.0	22.0	14.5	14.0	3.34	39
Stone Ledge	Wexford	18	8.0	12.0	9.7	9.5	1.41	44
Strawberry 1	Livingston	4	7.3	9.6				
Strawberry 2	Livingston	14	5.2	6.8	6.1	6.2	0.48	51
Sylvan	Newaygo	16	7.0	12.0	9.8	10.0	1.53	44
Tamarack	Livingston	17	8.0	14.0	10.5	10.5	2.05	43
Taylor	Oakland	18	14.5	19.0	16.0	16.0	1.09	37
Upper Sherwood 1	Oakland	17	3.7	5.9	5.1	5.2	0.67	54
Upper Sherwood 2	Oakland	17	3.7	6.1	5.1	5.1	0.77	54
Upper Sherwood 3	Oakland	17	3.7	6.3	5.2	5.6	0.89	53

APPENDIX 1
2000 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of Readings	Range Min.	Range Max.	Mean	Median	Standard Deviation	TSI_{SD} (transparency)
Van Etten	Iosco	18	3.0	6.0	4.1	4.0	1.16	57
Vaughn	Alcona	11	9.5	16.5	13.9	14.5	2.28	39
Viking	Otsego	18	5.0	13.0	8.1	7.0	3.07	47
Vineyard	Jackson	17	6.0	29.0	11.7	8.0	6.70	42
Wabasis	Kent	2	7.6	9.3				
Walled	Oakland	10	9.5	19.0	14.3	14.5	3.08	39
West Twin	Montmorency	18	8.5	14.5	11.9	12.0	1.60	41
White 1	Oakland	18	15.0	19.5	18.1	19.0	1.52	35
White 2	Oakland	18	17.0	22.7	20.3	21.0	1.98	34
White 3	Oakland	18	13.0	19.0	16.7	17.0	1.78	37
Winans (DB)	Livingston	14	7.4	12.9	10.9	11.4	1.74	43
Winans (H)	Livingston	14	7.4	13.0	10.9	11.1	1.66	43
Windover 1	Clare	11	7.5	30.0	19.5	20.0	6.32	34
Windover 2	Clare	11	7.5	27.0	19.3	21.0	5.82	34
Wolf	Lake	15	9.0	11.5	11.0	11.0	0.71	43
Woods	Kalamazoo	11	6.0	15.5	10.9	11.5	3.42	43
Zukey 1	Livingston	13	7.0	14.0	10.0	10.0	2.27	44
Zukey 2	Livingston	18	7.5	16.0	10.6	10.4	2.51	43

APPENDIX 2
2000 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring - Overturn (Volunteer)	(DEQ)	Late - Summer (Volunteer)	(DEQ)	Carlson TSI TP (summer TP)
Ann	Benzie	4 T		5		27
Arbutus	Gr. Traverse	2 T		15		43
Arnold	Clare	1 T		15	19	43
Avalon	Montmorency	1 T		8		34
Baldwin	Cass	7		11		39
Baldwin	Montcalm	22		21		48
Barlow	Barry	7		7		32
Baseline	Livingston	7		19		47
Bass	Kent	9		16		44
Bass	Livingston	5				
Bear	Kalkaska	2 T		15		43
Big Bear	Otsego	*		11		39
				(10)		
Big Bradford	Otsego	4 T		*		
		(2 T)				
Big Crooked	Van Buren	21		13		41
Big Pine Island	Kent	17		*		
Birch	Cass	7		8	9	34
Blue	Mason	16		18		46
Blue	Mecosta	3 T		11	9	39
Burkhart	Washtenaw	12		11		39
Campbell	Kent	36	30	21		48
Cedar	Van Buren	6		13		41
				(12)		
Chain	Iosco	11		17		45
Christiana	Cass	19		15		43
Clear	Jackson	8		15		43
Clear	Berrien	10		10		37
Clifford 1	Montcalm	9		*		
Clifford 2	Montcalm	13		*		
Corey	St. Joseph	4 T		8	14	34
Cowan	Kent	52		36		56
Cranberry	Kent	54		157		77
Crockery	Ottawa	58		26		51
		(60)				
Crooked	Clare	7		24		50
				(21)		
Crystal	Benzie	9		*		

APPENDIX 2
2000 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring - Overturn (Volunteer)	Spring - Overturn (DEQ)	Late - Summer (Volunteer)	Late - Summer (DEQ)	Carlson TSI TP (summer TP)
Cub	Kalkaska	3 T		16		44
Dean	Kent	12		12		40
				(11)		
Devils	Lenawee	5	5	15		43
Dewey	Cass	18		24		50
Diamond	Cass	8		6		30
Donnell	Cass	3 T		9		36
				(9)		
Eagle	Allegan	11		15		43
				(15)		
E. Twin	Montmorency	3 T		18		46
Evans	Lenawee	6		15		43
Fair	Barry	9		*		
Fenton	Genesee	13	13	14		42
			(10)			
Fish	Van Buren	17		*		
Forest	Oakland	*		*		
Gill	Livingston	20		16		44
Gunn	Mason	1 T		15		43
Hackert	Mason	5		15		43
Hamburg	Livingston	10		15		43
Hamilton	Dickinson	13		15		43
Harper	Lake	5		16		44
Higgins	Roscommon	3 T		*		
Horsehead	Mecosta	9		11	15	39
				(10)		
Hubbard	Alcona	7		6		30
Hunter's	Alcona	23		14		42
Hutchins	Allegan	*		*		
Island	Gr. Traverse	3 T	8	17		45
		(1 T)				
Juno	Cass	23		30		53
K.P.	Crawford	2 T		7		32
				(6)		
Keeler	Van Buren	6		14		42
Klinger	St. Joeseph	5		9		36
		(4 T)				
Lake George 1	Clare	12				

APPENDIX 2
2000 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring - Overturn (Volunteer)	Spring - Overturn (DEQ)	Late - Summer (Volunteer)	Late - Summer (DEQ)	Carlson TSITP (summer TP)
Lake George 2	Clare	17		22	18	49
Lake George 3	Clare	12		24		50
Lakeville	Oakland	9		15		43
				(11)		
Lancelot	Gladwin	16		21		48
Lancer	Gladwin	7		27		52
Lansing	Ingham	12		22		49
Lily	Clare	13		16		44
		(11)				
Little Crooked	Van Buren	*		13		41
Little Pine Island	Kent	*		20		47
Long	Gogebic	8		12		40
		(10)		(10)		
Long	Gr. Traverse	10		14		42
Long	Iosco	12		14		42
Louise	Dickinson	48		10		37
Margrethe	Crawford	2 T		9		36
		(6)				
Marl	Genesee	12	11	11		39
Mary	Dickinson	6		14		42
McGilvery	Gladwin	15		*		
Mecosta	Mecosta	3 T		13	13	41
Moon	Gogebic	8		9		36
Murray	Kent	24	29	10		37
		(22)				
Nepessing	Lapeer	17		32		54
				(33)		
North	Alcona	8		*		
N. Twin	Cass	6		10		37
Oneida	Livingston	8		17		45
Ore	Livingston	18		25		51
Osterhout	Allegan	7		19		47
		(8)				
Oxbow	Oakland	20		16		44
Painter	Cass	21		40		57
Paw Paw 1	Berrien	26		*		
Paw Paw 2	Berrien	23		*		
Pentwater	Oceana	5		21		48

APPENDIX 2
2000 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring - Overturn (Volunteer)	Spring - Overturn (DEQ)	Late - Summer (Volunteer)	Late - Summer (DEQ)	Carlson TSI TP (summer TP)
Pleasant	Washtenaw	19		*		
Pleasant	Wexford	13		26		51
Portage	Washtenaw	9		16		44
				(13)		
Pratt	Kent	36		25		51
Reeds	Kent	29		40		57
Robinson	Newaygo	45		*		
Round	Kent	20		20		47
Round	Lenawee	6	11	13		41
		(7)				
Round	Mecosta	14		18	17	46
					(17)	
S. Twin	Cass	9		11		39
Sage	Ogemaw	10		10		37
		(7)				
Sanford	Benzie	1 T		20		47
Sapphire	Missaukee	9		16		44
School Section 1	Mecosta	6		8		34
School Section 3	Mecosta	5		12		40
Secord	Gladwin	43		13		41
Shan-gri-la	Livingston	10		15		43
Shingle 1	Clare	12		19		47
Shingle 2	Clare	12		22	20	49
				(22)		
Silver	Genesee	9	7	7		32
		(8)				
Spider	Gr. Traverse	5	10	20		47
Stone Ledge	Wexford	11	17	34		55
Strawberry	Livingston	17		33		55
Tamarack	Livingston	20		14		42
		(16)				
Taylor	Oakland	22		19		47
Upper Sherwood	Oakland	17		*		
		(17)				
Van Etten	Iosco	31		41		58
Vaughn	Alcona	10		18		46
Viking	Otsego	14		25		51
Vineyard	Jackson	3 T		10		37

APPENDIX 2
2000 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring - Overturn (Volunteer)	Spring - Overturn (DEQ)	Late - Summer (Volunteer)	Late - Summer (DEQ)	Carlson TSI$_{TP}$ (summer TP)
Wabasis	Kent	29		17		45
Walled	Oakland	16		*		
West Londo	Iosco	18		16		44
W. Twin	Montmorency	3 T		12		40
White	Oakland	16		15		43
Winans	Livingston	9		15		43
				(15)		
Windover	Clare	2 T		*		
Wolf	Lake	3 T		*		
Woods	Kalamazoo	22		27		52
Zukey	Livingston	7		10		37

* no lake sample received, or sample turned in to late to process
T value reported is less than criteria of detection (5 ug/l)
( ) values in parenthesis are replicate sample results for QA/QC program
(note: late-summer data for samples from Cadillac, Grand Rapids, Jackson, Livonia, Long Lake, and Plainwell Districts coded, recommeded laboratory holding time was exceeded before analysis)

2000 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) Sampling Event May	June	July	Aug.	Sept.	Mean	Median	Standard Deviation	Carlson TSI_{CHL} (chlorophyll)
Ann	Grand Traverse	3	2	1	2	2	2.0	2	0.71	37
Arbutus	Grand Traverse	2	<1	4	3	5	2.9	3	1.75	41
Arnold	Clare	2	<1	2	3	2	1.9	2	0.89	37
						(3),[3,(3)]				
Avalon	Montmorency	*	*	1	2	1				
Baldwin	Cass	*	*	*	*	*				
Baldwin	Montcalm	2	2	6	8	10	5.6	6	3.58	48
Barlow	Barry	2	3	3	4	3	3.3	3	0.50	41
Bass	Kent	*	<1	5	6	6	4.4	6	2.63	47
Big Bear	Otsego	1	1	2	3	4	2.2	2	1.30	37
				(2)						
Big Bradford	Otsego	4	<1	2	*	*				
Big Crooked	Van Buren	5	3	3	4	5	3.8	4	0.96	43
					[2]					
Big Pine Island	Kent	6	7	7	*	*				
Birch	Cass	5	2	1	2	3	2.0	2	0.82	37
						[2]				
Blue	Mecosta	<1	2	3	3	2	2.1	2	1.02	37
						[2]				
Burkhart	Washtenaw	2	4	3	4	6	3.8	4	1.48	44
Cedar	Van Buren	2	2	4	4	5	3.3	3	1.50	41
Christiana	Cass	2	3	8	6	6	5.0	6	2.45	48
Clear	Berrien	2	6	3	6	8	5.0	6	2.45	48
Corey	St. Joseph	2	4	4	4	4	3.6	4	0.89	44
						[3]				
Cowan	Kent	<1	9	16	11	24	12.1	11	8.69	54
Crooked	Clare	3	<1	4	3	6	3.3	3	1.99	41
Crystal	Benzie	*	*	*	*	*				
Devils	Lenawee	*	2	7	5	4	4.3	4	2.52	44
			[3]							
Dewey	Cass	6	5	8	15	26	11.3	7	9.91	50
					(13)					
Diamond	Cass	<1	<1	2	5	4	2.4	2	2.04	37
East Twin	Montmorency	3	3	3	5	<1	2.9	3	1.60	41
Evans	Lenawee	2	7	5	3	5	4.4	5	1.95	46
Fair	Barry	2	6	8	*	*				
Fenton	Genesee	2	2	2	2	3	2.2	2	0.45	37
Fish	Van Buren	15	2	9	6	17	9.8	9	6.22	52

APPENDIX 3
2000 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) Sampling Event May	June	July	Aug.	Sept.	Mean	Median	Standard Deviation	Carlson TSI_{CHL} (chlorophyll)
				[11]						
Gunn	Mason	2	3	4	5	5	3.8	4	1.30	44
Hackert	Mason	1	3	2	2	2	2.0	2	0.71	37
Harper	Lake	1	2	2	2	3	2.0	2	0.71	37
Higgins	Roscommon	*	*	*	*	*				
Horsehead	Mecosta	3	3	3	4	5	3.6	3	0.89	41
						[4]				
Hubbard	Alcona	*	4	2	1	2	2.3	2	1.26	37
Island	Grand Traverse	3	<1	2	3	2	2.1	2	1.02	37
			(<1)							
K.P.	Crawford	*	*	*	*	*				
Keeler	Van Buren	3	3	<1	3	4	2.7	3	1.30	41
		[2]								
Juno	Cass	2	5	17	12	13	9.8	12	6.14	55
Klinger	St. Joseph	<1	2	3	4	3	2.4	3	1.49	40
Lake George	Clare	<1	7	7	6	12	6.5	7	4.09	50
						[10]				
Lancelot	Gladwin	*	2	11	3	3	4.8	3	4.19	41
Lancer	Gladwin	*	4	4	3	5	4.0	4	0.82	44
Lansing	Ingham	12	4	7	5	3	6.2	5	3.56	46
Lily	Clare	<1	2	2	2	2	1.6	2	0.75	37
Little Crooked	Van Buren	3	3	5	7	4	4.3	4	1.89	43
					[5]					
Long	Grand Traverse	2	1	2	1	3	1.8	2	0.84	37
Long	Iosco	2	4	4	6	4	4.0	4	1.41	44
McGilvery	Gladwin	*	*	*	*	*				
Mecosta	Mecosta	<1	1	2	4	2	1.9	2	1.34	37
						[3]				
Moon	Gogebic	2	2	3	5	4	3.2	3	1.30	41
						(6)				
Nepessing	Lapeer	4	7	8	8	21	10.0	8	7.53	50
		(4)								
Ore	Livingston	4	3	3	8	12	6.0	4	3.94	44
			(2)							
Osterhout	Allegan	2	4	6	5	4	4.2	4	1.48	44
				(8),[9]						
Painter	Cass	4	2	11	31	11	11.8	11	11.48	54
Paw Paw	Berrien	*	*	7	*	*				

APPENDIX 3
2000 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) Sampling Event May	June	July	Aug.	Sept.	Mean	Median	Standard Deviation	Carlson TSI_{CHL} (chlorophyll)
Pentwater	Oceana	4	5	7	21	12	9.8	7	6.98	50
Reeds	Kent	4	15	15	6	4	8.8	6	5.72	48
						(*)				
Robinson	Newaygo	15	10	30	*	*				
Round	Kent	2	5	19	7	8	8.2	7	6.46	50
Round	Lenawee	<1	1	5	5	5	3.3	5	2.33	46
		(<1)	[2,(2)]							
Round	Mecosta	4	3	9	9	12	7.4	9	3.78	52
						[7]				
Sage	Ogemaw	6	4	4	3	5	4.4	4	1.14	44
					(4)					
Sapphire	Missaukee	3	2	4	4	4	3.4	4	0.89	44
School Section	Mecosta	<1	<1	3	4	5	2.6	3	2.04	41
Secord	Gladwin	3	3	2	3	2	2.6	3	0.55	41
Shingle	Clare	<1	3	3	8	7	4.3	3	3.11	41
						[4]				
Spider	Grand Traverse	<1	<1	1	5	4	2.2	1	2.14	31
			(<1)							
Stone Ledge	Wexford	4	13	4	2	11	6.8	4	4.87	44
Twin (North)	Cass	3	3	4	4	4	3.6	4	0.55	44
Twin (South)	Cass	2	4	4	4	5	3.8	4	1.10	44
Van Etten	Iosco	2	1	2	47	11	12.6	5	19.65	46
Viking	Otsego	4	4	24	23	51	21.2	23	19.31	61
Vineyard	Jackson	<1	3	3	3	2	2.3	3	1.10	41
Walled	Oakland	2	2	6	*	*				
West Twin	Montmorency	4	1	4	3	3	3.0	3	1.22	41
White	Oakland	*	*	*	4	4				
Windover	Clare	2	2	1	*	*				
Woods	Kalamazoo	2	23	18	6	8	11.4	8	8.76	51

* no sample received, sample turned in to late to process, sample processed incorrectly or contaminated
( ) values in parenthesis are replicate sample results for QA/QC program
[ ] values in brackets are DEQ side-by-side sample results for QA/QC program

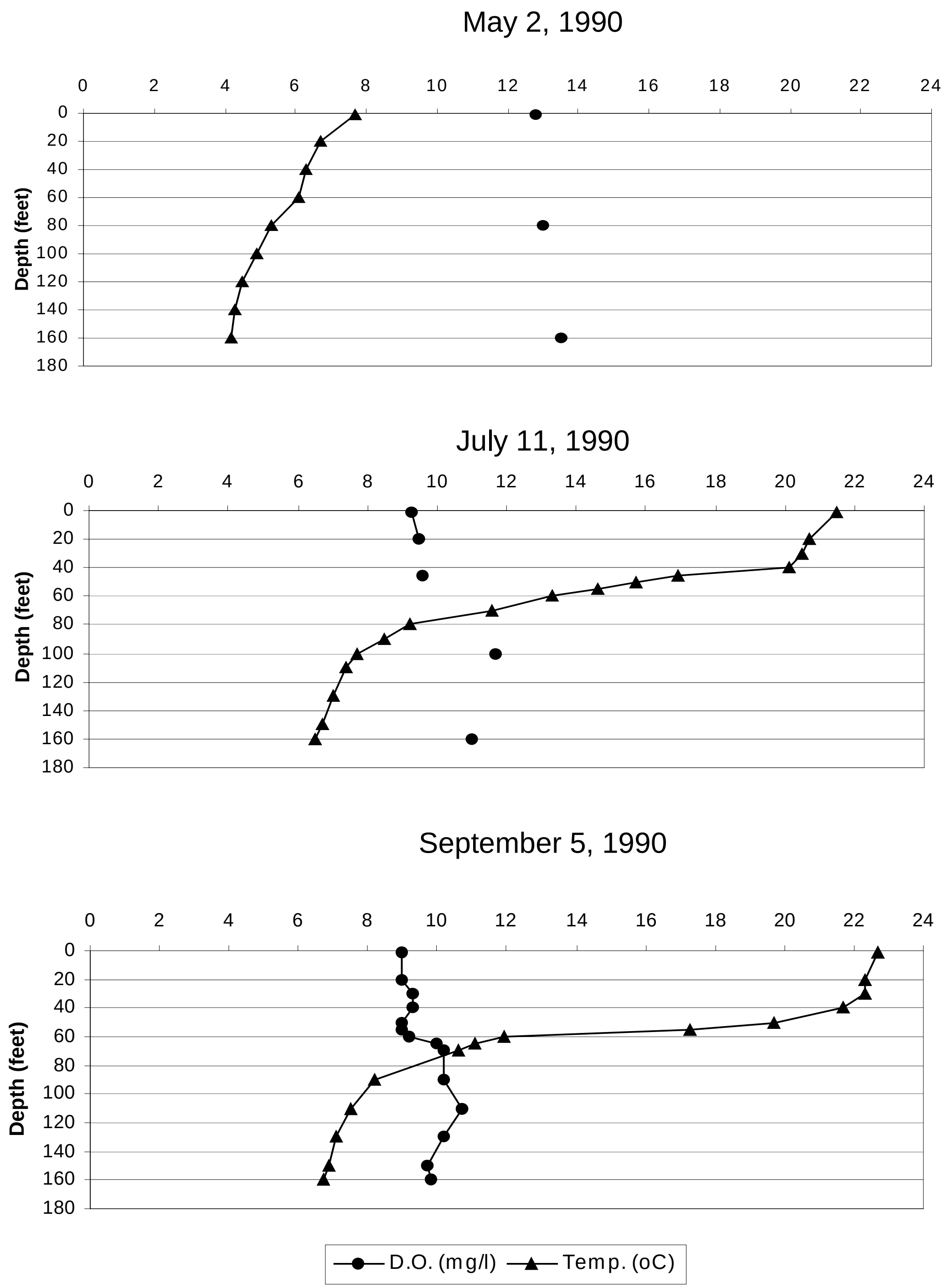
APPENDIX 4
2000 COOPERATIVE LAKES MONITORING PROGRAM
DISSOLVED OXYGEN AND TEMPERATURE RESULTS

County	Participating Lakes
St. Joseph	Corey Lake
Cass	Painter Lake
	Juno Lake
	Christiana Lake
	Birch Lake
	Diamond Lake
Lenawee	Devils Lake
	Round Lake
	Evans Lake
Jackson	Vineyard Lake
Mecosta	Mecosta Lake
	Round Lake
	Blue Lake
	Horeshead Lake
	School Section Lake
Clare	Lake George
	Shingle Lake
	Windover Lake
	Arnold Lake

On the following pages five, representative dissolved oxygen/temperature patterns are illustrated. The first is of a high quality oligotrophic lake, which has a very large hypolimnion volume. The lake maintains high oxygen levels in the hypolimnion all summer. The second pattern represents a good quality oligotrophic/mesotrophic lake with a large hypolimnion volume. It retains some oxygen in the hypolimnion all summer, but the deepest parts of the lake do drop to zero dissolved oxygen. The third pattern is of a good quality oligotrophic/mesotrophic lake with a small hypolimnion volume. This lake keeps some dissolved oxygen in the hypolimnion into mid-summer, but by late summer the entire hypolimnion is devoid of oxygen. The fourth pattern is a productive eutrophic lake with a small hypolimnion. Within a few weeks of spring overturn the hypolimnion has lost all oxygen. This anaerobic condition persists all summer. The final pattern is a productive eutrophic lake, which is too shallow to maintain stratification. It loses oxygen in the deeper water, but summer storms drive wave energy into the deepest parts of the lake renewing the oxygen supply to these waters.

Oligotrophic Lake with a Very Large Volume Hypolimnion

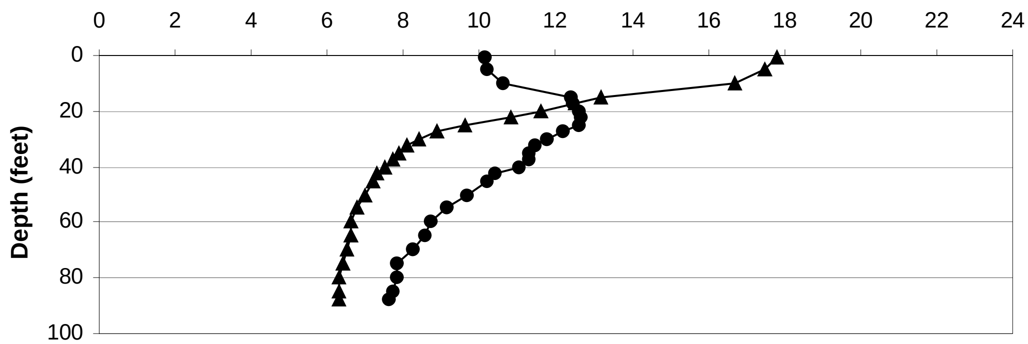
Elk Lake in Grand Traverse County is an oligotrophic lake with a large volume hypolimnion. As an oligotrophic lake, it produces less organic material that must be decomposed. Its large volume hypolimnion has a substantial oxygen supply that is not reduced significantly by the decomposition of the limited organic material which falls into the hypolimnion during the summer. Consequently, dissolved oxygen levels remain high in the hypolimnion all summer long. In fact, dissolved oxygen levels are actually higher in the upper hypolimnion than at the water surface. The colder hypolimnion water is able to hold more oxygen than the warmer epilimnion (surface) waters.



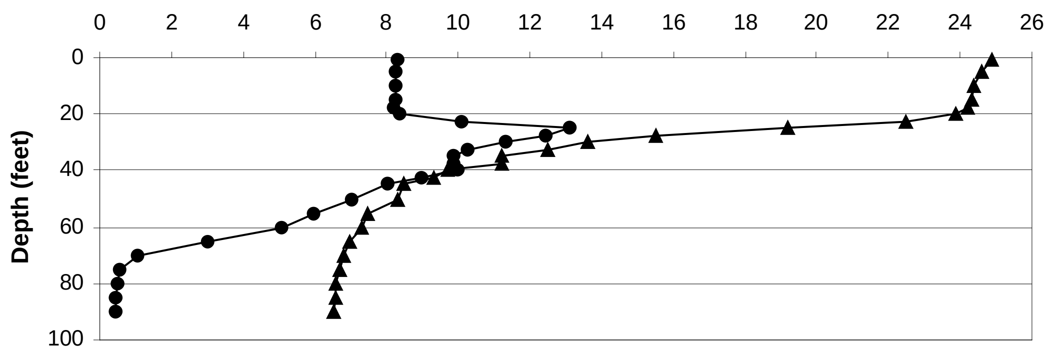
Oligotrophic/Mesotrophic Lake with a Large Volume Hypolimnion

Birch Lake in Cass County is an oligotrophic/mesotrophic lake with a large hypolimnion. It produces minor amounts of organic material that must be decomposed. Its hypolimnion has a substantial oxygen supply that is gradually depleted by the decomposition of the organic material. Dissolved oxygen levels remain high in the hypolimnion into mid-summer. By August oxygen is gone in the deepest waters, but the upper hypolimnion retains some oxygen even into late summer (September). Also, note that oxygen concentrations at mid-depth (20 to 40 feet) are higher than at the surface. This is due to a layer of deep algae producing oxygen in the colder water, which can hold more dissolved oxygen.

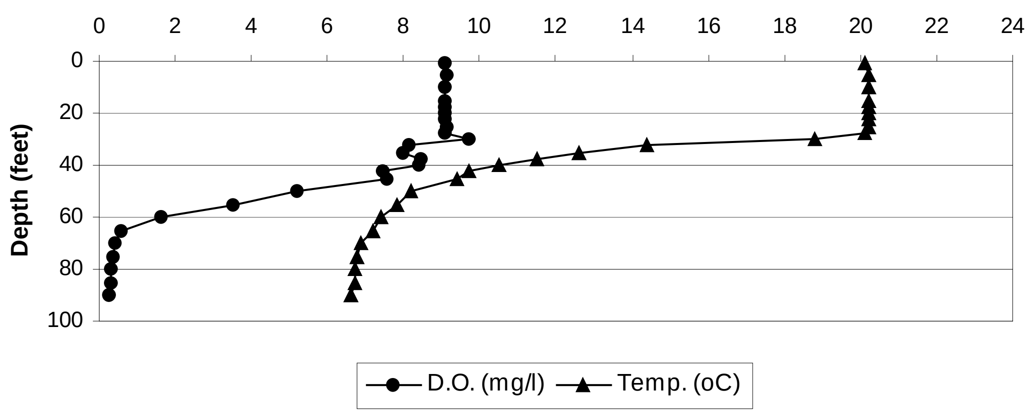
May 5, 2000



August 3, 2000

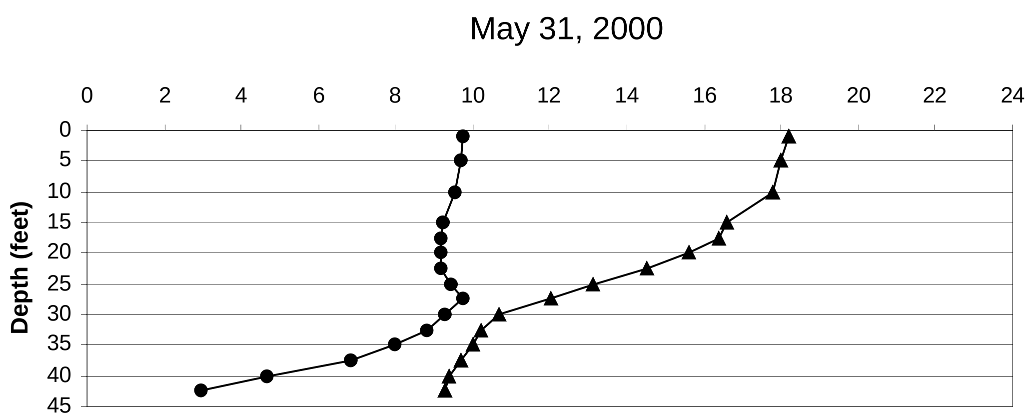


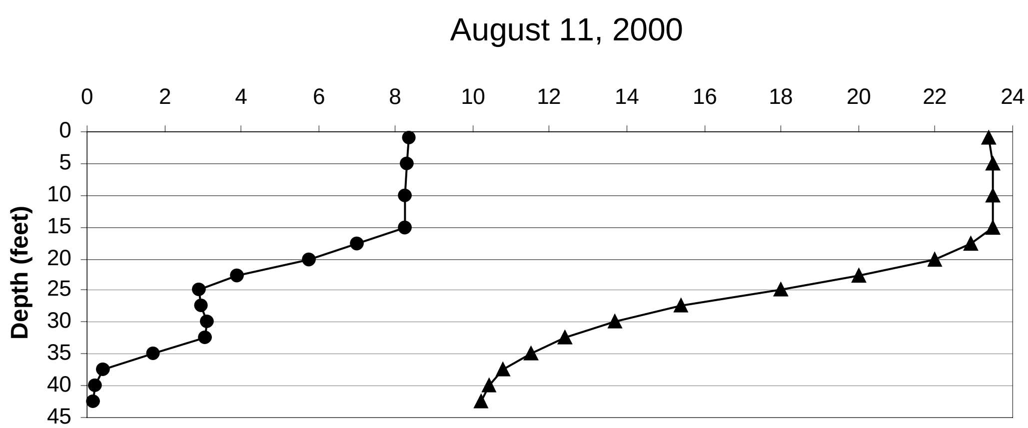
September 8, 2000

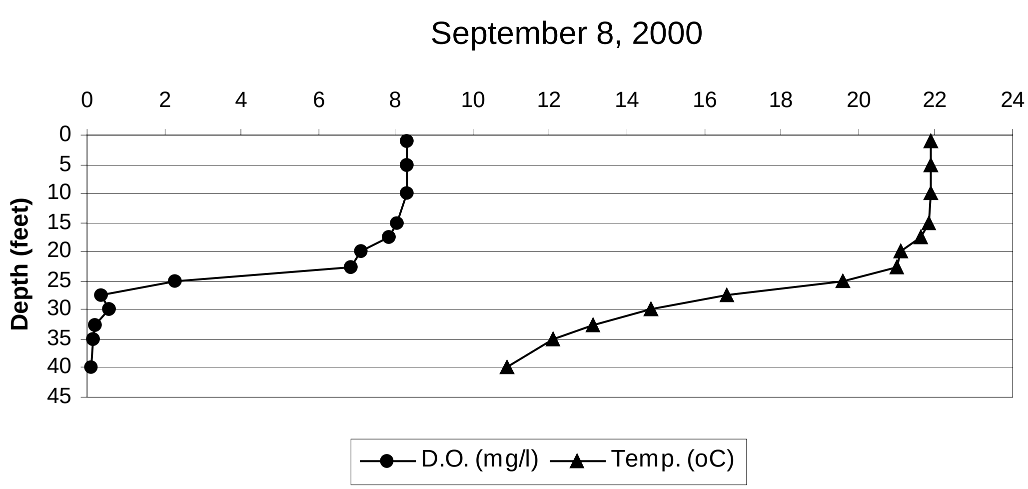


Oligotrophic/Mesotrophic Lake with a Small Volume Hypolimnion

Blue Lake in Mecosta County is an oligotrophic/mesotrophic lake with a small volume hypolimnion. As an oligotrophic/mesotrophic lake it produces minor amounts of organic material that must be decomposed. Its hypolimnion has a limited oxygen supply that is gradually depleted by the decomposition of the organic material which falls into the hypolimnion during the summer. Dissolved oxygen levels remain high in the hypolimnion into mid-summer, but by August oxygen is gone in the deepest waters, and by late-summer (September) the entire hypolimnion is without oxygen.

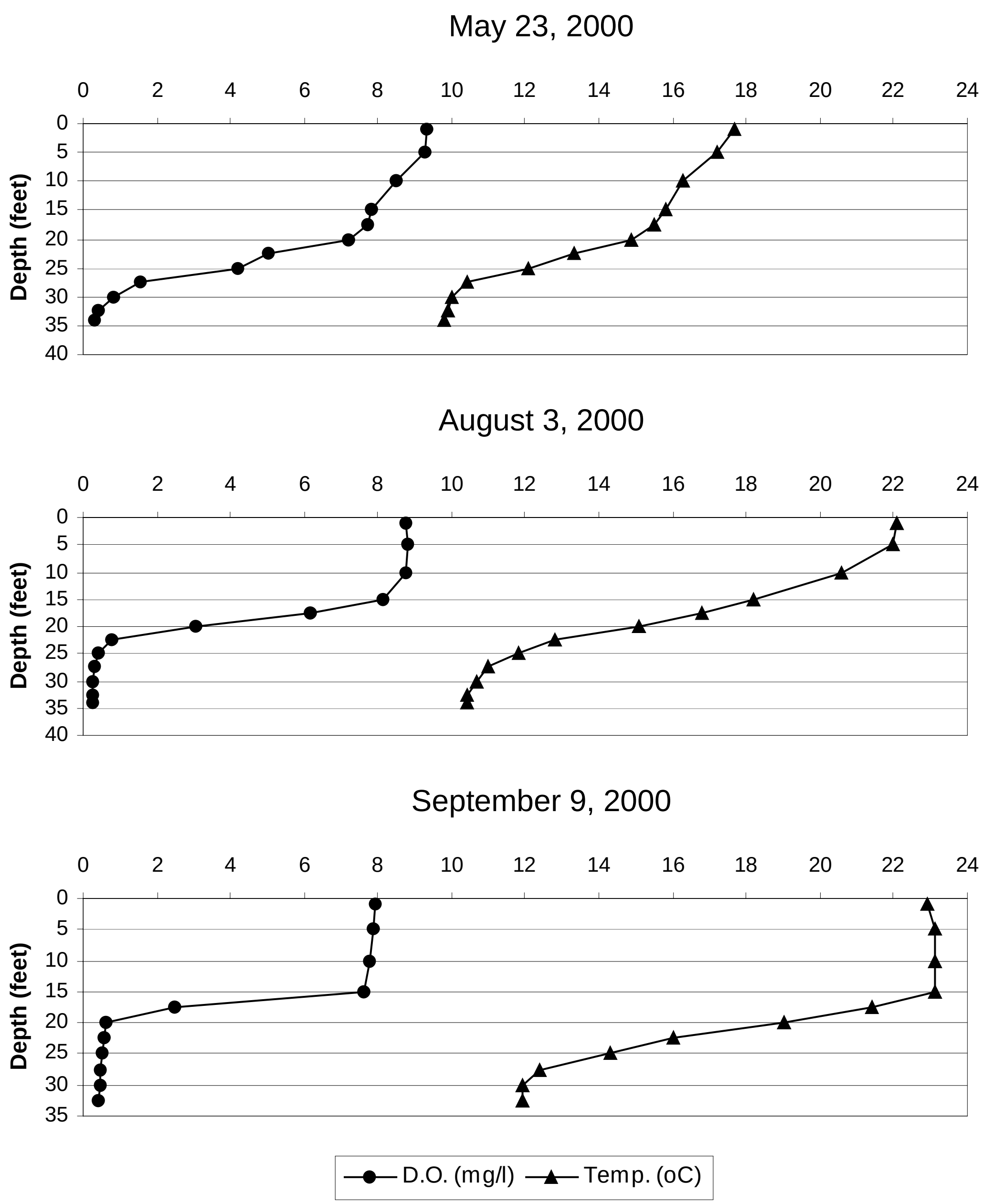






Eutrophic Lake with a Small Volume Hypolimnion

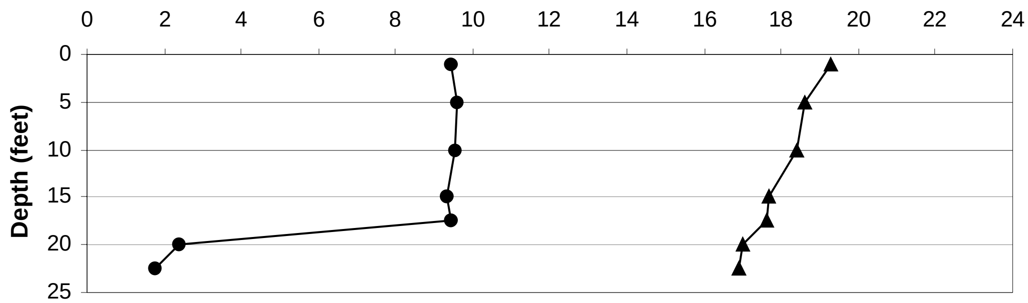
Juno Lake in Cass County is a eutrophic lake with a small volume hypolimnion. As a eutrophic lake it produces abundant amounts of organic material that must be decomposed. Its hypolimnion has a small oxygen supply that is rapidly depleted by the decomposition of the organic material which falls into the hypolimnion during the summer. Dissolved oxygen levels in the hypolimnion drop to near zero within a few weeks of spring overturn. With no oxygen re-supply from the upper waters and atmosphere, the hypolimnion is devoid of oxygen all summer.



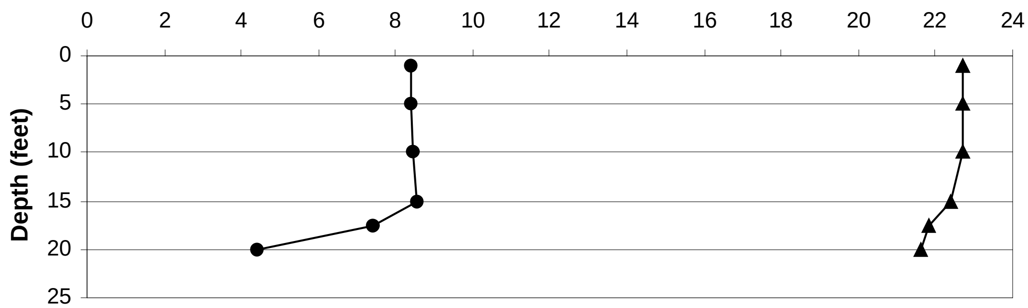
Shallow Mesotrophic Lake that does not Maintain Summer Stratification

School Section Lake in Mecosta County is a shallow mesotrophic lake with insufficient depth to maintain stratification all summer. As a mesotrophic lake it produces moderate amounts of organic material that must be decomposed. Its hypolimnion, if present, has a very small oxygen supply that is rapidly depleted by the decomposition of the organic material which falls into the deeper parts of the lake during the summer. Dissolved oxygen levels in the deeper water can drop to zero within a few weeks of spring overturn. Because the lake is shallow, summer storms can drive wave energy into the deepest parts of the lake breaking up any stratification present and re-suppling the deep water with oxygen. In the calm periods between storms, dissolved oxygen is again quickly lost.

May 31, 2000



June 15, 2000



July 16, 2000