COOPERATIVE LAKES MONITORING PROGRAM

Michigan's Citizen Volunteer
Partnership for Lakes

"MI Lakes - Ours to Protect"

ANNUAL SUMMARY REPORT

2004

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

MiCorps
Monitoring Michigan's Water Quality

Michigan's Lakes and the Tragedy of the Commons

In 1968, Garrett Hardin published his classic environmental essay *The Tragedy of the Commons* in the journal of *Science*. In it he succinctly depicted the degradation and exploitation of the environment to be expected whenever many individuals share a common resource, such as federal rangeland, state and national parks, the atmosphere, streams and lakes. Using a community pasture as an example, he explained how each herder added more and more animals to his herd until the pasture was destroyed by overgrazing. Each herder benefited monetarily by adding animals to his herd, but bore no responsibility for the pasture and its sustainability.

While Hardin popularized the tragedy of the commons, others before him identified the characteristic fate of common property. In fact, two thousand years ago, Aristotle in his book *Politics* stated, "what is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest". Lakes and streams are clearly a common property, shared by the riparian property owners and the community of citizens who use and enjoy the water, fish, wildlife and aesthetic appeal.

True to the tragedy of the commons, most lakes provide countless hours of recreational enjoyment for numerous users. Some receive waste discharges from municipal and industrial sources. Nearly all are impacted by urban and agricultural development and stormwater runoff, septic systems and lawn fertilizers, increasing weed growth, algae blooms and muck accumulation. Very few are managed to sustain their quality for future generations. With over 11,000 lakes in Michigan, limited state agency staff can provide only partial oversight and must concentrate on the most serious problems. Local government although possessing management tools like Lake Improvement Boards and Watershed Councils address police and fire protection, schools, infrastructure development, and waste management as higher priorities. Riparian property owners who should be the leading advocates for lake protection and promoting collaborative management partnerships are more interested in recreational activities such as swimming, fishing and boating.

Unfortunately most lakes are fulfilling Hardin's principle of the tragedy of the commons. Only a few exceptional communities are proof that the principle is not an irrefutable law of human society. When communities accept ownership in their natural resources, lakes and streams can be sustainable commons not only in quantity but quality. The more each lake owner and user invests in this responsibility the more certain our children will be, that they will “inherit our water resources in the same quality that we the present generation borrowed it from them”. Working together we can protect Michigan’s lakes.

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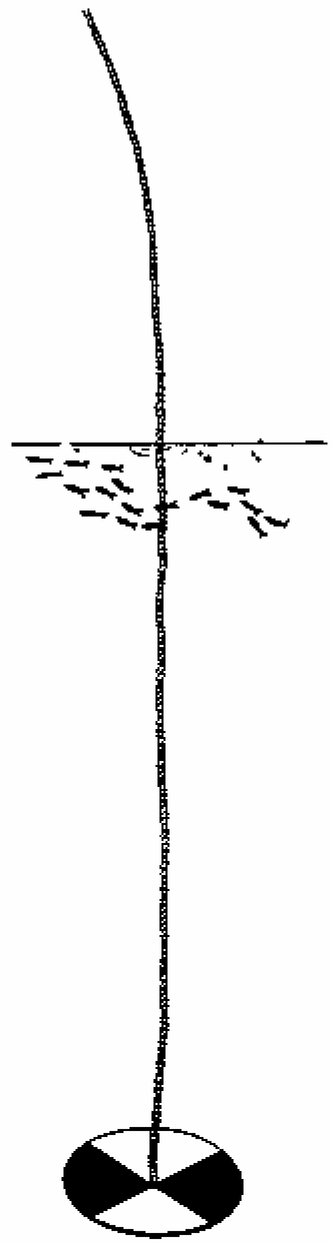

DATA CORRECTIONS FROM PREVIOUS REPORTS

Data tabulation errors were identified and the following data corrections made.

- **Harper Lake, Lake County — Spring Total Phosphorus 2002, Volunteer Sample is correct, Replicate Sample should be 12 ug/l instead of 19 ug/l.**

- **Austin Lake, Osceola County — Spring Total Phosphorus 2002, Volunteer Sample should be 19 ug/l instead of 17 ug/l and the Replicate Sample should be17 ug/l instead of 9 ug/l.**

If you believe that the tabulated data for your lake in this Report are in error please contact Ralph Bednarz, CLMP program coordinator by telephone at 517-335-4211 or email at bednarzr@michigan.gov. It is important for the credibility of the CLMP that all data be accurately reported. When tabulation and reporting errors are found they need to be identified and a correction statement issued. We appreciate your support in the review of CLMP data and maintaining a high level of quality for the Program.

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 human 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) Water Bureau 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 is also a principal part of the Michigan Clean Water Corps (MiCorps). 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

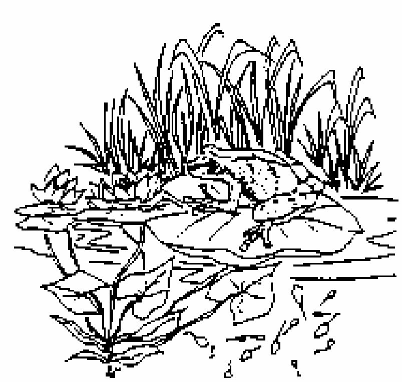
A lake's condition is influenced by many factors, such as the amount of recreational use it receives, shoreline development, and water quality. Lake *water quality* is a general term covering many aspects of lake chemistry and biology. The health of a lake is determined by its water quality.

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



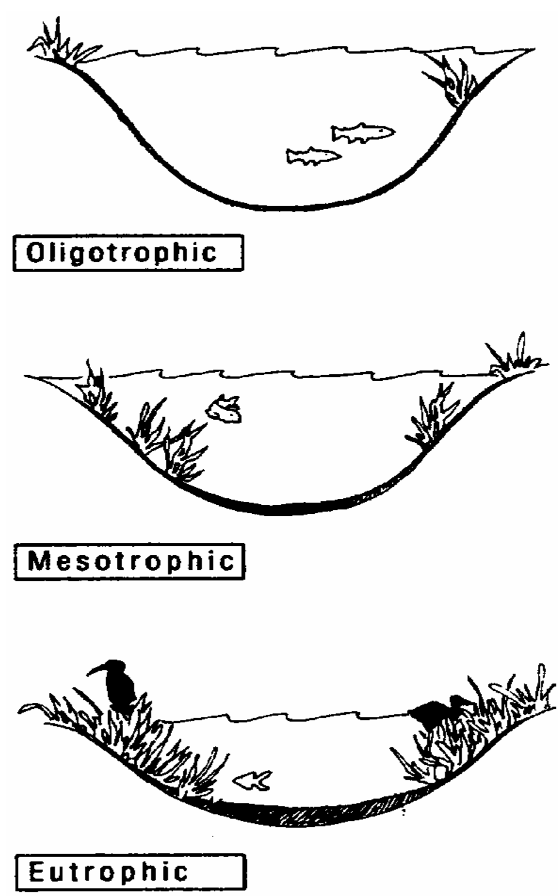
Increasing lake productivity can impact water quality and result in problems such as excessive weed growth, algal blooms, and mucky bottom sediments. *Productivity* refers to the amount of plant and animal life that can be produced within the lake.

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

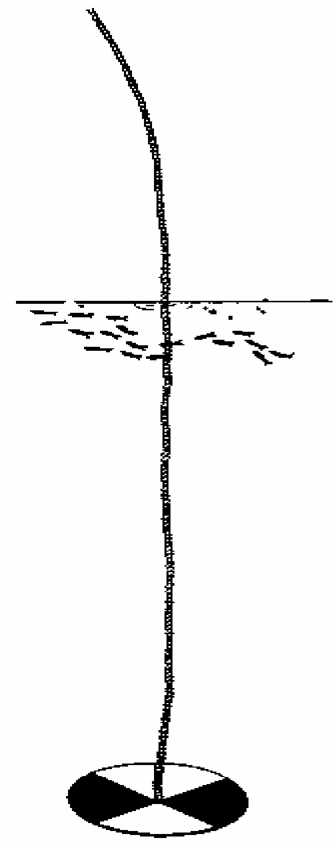
A lake's ability to support plant and animal life defines its level of productivity, or *trophic state.* Lakes are commonly classified based on their productivity. Low productive *oligotrophic* lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient *dissolved 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 is 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 pro gressing 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.

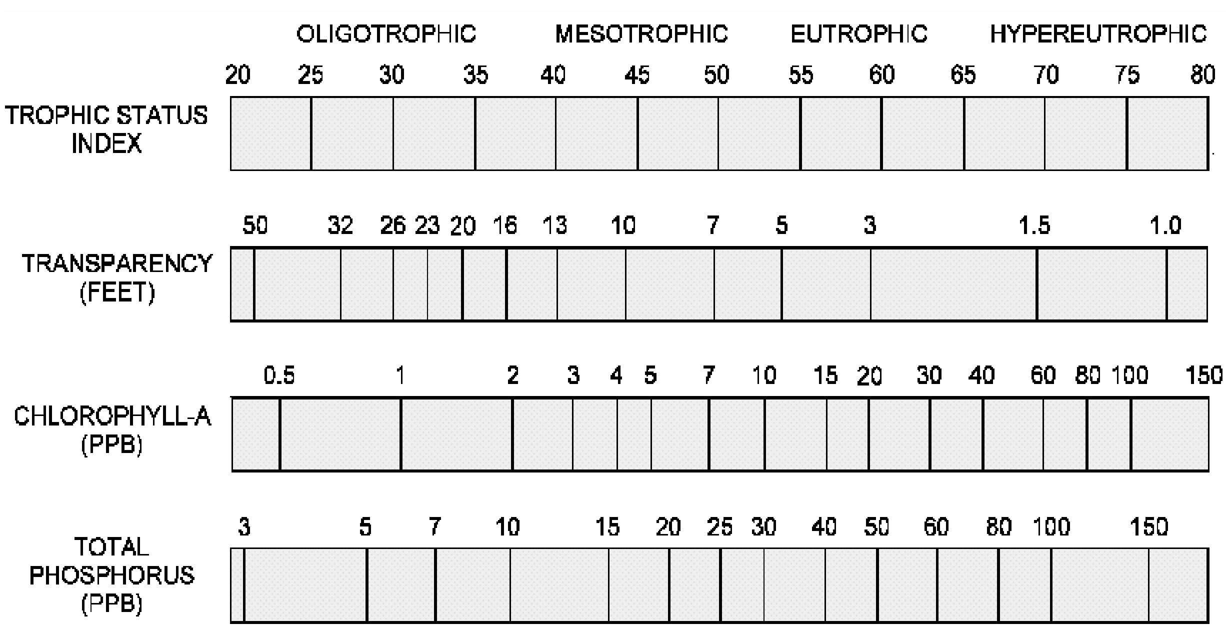
For those preferring to use the general lake classification scheme, the TSI values which correspond approximately with the trophic state terms are illustrated in the figure below. However, the dividing lines between these categories are somewhat arbitrary since lake water quality is a continuum and there 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.

OTHER MEASURES OF

CARLSON'S TROPHIC STATE INDEX



(Source: Minnesota Pollution Control Agency)

LAKE PRODUCTIVITY

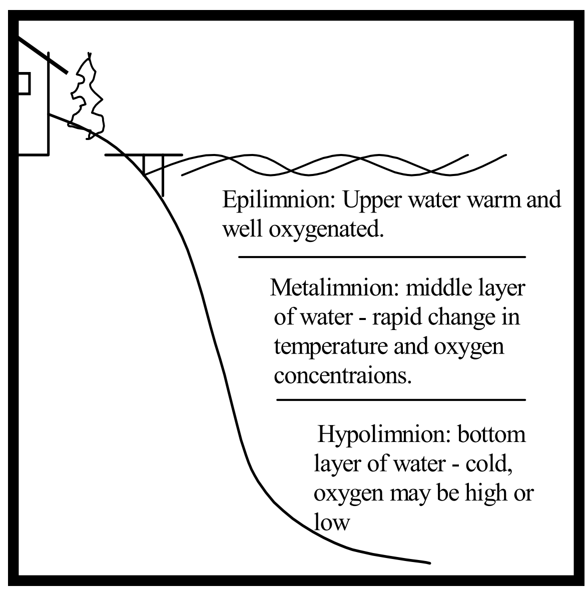
Dissolved Oxygen (DO) and Temperature

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 Celsius. In the winter there is only a few degrees difference between the water under the ice (0 degrees Celsius) and the water on the bottom (4 degrees Celcius). 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.

This figure shows how lakes over 25 feet deep are



divided into three layers during the summer.

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.

Aquatic Plant Mapping

A major component of the plant kingdom in lakes are the large, leafy, rooted plants. Compared to the microscopic algae the rooted plants are large. Sometimes they are collectively called the "macrophytes". "Macro" meaning large and "phyte" meaning plant. It is these macrophytes that some people sometimes complain about and refer to as lake weeds.

Far from being weeds macrophytes or rooted aquatic plants are a natural and essential part of the lake, just as grasses, shrubs and trees are a natural part of the land. Their roots are a fabric for holding sediments in place, reducing erosion and maintaining bottom stability. They provide habitat for fish, including structure for food organisms, nursery areas, foraging and predator avoidance. Waterfowl, shore birds and aquatic mammals use plants to forage on and within, and as nesting materials and cover.

Though plants are important to the lake, overabundant plants can negatively affect fish populations, fishing and the recreational activities of property owners. Rooted plant populations increase in abundance as nutrient concentrations increase in the lake. As lakes become more eutrophic rooted plant populations increase. They are rarely a problem in oligotrophic lakes, only occasionally a problem in mesotrophic lakes, sometimes a problem in eutrophic lakes and often a problem in hypereutrophic lakes.

In certain eutrophic and hypereutrophic lakes with abundant rooted plants it may be advantageous to manage the lake and its aquatic plants for the maximum benefit of all users. To be able to do this effectively it is necessary to know the plant species present in the lake and their relative abundance and location. A map of the lake showing the plant population locations and densities greatly aids management projects.

CLMP PROJECT 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 2004 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.

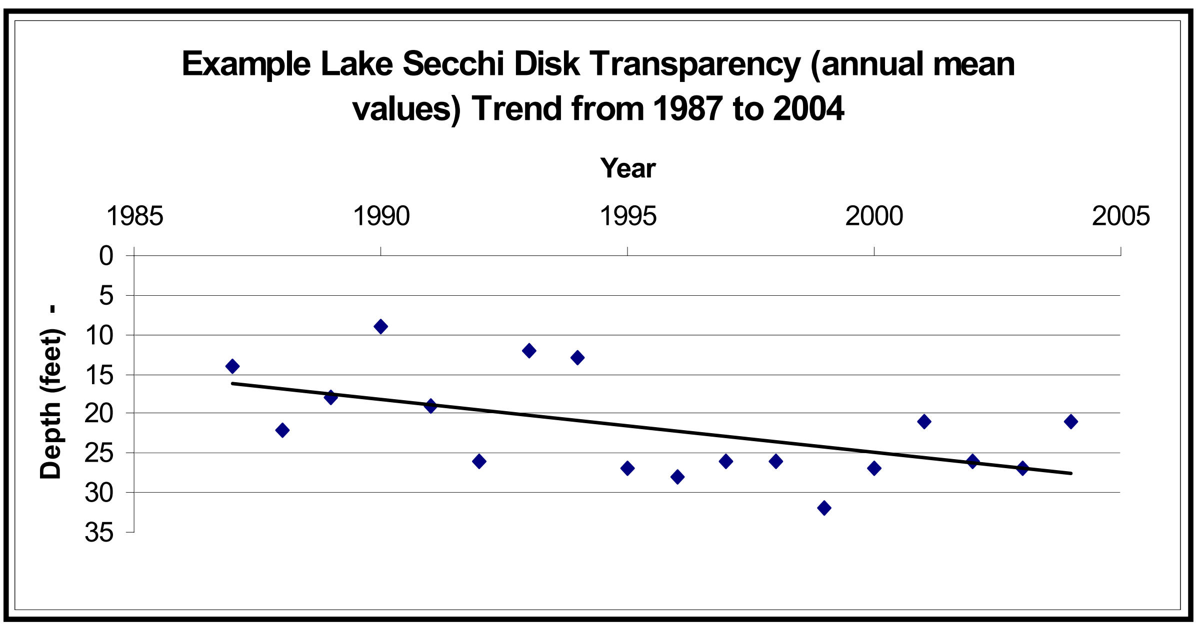
The data range and standard deviation gives an indication of seasonal variability in transparency in the lake. Lakes with highly variable Secchi disk readings need to be sampled frequently to provide a representative mean summer transparency value. Few measurements and inconsistent sampling periods for 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 Secchi disk transparency annual means or TSI_{SD} values can be compared to evaluate changes, or trends, in trophic status of the lake over time, see the figure below.

During 2004, Secchi disk transparency data were reported for 182 lakes (222 basins). Over 3,200 transparency measurements were reported, ranging from 0.5 to 50 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 12.2 feet. The median value was 11.0 feet. The Carlson TSI_{SD} values ranged from 26 to 82 for these lakes with a mean value of 43. A Carlson TSI value of 43 is generally indicative of a 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 2004 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 2004, samples for total phosphorus measurements were collected on 181 lakes. The spring overturn total phosphorus results ranged from <5 to 112 ug/l with a mean (average) of 13 ug/l and a median value of 11 ug/l. The late summer total phosphorus results ranged from <5 to 270 ug/l with 15 ug/l as the mean and 12 ug/l as the median. The Carlson TSI_{TP} values ranged from <24 to 85 for these lakes with a mean value of 41. A Carlson TSI value of 41 is generally indicative of a good quality mesotrophic lake (see page 8).

Chlorophyll *a*

Chlorophyll is the green photosynthetic pigment in the cells of plants. The 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. Volunteers were asked to collect and process five sets of chlorophyll *a* samples, one set per month from May through September. For purposes of calculating TSI values only those lakes that had data for at least four of the five sampling events were used. During 2004 volunteers collected a minimum of four samples on 93 lakes.

Results from the chlorophyll monitoring for 2004 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 about one-third of the lakes. About 545 chlorophyll samples were collected and processed in 2004. The chlorophyll *a* levels ranged from <1 to 71 ug/l over the five-month sampling period. The overall mean (average) was 4.0 ug/l and the median was 2.6 ug/l. The Carlson TSI_{CHL} values ranged from <31 to 65 with a mean value of 41. A Carlson TSI value of 41 is generally indicative of a good quality 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 2004, CLMP participants in

the dissolved oxygen/temperature project sampled 35 lakes. A total of 274 dissolved oxygen/temperature profiles were recorded. The lakes involved in the project 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 2004 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, an oligotrophic/mesotrophic lake with a large volume hypolimnion, an 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 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.

Aquatic Plant Mapping

To create the volunteer's aquatic plant map and data sheets, sampling transects are identified on each lake. Along each transect, plant samples are collected at the one, four and eight foot depths with a constructed sampling rake. The rake is tossed out into the lake and retrieved from the four compass directions. The density of each plant species is determined by its presence on one, two, three or all four of the rake tosses. The data from all the transects are calculated to create the plant distribution map and data sheet. A complete description of sampling procedures is provided in Wandell and Wolfson, 2000.

AQUATIC PLANT SAMPLING RAKE

Cut the handles off of two garden rakes and bolt the rakes back to back with two "C" bolts. Use a small hose clamp between the rake tines to prevent side to side slipping. Drill a hole in the remaining wooden handle core and twist into the hole a moderately large eye bolt. The rope should be about 20 feet long. File off any sharp edges. Wear gloves when using the rake to protect the hands from cuts.

During 2003, an evaluation of the aquatic plant monitoring project was made and presented in the CLMP 2003 Report, Appendix 5. The results of this study of volunteer aquatic plant survey methods suggested that:

- Citizen volunteers are capable of conducting good qualitative aquatic plant surveys, if properly trained and provided limited professional assistance, and

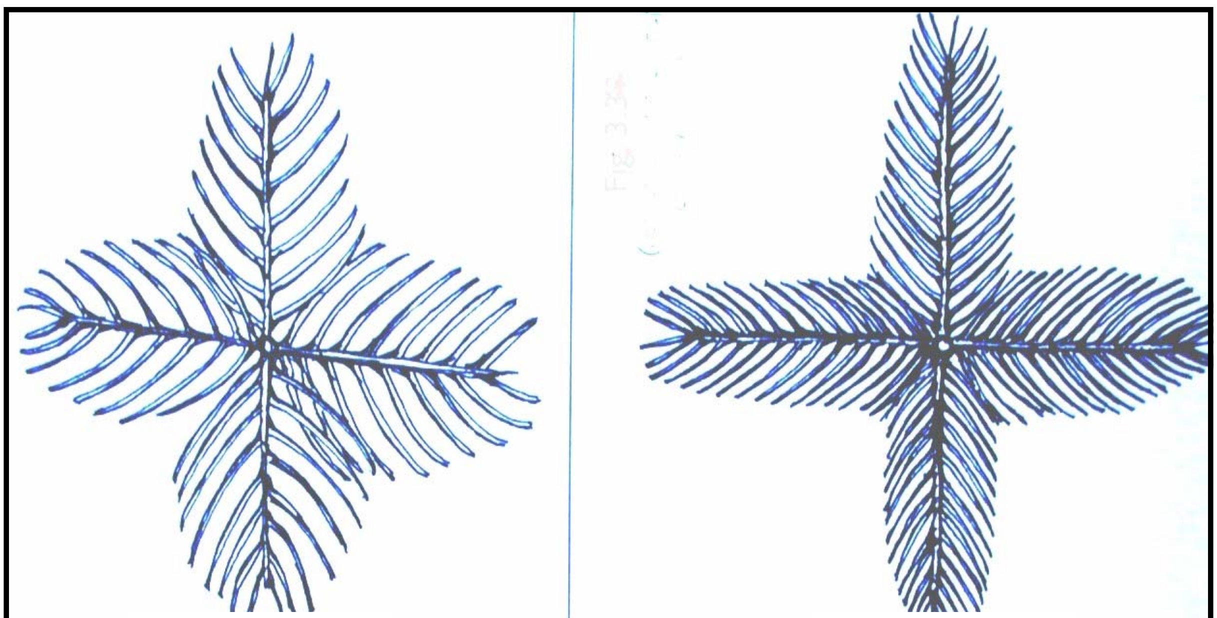
- Volunteer survey methods compare reasonably well with DEQ methods to qualify aquatic plant species, densities and distributions in a lake.

The results warranted continuing aquatic plant monitoring as a component of the CLMP.

During 2004, CLMP participants in the aquatic plant project sampled three lakes for aquatic plants. Two lake surveys were incomplete and may be finished in 2005. Little Glen Lake in Leelanau County had been surveyed in previous years. The lake had sparse plant growth.

The community at Glen Lake modified the plant sampling program in 2004 to address the specific concerns at their lake. Because of sparse plant populations and shallow depth, maximum depth 14 feet, the lake could be subject to a serious invasion by exotic species, like Eurasian milfoil. Eurasian milfoil is an exotic plant that has caused major problems for North American lakes. While similar in appearance to native milfoils, see figure below, it is significantly more recreationally disruptive.

The figures below represent stem cross sections at a leaf node for both native and Eurasian milfoils. Note that Eurasian milfoil has more leaflets on each leaf than native milfoils. Eurasian milfoil generally has more than twelve leaflets on one side of the leaf's central axis, while native milfoils have less than twelve.



Native milfoil　　Eurasian milfoil

Also being in the Sleeping Bear National Shoreline the lake has significant public access, greatly increasing the potential for introduction of exotic species from outside sources.

The community set up more sampling transects and used volunteer monitors to look only for exotic species. This allowed them to concentrate their efforts on finding exotic plant infestations at the earliest stages. This will allow the community to implement exotic plant control strategies in a small area rather than waiting until the plant has covered a large area of the lake. No evidence of Eurasian milfoil or other exotic aquatic plants were recorded for Little Glen Lake in 2004.

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.

Wandell, H. and Wolfson, L. 2000. A Citizen's Guide for the Identification, Mapping and Management of the Common Rooted Aquatic Plants of Michigan Lakes. MSU Extension Water Quality Series WQ-55.

A PROFILE OF HOW A COMMUNITY HAS USED CLMP DATA TO PROTECT THEIR LAKE

Blue Lake, Mason County: Reducing Nutrient Inputs to Protect a Small Oligotrophic Lake

Blue Lake is a small (70 acres), deep (62 feet) lake in the rural area of Mason County. The shoreline is entirely developed but much of the watershed is forested. The Blue Lake community has participated in the Cooperative Lakes Monitoring Program, Secchi disk monitoring project since 1987 and the total phosphorus project since 1998. During this sampling period the Secchi disk TSI value has averaged about 32 and the total phosphorus TSI about 38. These data would suggest that the lake is oligotrophic.

Small oligotrophic lakes, like Blue, can be highly susceptible to nutrient inputs. In fact, the residents at Blue Lake began to notice that some years the water was green with algal blooms and the rooted plant populations were expanding. One year the Secchi disk TSI value was up to 45. The community decided to take action to reduce nutrient loading and protect the lake's high quality nature.

Even a cursory evaluation of the situation revealed that the source of the problem was the lake community's own development. Since most of the watershed was forested, the primary source of nutrients was the riparian development along the shore. As Pogo so profoundly stated, "we have met the enemy and he is us".

To address this condition the lake community began a program of educating riparian property owners and taking actions where the opportunities occurred. The education program included providing all property owners with information regarding: lawn fertilization, maintenance of septic systems, protection and restoration of native shorelines and good riparian land management such as leaf composting and disposal of campfire ashes. The community worked with the local government to correct a very serious erosion problem on the lake's access road which was contributing a significant amount of sediments to a wetland adjoining the lake. When an environmentally important parcel of land became available for purchase, the community worked with the seller to buy the land and retain it in a natural state. To encourage septic system maintenance, the lake association reimburses a home owner a portion of their septic system pumping cost.

The community's actions appear to be having an effect. Not only are property owners more aware of the quality of their lake and the impact their actions have on it, but the last few years the TSI values are again less than 38, within the oligotrophic trophic statues range.

Do you have a success story of how your community has used the CLMP data to implement a protection program for your lake? We would like to hear from you. Send your community's success story to:

Mr. Ralph Bednarz
Michigan Dept of Environmental Quality
Water Bureau
P.O. Box 30273
Lansing, MI 48909-7773
Telephone: 517-335-4211
http://www.michigan.gov/deq

ACKNOWLEDGMENTS

Ralph Bednarz of the Michigan Department of Environmental Quality, Water Bureau, and Howard Wandell from Michigan State University Department of Fisheries and Wildlife prepared this report. Brian Carley, Bruce Bonnell and volunteer samplers compiled data. Ralph Bednarz, along with Donald Winne and Pearl Bonnell of the Michigan Lake and Stream Associations, Inc., coordinate the CLMP.

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

2004 Secchi Disk Transparency Results

Appendix 2

2004 Total Phosphorus Results

Appendix 3

2004 Chlorophyll Results

Appendix 4

2004 Dissolved Oxygen and Temperature Participating Lakes and Example Results

APPENDIX 1
2004 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)
Ann	Benzie	18	13.0	26.0	16.4	15.5	4.09	37
Arbutus 1	Grand Traverse	18	10.0	13.0	12.4	13.0	1.04	41
Arbutus 2	Grand Traverse	18	12.0	28.0	17.4	14.0	5.22	36
Arbutus 3	Grand Traverse	18	13.0	24.0	16.8	14.5	3.90	36
Arbutus 4	Grand Traverse	18	12.0	23.0	16.2	14.0	3.76	37
Arbutus 5	Grand Traverse	18	11.0	19.0	14.1	13.0	2.70	39
Arnold	Clare	12	13.0	23.0	17.3	17.3	3.26	36
Avalon	Montmorency	19	18.0	50.0	31.1	32.0	8.34	28
Baldwin	Montcalm	19	7.2	17.0	11.4	11.0	3.10	42
Barlow	Barry	16	6.0	18.0	9.7	9.4	3.20	44
Bear	Manistee	15	8.0	13.5	10.8	11.0	1.37	43
Bear 1	Kalkaska	17	22.0	45.5	33.3	37.0	7.53	27
Bear 2	Kalkaska	17	23.0	45.5	34.1	36.5	7.49	26
Beaver	Alpena	15	11.7	26.5	16.0	15.2	3.72	37
Bellaire	Antrim	19	11.0	22.0	15.8	15.0	3.06	37
Big	Osceola	17	14.0	24.5	18.1	18.0	2.81	35
Big Bradford	Otsego	10	14.0	24.0	18.7	18.0	2.71	35
Big Platte	Benzie	19	10.5	26.0	19.1	21.0	3.94	35
Big Star	Lake	14	9.3	13.3	11.0	10.8	1.23	43
Bills 1	Newaygo	17	7.0	18.5	10.4	9.0	3.39	43
Bills 2	Newaygo	14	7.0	23.0	11.9	10.5	4.68	41
Birch	Cass	19	12.0	43.0	19.6	14.0	9.26	34
Blue	Mason	13	15.0	26.5	21.0	21.0	3.32	33
Bostwick	Kent	5	5.7	12.0				
Brighton	Livingston	5	4.0	5.0				
Brooks	Newaygo	9	2.5	5.0	3.2	3.0	0.87	61
Byram 1	Genesee	18	8.0	29.0	13.2	12.0	4.93	40
Byram 2	Genesee	18	8.0	25.0	12.9	12.0	4.17	40
Byram 3	Genesee	18	8.0	25.0	12.9	12.0	4.17	40

APPENDIX 1
2004 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)
Camp	Kent	12	11.8	13.5	12.7	12.9	0.54	40
Canadian (Main)	Mecosta	10	9.0	13.0	10.8	10.3	1.36	43
Canadian (West)	Mecosta	9	10.5	15.0	12.2	12.0	1.44	41
Cedar	Van Buren	19	9.0	31.0	15.4	13.5	4.99	38
Cedar(BriarwoodBay)	Alcona\Iosco	11	6.9	13.0	10.6	10.8	1.99	43
Cedar(Schmidt's Pt.)	Alcona\Iosco	11	5.5	9.8	7.8	8.5	1.79	47
Center	Osceola	8	14.0	18.5	16.2	16.0	1.44	37
Chain	Iosco	9	8.5	11.0	9.8	9.0	1.12	44
Chemung	Livingston	5	11.4	22.0				
Christiana	Cass	14	6.0	13.5	8.2	6.5	2.59	47
Clam	Antrim	13	17.0	22.0	20.3	21.0	1.65	34
Clear	St. Joseph	6	10.0	17.5				
Clear 1	Jackson	10	8.5	16.0	11.2	10.3	2.71	42
Clear 2	Jackson	11	10.0	12.0	10.8	10.5	0.69	43
Clifford 1	Montcalm	19	11.0	19.0	14.3	14.0	2.33	39
Coldwater	Branch	11	5.0	10.5	7.4	6.5	1.73	48
Corey	St. Joseph	16	7.0	19.5	10.3	8.0	4.26	44
Cowan	Kent	19	2.5	6.5	4.3	4.5	0.93	56
Crooked (Big)	Van Buren	17	12.0	22.0	14.4	13.5	2.88	39
Crystal	Benzie	7	20.0	29.0				
Crystal	Hillsdale	19	13.5	22.0	15.3	15.0	2.20	38
Crystal	Newaygo	12	8.0	26.0	15.4	16.0	5.88	38
Cub	Kalkaska	16	19.0	24.0	22.8	24.0	1.68	32
Davis	Cass	19	1.8	17.0	10.5	10.4	3.03	43
Deer	Alger	9	6.2	9.2	7.2	7.1	0.83	49
Derby	Montcalm	16	13.0	23.0	18.1	18.0	3.20	35
Devils	Lenawee	6	9.0	14.0				
Diamond	Cass	19	8.0	20.0	11.1	10.0	2.88	42
Eagle	Allegan/Van Buren	14	9.5	14.0	11.4	11.5	1.17	42

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min	Range Max	Mean	Median	Standard Deviation	Carlson TSISD (transparency)
East Crooked	Livingston	16	10.0	13.0	11.6	11.5	1.09	42
Emerald	Newaygo	18	8.0	16.0	11.6	11.0	1.85	42
Evans	Lenawee	16	15.0	31.0	19.0	18.0	3.99	35
Fair	Barry	19	8.1	17.6	10.3	9.5	2.37	43
Fenton	Genesee	9	16.0	17.8	17.3	17.5	0.56	36
Fish	Van Buren	19	6.0	11.0	8.4	8.0	1.57	46
Fisher	St. Joseph	19	6.5	20.5	10.8	9.5	4.23	43
Freska	Kent	13	7.0	10.1	8.9	8.7	0.91	46
George	Clare	19	7.0	16.0	9.1	7.5	2.93	45
Gill/Gut	Livingston	12	9.0	14.0	11.7	12.0	1.37	42
Gillette	Jackson	12	9.0	14.0	11.7	12.0	1.37	42
Glen, Big	Leelanau	15	13.0	23.0	17.5	17.0	2.67	36
Glen, Little	Leelanau	19	4.5	9.0	6.8	6.5	1.37	50
Goshorn	Allegan	19	2.7	7.5	5.4	5.5	1.83	53
Gourdneck	Kalamazoo	15	8.0	18.0	12.4	13.0	3.61	41
Grass	Jackson	10	5.0	5.0	5.0	5.0	0.00	54
Gratiot	Keweenaw	18	15.8	24.9	20.2	20.0	2.19	34
Hamburg	Livingston	19	10.6	18.5	14.7	14.0	2.31	38
Hamilton	Dickinson	15	12.0	16.0	13.3	13.0	1.18	40
Hamlin, Lower	Mason	19	7.5	15.0	10.2	9.5	1.77	44
Hamlin, Upper	Mason	19	4.5	10.0	7.4	7.0	1.73	48
Hawk	Oakland	17	7.0	13.0	9.5	9.0	1.70	45
Hess	Newaygo	17	1.5	4.5	2.8	3.0	0.72	62
Hicks	Osceola	15	3.3	8.2	5.2	4.6	1.46	53
Higgins	Roscommon	7	19.0	32.0				
High	Kent	8	9.3	18.2	13.0	13.1	2.78	40
Horsehead	Mecosta	17	11.0	16.5	12.8	12.0	1.45	40
Houghton 1	Roscommon	19	5.0	9.0	6.6	6.0	1.13	50
Houghton 2	Roscommon	18	5.0	9.0	6.7	6.0	1.27	50

APPENDIX 1
2004 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)
Hubbard 1	Alcona	12	10.0	19.0	14.9	14.5	2.70	38
Hubbard 2	Alcona	12	10.0	19.5	14.8	15.0	3.32	38
Hubbard 3	Alcona	12	13.0	22.0	16.9	17.0	3.22	36
Hubbard 4	Alcona	13	11.0	23.0	15.9	15.0	3.48	37
Hubbard 5	Alcona	11	13.0	20.0	16.7	16.0	2.79	37
Hubbard 6	Alcona	17	9.0	24.0	16.0	16.0	4.09	37
Hubbard 7	Alcona	11	13.0	21.0	16.3	15.5	2.86	37
Hunter 1	Gladwin	17	7.0	15.0	11.9	12.0	2.09	41
Hunters 1	Alcona	15	8.7	15.5	11.9	11.0	2.07	41
Hunters 2	Alcona	15	9.5	16.0	11.9	11.5	2.18	41
Hutchins	Allegan	19	4.0	15.0	8.8	8.0	2.34	46
Indian	Kalamazoo	15	4.0	16.0	10.2	9.5	3.38	44
Indian	Osceola	19	14.0	21.0	17.0	17.0	2.11	36
Island	Grand Traverse	11	16.0	27.0	21.8	23.0	3.60	33
Island 1	Ogemaw	18	11.5	20.2	15.8	16.3	2.62	37
Island 2	Ogemaw	18	11.3	19.0	15.6	16.1	2.50	37
Jewell	Alcona	14	7.0	9.5	8.1	8.0	0.60	47
Juno	Cass	13	4.5	9.0	6.5	6.5	1.14	50
Kimball	Newaygo	12	3.5	10.0	6.8	6.3	1.76	50
Kirkwood	Oakland	19	3.1	8.0	4.6	4.0	1.58	55
Klinger	St. Joseph	17	7.0	32.5	13.7	9.5	8.21	39
Lake Margrethe 1	Crawford	19	13.0	22.0	16.4	14.0	3.08	37
Lake Nepessing	Lapeer	18	12.0	17.0	14.1	14.0	1.71	39
Lakeville	Oakland	18	14.0	24.0	18.2	19.0	3.05	35
Lancelot 1	Gladwin	9	6.5	8.3	7.6	7.5	0.60	48
Lancelot 2	Gladwin	9	7.0	8.5	8.0	8.2	0.51	47
Lancelot 3	Gladwin	9	4.5	11.0	8.5	9.0	1.85	46
Lancer 1	Gladwin	10	5.0	8.0	6.4	6.0	1.06	50
Lancer 2	Gladwin	10	4.0	10.0	6.9	7.0	1.52	49

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSI_{SD}
		Readings	Min	Max	Mean	Median	Deviation	(transparency)
Lancer 3	Gladwin	10	4.5	8.0	6.4	6.0	1.06	50
Lancer 4	Gladwin	10	3.5	6.0	4.8	5.0	0.75	55
Lancer 5	Gladwin	10	3.0	6.0	5.5	6.0	1.07	53
Lansing	Ingham	18	3.9	9.1	6.1	5.8	2.00	51
Lily	Clare	16	7.8	10.0	8.8	8.8	0.74	46
Little Bradford	Otsego	9	16.0	26.0	19.7	18.0	3.43	34
Little Crooked	Cass	13	11.8	17.5	14.8	14.3	1.98	38
Little Fisher	St. Joseph	19	7.5	15.0	10.6	9.8	2.35	43
Little Paw Paw	Berrien	15	3.0	7.3	4.8	4.7	1.07	55
Long	Branch	11	3.5	7.5	4.8	4.5	1.25	55
Long	Grand Traverse	19	19.0	36.0	27.5	27.0	5.21	29
Long	Iosco	13	7.2	12.0	9.5	9.5	1.36	45
Long (North)	Montmorency	18	10.0	29.0	16.9	15.0	6.01	36
Long (South)	Montmorency	18	13.0	28.0	17.1	16.0	3.52	36
Long(Sylvania)	Gogebic	17	12.0	20.0	14.1	13.0	2.37	39
Long(West)	Gogebic	16	12.0	18.0	13.4	13.0	1.63	40
Louise	Dickinson	15	13.0	19.0	15.7	15.0	2.16	37
Lower Reynolds	Van Buren	14	8.0	12.5	10.3	10.5	1.31	44
Magician	Cass	14	6.0	22.5	13.2	12.0	5.49	40
Mary	Dickinson	15	13.0	20.0	15.3	15.0	2.16	38
Mecosta	Mecosta	14	9.0	16.0	12.5	12.0	2.43	41
Mill	Van Buren	8	12.0	16.0	13.9	14.3	1.35	39
Miner	Allegan	11	6.9	12.3	10.5	11.4	1.73	43
Moon	Gogebic	18	16.0	29.0	22.2	22.0	4.20	32
Mullet	Cheboygan	13	14.0	19.0	16.9	16.5	1.75	36
Murray	Kent	15	5.2	11.2	7.6	7.2	1.94	48
Muskellunge 1	Montcalm	16	7.2	15.4	9.3	8.7	2.13	45
Muskellunge 2	Montcalm	3	4.5	8.1				
North Buckhorn	Oakland	18	7.5	13.0	11.8	12.5	1.52	41

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSI_{SD}
		Readings	Min	Max	Mean	Median	Deviation	(transparency)
Oneida	Livingston	13	7.0	10.3	8.3	8.3	1.02	47
Ore	Livingston	18	7.0	14.0	9.4	9.3	2.39	45
Orion	Oakland	9	10.0	19.0	13.1	12.0	2.70	40
Osterhout	Allegan	10	4.0	6.0	5.1	5.0	0.57	54
Painter	Cass	13	3.5	8.0	5.2	5.0	1.11	53
Pentwater 2	Oceana	8	3.4	8.1	6.4	6.7	1.51	50
Pentwater 4	Oceana	8	3.7	8.4	6.7	7.1	1.55	50
Pentwater 5	Oceana	8	5.2	12.0	8.6	8.0	2.50	46
Perch	Hillsdale	19	4.0	8.7	6.1	6.0	1.44	51
Pickerel	Newaygo	12	7.0	14.0	10.6	10.5	2.11	43
Picnic	Montcalm	19	2.0	14.5	6.3	6.5	2.73	51
Pleasant	St. Joseph	18	7.0	16.0	12.1	13.0	2.83	41
Pleasant 1	Washtenaw	15	7.4	15.8	10.5	9.9	2.71	43
Pleasant 1	Wexford	12	5.0	8.0	6.0	5.7	0.98	51
Pleasant 2	Washtenaw	15	7.3	14.6	10.1	10.2	1.99	44
Pleasant 3	Washtenaw	15	7.5	14.3	10.1	9.8	1.92	44
Ponemah	Genesee	19	5.7	14.0	9.4	9.2	2.16	45
Portage	Jackson	10	9.0	15.0	10.8	9.8	2.11	43
Portage	Livingston	16	8.2	18.0	11.2	10.9	2.29	42
Pretty	Mecosta	6	10.2	15.3				
Puterbaugh	Cass	17	7.0	16.5	10.9	12.0	3.11	43
Randall	Branch	13	5.5	12.5	7.6	7.5	1.64	48
Ranger	Otsego	9	9.0	14.0	11.6	12.0	1.76	42
Reeds	Kent	14	4.1	11.6	6.7	6.7	2.00	50
Reynolds (Upper)	Van Buren	14	9.0	17.0	13.4	14.0	2.40	40
Robinson	Newaygo	19	5.0	10.0	7.7	7.0	1.37	48
Round	Clinton	18	4.5	15.5	6.7	5.5	3.04	50
Round	Lenawee	6	9.3	19.3				
Round 1	Mecosta	14	6.0	14.0	9.5	9.0	1.99	45

APPENDIX 1
2004 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)
Sanford	Midland	17	3.5	10.5	6.7	7.0	2.02	50
Sapphire	Missaukee	16	7.5	8.5	8.0	8.0	0.34	47
Scenic	Shiawassee	16	4.6	9.2	6.1	5.5	1.37	51
School Section 1	Mecosta	19	6.7	17.3	9.7	7.7	3.32	44
School Section 3	Mecosta	19	6.3	14.2	9.0	7.7	2.44	45
Shavehead 1	Cass	12	5.0	11.0	8.1	8.0	2.16	47
Shavehead 2	Cass	11	5.0	11.0	7.6	8.0	2.01	48
Sherwood	Oakland	15	7.0	10.0	8.5	8.5	0.89	46
Shingle	Clare	19	8.0	16.0	10.4	10.0	2.09	43
Silver	Grand Traverse	18	15.0	41.5	24.8	21.3	8.82	31
Silver	Livingston	19	11.0	22.0	14.6	14.0	3.36	38
Silver	Van Buren	19	8.2	12.4	10.2	10.0	1.41	44
Silver 1	Genesee	19	9.5	22.0	14.1	12.5	4.22	39
Silver 2	Genesee	19	7.0	18.0	12.5	12.0	3.34	41
Silver 3	Genesee	19	8.0	19.0	12.8	12.0	3.49	40
Smallwood	Gladwin	9	1.5	8.5	5.3	5.0	2.26	53
Spider 1	Grand Traverse	16	10.0	23.0	15.5	14.0	4.62	38
Spider 2	Grand Traverse	14	10.0	22.0	14.3	12.7	4.50	39
Spider 3	Grand Traverse	14	11.0	22.0	14.4	13.0	3.99	39
Starvation	Kalkaska	8	17.3	26.0	22.6	23.1	2.86	32
Stone Ledge	Wexford	15	8.0	13.0	10.4	10.0	1.45	43
Stoney	Oceana	5	4.5	12.0	8.2	8.5	2.86	47
Strawberry	Livingston	18	7.0	9.1	7.6	7.5	0.48	48
Sylvan	Newaygo	18	9.5	16.0	12.3	12.5	2.01	41
Taylor	Oakland	19	16.0	20.0	18.1	18.0	1.05	35
Thurston Pond	Washtenaw	8	0.5	1.1	0.7	0.6	0.23	82
Torch North	Antrim	16	15.0	40.0	25.4	27.5	8.18	30
Torch South	Antrim	13	16.5	36.0	24.5	26.0	6.33	31

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min	Range Max	Mean	Median	Standard Deviation	Carlson TSI_{SD} (transparency)
Twin, Big (north)	Cass	18	6.0	20.0	11.7	10.8	4.29	42
Twin, Little	Cass	14	4.6	14.6	8.1	7.1	3.30	47
Twin, East	Montmorency	9	7.0	15.0	10.7	11.1	3.21	43
Twin, West	Montmorency	10	9.3	16.1	11.9	12.0	2.08	41
Upper Crooked 1	Barry	19	6.0	17.2	10.0	9.0	3.17	44
Upper Crooked 2	Barry	19	6.5	13.0	8.8	8.0	2.03	46
Van Etten	Iosco	18	3.0	7.2	4.7	4.6	0.97	55
Vaughn	Alcona	16	5.3	9.0	7.0	6.8	1.16	49
Viking	Otsego	19	6.0	19.0	11.8	10.0	5.15	41
Vineyard	Jackson	16	8.0	18.0	12.0	12.0	3.16	41
Wahbememe	St. Joseph	17	13.0	32.0	17.9	17.0	4.47	36
Wells	Osceola	18	10.0	18.0	13.9	13.8	2.35	39
West Crooked	Livingston	17	6.0	11.5	8.1	7.5	1.60	47
White	Oakland	9	16.0	25.0	20.7	20.5	2.66	33
Whitehead	Livingston	9	10.5	15.9	13.9	14.2	1.54	39
Wildwood	Cheboygan	12	15.1	16.1	15.7	15.8	0.35	37
Windover	Clare	14	12.0	24.0	16.4	16.5	3.67	37
Wolf	Lake	3	10.0	13.3				
Woods	Kalamazoo	17	7.5	15.0	11.0	10.5	2.21	43
Zukey 1	Livingston	17	5.0	14.8	10.1	10.0	2.56	44

APPENDIX 2
2004 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring Overturn				Late Summer				Carlson TSI_{TP}
		Vol	Rep.	DEQ	Rep.	Vol	Rep	DEQ	Rep	(summer TP)
ANN	BENZIE	6 h				6				30
ARBUTUS	GR TRAVERSE	5 h				9		9	10	36
ARNOLD	CLARE	7 h				7				32
AVALON	MONTMORENCY	4 T,h				5				27
BALDWIN	MONTCALM					14				42
BARLOW	BARRY	7				10				37
BEAR	KALKASKA	6 h				7				32
BEAVER	ALPENA	*				*				
BELLAIRE	ANTRIM	13				5				27
BIG	OSCEOLA	11 h				13				41
BIG BRADFORD	OTSEGO	10 h				7				32
BIG PINE ISLAND	KENT					18				46
BIG STAR	LAKE					8				34
BIG PLEASANT	ST. JOSEPH	6		7		*				
BILLS	NEWAYGO	11				8				34
BIRCH	CASS	5				11				39
BLUE	MASON	12 h				8				34
BLUE	MECOSTA	4 T				8				34
BRACE, LOWER	CALHOUN					11		11		39
BRACE, UPPER	CALHOUN					9		9	10	36
BOSTWICK	KENT	14				35				55
BRIGHTON	LIVINGSTON	36				35				55
BUCKHORN, NORTH	OAKLAND	18				9	8			36
CANADIAN	MECOSTA	14	15	18		16				44
CANADIAN WEST	MECOSTA	13		16		15				43
CEDAR	ALCONA/IOSCO	10 h	10 h			14				42
CEDAR	VAN BUREN	7				9				36
CENTER	OSCEOLA	12 h				8				34
CHAIN	IOSCO	14 h				15				43
CHEMUNG	LIVINGSTON	17				15				43
CHILSON POND	LIVINGSTON	20				19				47
CHRISTIANA	CASS	15 d				19				47
CLAM	ANTRIM	10				7				32

Lake	County	Total Phosphorus (ug/l) Spring Overturn Vol	Spring Overturn Rep.	Spring Overturn DEQ	Spring Overturn Rep.	Late Summer Vol	Late Summer Rep	Late Summer DEQ	Late Summer Rep	Carlson TSITP (summer TP)
CLEAR	JACKSON	9				11				39
CLIFFORD	LIVINGSTON	16		17		*				
CLIFFORD	MONTCALM	14		20		13				41
COREY	ST. JOSEPH	4 T				9				36
COWAN	KENT	25	25			19		24		47
CROOKED	LIVINGSTON	*				11				39
CROOKED, BIG	VAN BUREN					12				40
CROOKED, LITTLE	VAN BUREN					9				36
CROOKED, EAST	LIVINGSTON	17		14	16	14				42
CROOKED. WEST	LIVINGSTON	9		9		12				40
CROOKED, UPPER	BARRY	23				21				48
CRYSTAL	BENZIE	5 h				4 T				<24
CRYSTAL	HILLSDALE					9				36
CRYSTAL	NEWAYGO	11				14				42
CUB	KALKASKA	10 h				6				30
DAVIS	CASS	23	22			16				44
DEER	ALGER	11 h	11 h			7				32
DERBY	MONTCALM	4 T	3 <			10	9			37
DEVILS	LENAWEE	8 a				*				
DIAMOND	CASS	4 T				10				37
DONNELL	CASS	6 b		9		*				
EAGLE	ALLEGAN	*				*				
EMERALD	NEWAYGO	10				10				37
EVANS	LENAWEE	*				9				36
FAIR	BARRY					13				41
FARWELL	JACKSON	5				5		4 T		27
FENTON	GENESEE	*				10				37
FISH	VAN BUREN	9 b,c				*				
FISH	LIVINGSTON	*				10				37
FISHER	ST. JOSEPH	3 <				9				36
FISHER, LITTLE	ST. JOSEPH	9				10				37
FRESKA	KENT					12				40
GEORGE	CLARE	11 h				11				39

APPENDIX 2
2004 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l)								Carlson
		Spring Overturn				Late Summer				TSI$_{TP}$
		Vol	Rep.	DEQ	Rep.	Vol	Rep	DEQ	Rep	(summer TP)
GILL	LIVINGSTON	24 e				13				41
GILLETTS	JACKSON	15	20			10	16	13		37
GLEN, BIG	LEELANAU	6 h				14				42
GLEN, LITTLE	LEELANAU	7 h				16				44
GOSHORN	ALLEGAN	23	25			32				54
GOURDNECK	KALAMAZOO	*				13				41
GRASS	JACKSON	18		20	23	13				41
GRATIOT	KEWEENAW					5				27
GUNN	MASON	11 h				8				34
HAMBURG	LIVINGSTON	12				8				34
HAMILTON	DICKINSON	12 h				11				39
HAMLIN, LOWER	MASON	15 h				27				52
HAMLIN, UPPER	MASON	16 h				32				54
HESS	NEWAYGO	41 h				29				53
HICKS	OSCEOLA					41	40			58
HIGGINS	ROSC/CRAWF	7 h				10				37
HIGH	KENT					13		21		41
HORSEHEAD	MECOSTA					10				37
HOUGHTON	ROSCOMMON	13 h				21				48
HUBBARD	ALCONA	7 h				8				34
HUNTERS	ALCONA	27 h				19				47
HUTCHINS	ALLEGAN					17				45
INCHWAGH	LIVINGSTON	*				*				
INDIAN	KALAMAZOO	7				9				36
INDIAN	MONTCALM	14				22				49
INDIAN	OSCEOLA	10 h				17	17			45
ISLAND	GR TRAVERSE	9 h				10				37
ISLAND	OSCO/OGEMAW	11 h				11				39
JEWELL	ALCONA	12 h				15				43
JUNO	CASS	24 d				31				54
KEELER	VAN BUREN	*				*				
KIMBALL	NEWAYGO	40				22				49
KLINGER	ST. JOSEPH	5				7				32

APPENDIX 2
2004 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l)								Carlson
		Spring Overturn				Late Summer				TSITP
		Vol	Rep.	DEQ	Rep.	Vol	Rep	DEQ	Rep	(summer TP)
LAKEVILLE	OAKLAND	6				11				39
LANCELOT	GLADWIN	29 h				23				49
LANCER	GLADWIN	17 h				26				51
LANSING	INGHAM	17				24		28		50
LILY	CLARE	20 h				18				46
LIMEKILN	LIVINGSTON	*				36				56
LONG	GOGEBIC	7 h				8	8			34
LONG	GR TRAVERSE	6 h				7				32
LONG	IOSCO	9 h,a				g				
LONG	MONTMOR-ENCY	5 h	4 T,h			4 T				<24
LOUISE	DICKINSON	15 h	21 h			12				40
MAGICIAN	CASS	11				12				40
MARGRETHE	CRAWFORD	7 h				10				37
MARL	GENESEE	6				7				32
MARY	DICKINSON	18 h				10				37
MECOSTA	MECOSTA	5				10				37
MOON	GOGEBIC	4 T,h				4 T				<24
MULLETT	CHEBOYGAN	6 h				4 T				<24
MURRAY	KENT	34				14				42
MUSKELLUNGE	MONTCALM	13				15				43
NEPESSING	LAPEER	11	9			13				41
ONEIDA	LIVINGSTON	16	18			13				41
ORE	LIVINGSTON	18				18		22		46
ORION	OAKLAND	6				9				36
OSTERHOUT	ALLEGAN	*				*				
OXBOW	OAKLAND	*				8				34
PAINTER	CASS	19 d				27				52
PENTWATER	OCEANA	21				30	30			53
PERCH	HILLSDALE					24	25			50
PICNIC	MONTCALM					21	23	30		48
PICKERAL	NEWAYGO	25				14	14			42
PLEASANT	ST. JOSEPH					10				37
PLEASANT	WASHTENAW	21				18				46

APPENDIX 2
2004 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

Lake	County	Total Phosphorus (ug/l) Spring Overturn Vol	Rep.	DEQ	Rep.	Late Summer Vol	Rep	DEQ	Rep	Carlson TSITP (summer TP)
PLEASANT	WEXFORD	15 h	14 h			*				
PONEMAH	GENESEE					23				49
PORTAGE	JACKSON	8		10		12				40
PORTAGE	WASHTENAW					14				42
PRETTY	MECOSTA	6				12				40
RANDALL	BRANCH	17				20				47
RANGER	OTSEGO	*				8	8			34
ROBINSON	NEWAYGO	28				14				42
ROUND	CLINTON	*				21	21			48
ROUND	LENAWEE	9				7				32
ROUND	MECOSTA	10				11				39
SANDY BOTTOM	LIVINGSTON	*				17				45
SANFORD	BENZIE	14 h				i				
SANFORD	MIDLAND	*				19	20			47
SAPPHIRE	MISSAUKEE	12 h,b,d				12				40
SCHOOL SEC.	MECOSTA	7 b				13				41
SHAVEHEAD	CASS					13	12			41
SHINGLE	CLARE	14 h				14				42
SILVER	GENESEE	3 <				9				36
SILVER	GR TRAVERSE	9 h				8				34
SILVER	LIVINGSTON	9				12				40
SILVER	VAN BUREN					11	10			39
SMALLWOOD	GLADWIN	*				24				50
SPIDER	GR TRAVERSE	12 h				8		8		34
STONE LEDGE	WEXFORD	27 h				14				42
STONY	OCEANA	10 f				20				47
STRAWBERRY	LIVINGSTON	17				23				49
SYLVAN	NEWAYGO	7				8				34
TAYLOR	OAKLAND	10	12			12				40
THURSTON	WASHTENAW	112				270				85
TORCH, NORTH	ANTRIM	2 <,h				14				42
TORCH, SOUTH	ANTRIM	13				10				37
TWIN, BIG	CASS	6				10				37

APPENDIX 2
2004 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

		Total Phosphorus (ug/l)								Carlson
Lake	County	Spring Overturn				Late Summer				TSI_{TP}
		Vol	Rep.	DEQ	Rep.	Vol	Rep	DEQ	Rep	(summer TP)
TWIN, LITTLE	CASS	8				9				36
TWIN, EAST	MONTMORENCY	10 h				15				43
TWIN, WEST	MONTMORENCY	7 h				8				34
VAN ETTEN	IOSCO					30	31			53
VAUGHN	ALCONA	24 h				20	21			47
VIKING	OTSEGO	23 h				23				49
VINEYARD	JACKSON	9				8		7		34
WALLED	OAKLAND	10				*				
WELLS	OSCEOLA	17 h				15	14			43
WHITE	OAKLAND	8				13				41
WHITEWOOD	LIVINGSTON					17				45
WILDWOOD	CHEBOYGAN	22 h				*				
WINANS	LIVINGSTON	*				*				
WINDOVER	CLARE	10 h				7				32
WOLF	LAKE	13 h	13 h			8				34
WOODS	KALAMAZOO	18				14				42
ZUKEY	LIVINGSTON	11	7			9				36

* No lake sample received, or sample turned in too late to process.

T Value reported is less than limit of quantification (5 ug/l).

< Value is less than method detection limit (3 ug/l)

a No field sheets received

b Sample bottles over full.

c Non-standard cap on sample bottle

d Sampling date on field sheet does not correspond with date on sample bottle label

e Ink on sample bottle label not readable

f Only one sample bottle received

g Sample received in a non standard bottle

h Recommended laboratory holding time was exceeded

i Sample not collected during the standard collection time

APPENDIX 3
2004 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) May	June	July	Aug	Sept	Mean	Median	Std. Devia-tion	Carlson TSICHL
ANN	BENZIE	1.3	2.0	2.0	2.9	2.5	2.1	2.0	0.6	37
ARBUTUS	GR. TRAVERSE	1.0<	1.2	2.0	2.1	2.0	1.6	2.0	0.7	37
MDEQ						2.3				
MDEQ/Rep						2.5				
ARNOLD	CLARE	1.0<,d	1.2	3.1	2.5	2.1	1.9	2.1	1.0	38
Vol/Rep			1.4			3.0				
AVALON	MONTMORENCY	1.0<	1.3	1.0<	1.0	2.3	1.1	1.0	0.7	31
BALDWIN	MONTMORENCY	*	*	4.2	4.5	1.0<				
BARLOW	BARRY	1.2	2.8	2.6	3.0	2.2	2.4	2.6	0.7	40
BELLAIRE	ANTRIM	1.8	1.2	2.4	1.7	1.6	1.7	1.7	0.4	36
BIG	OSCEOLA	1.0<	1.0<	3.2	2.1	2.5	1.8	2.1	1.2	38
BIG BRADFORD	OTSEGO	1.1	1.3	1.4	1.9	1.9	1.5	1.4	0.4	34
BIG PINE ISLAND	KENT	8.9	16.0	6.1	l	6.1	9.3	7.5	4.7	50
BILLS	NEWAYGO	2.2	2.0	2.9	2.8	1.7	2.3	2.2	0.5	38
BIRCH	CASS	4.1	1.0<	2.6	2.8	2.8	2.6	2.8	1.3	41
BLUE	MECOSTA	1.5	1.4	4.3	2.7	2.5	2.5	2.5	1.2	40
BOSTWICK	KENT	*	2.6d	7.3	8.9	7.0	6.5	7.2	2.7	50
BRIGHTON	LIVINGSTON	4.2	6.0	5.9	7.7	4.0	5.6	5.9	1.5	48
Vol/Rep		6.8								
MDEQ						8.2				
MDEQ/Rep						8.8				
CEDAR	ALCONA	2.3	2.9	7.0	3.5	4.9	4.1	3.5	1.9	43
Vol/Rep					3.6					
CEDAR	VAN BUREN	1.0<	1.5	2.3	2.8	3.2	2.1	2.3	1.1	39
Vol/Rep			1.5							
CHEMUNG	LIVINGSTON	1.0<	1.0<	4.7	3.3	3.3	2.5	3.3	1.9	42
CHRISTIANA	CASS	2.2	6.5	3.7	6.7	7.7	5.4	6.5	2.3	49
CLAM	ANTRIM	1.0<	1.0	1.5	1.1	1.3	1.1	1.1	0.4	32
Vol/Rep				1.7						
COREY	ST. JOSEPH	2.4	3.5	2.9	3.0	2.0	2.8	2.9	0.6	41
COWAN	KENT	4.2	8.9	16.0	10.0	9.1	9.6	9.1	4.2	52
Vol/Rep						9.4				
MDEQ						14.0				
MDEQ/Rep						14.0				

APPENDIX 3
2004 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) May	June	July	Aug	Sept	Mean	Median	Std. Devia-tion	Carlson TSICHL
CROCKERY	OTTAWA	*	*	*	*	*				
CROOKED	LIVINGSTON	*	1.7	3.1	*	5.4				
CRYSTAL	BENZIE	1.1	1.0<	1.0<	1.0<	1.0	<1.0	<1.0	0.3	<31
CRYSTAL	HILLSDALE	1.2	2.2	2.2	2.6	3.0	2.2	2.2	0.7	38
CRYSTAL	NEWAYGO	1.0	1.0	1.3	5.5	7.4	3.2	1.3	3.0	33
DEER	ALGER	4.0	2.5	2.5	2.5g	*	2.9	2.5	0.8	40
DERBY	MONTMORENCY	1.3	2.0	3.6	1.6	1.8	2.1	1.8	0.9	36
DEVILS	LENAWEE	l	l	2.3	3.2	2.2d				
DIAMOND	CASS	1.0	1.0	3.7	2.8	3.0	2.3	2.8	1.2	41
EAGLE	ALLEGAN	2.7	2.9d	4.8	3.7	5.6	3.9	3.7	1.2	43
Vol/Rep			3.6							
EVANS	LENAWEE	1.8	1.6	2.1	4.2	4.2	2.8	2.1	1.3	38
FAIR	BARRY	1.0<,f	4.2f	3.4f	4.5c	3.8c	3.3	3.8	1.6	44
FARWELL	JACKSON	*	*	*	1.3	1.5				
MDEQ						1.4				
MDEQ/Rep						1.4				
FISH	LIVINGSTON	*	2.0	1.5	*	1.8				
FISH	VAN BUREN	4.4	7.9	15.0	*	*				
FISHER	ST. JOSEPH	1.0<	2.2	2.6	3.1	2.2	2.1	2.2	1.0	38
FISHER, LITTLE	ST. JOSEPH	1.0	1.9	1.6	1.6	2.0	1.6	1.6	0.4	35
GEORGE	CLARE	1.6	2.5	6.2	4.1	3.5	3.6	3.5	1.7	43
GILLETTS	JACKSON	4.5b	1.1b	3.8b	*	4.1	3.4	4.0	1.5	44
Vol/Rep						3.2				
MDEQ						4.8				
MDEQ/Rep						4.6				
GLEN, BIG	LEELANAU	1.8	1.0<	1.0<	1.0<	1.0	<1.0	<1.0	0.6	<31
GLEN, LITTLE	LEELANAU	2.5	1.5	1.5	1.8	1.8	1.8	1.8	0.4	36
GOSHORN	ALLEGAN	25.0	14.0	4.5	15.0	24.0	16.5	15.0	8.4	57
Vol/Rep					17.0					
GUNN	MASON	*	*	*	*	*				
HAMLIN, LOWER	MASON	2.4	8.3	8.4	5.4	1.5	5.2	5.4	3.2	47
HAMLIN, UPPER	MASON	17.0	20.0	8.0	3.5	7.2	11.1	8.0	7.0	51
Vol/Rep		16.0								

APPENDIX 3
2004 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) May	June	July	Aug	Sept	Mean	Median	Std. Devia-tion	Carlson TSICHL
HESS	NEWAYGO	6.9	8.5	9.3	4.8	7.0	7.3	7.0	1.7	50
HIGGINS	ROSCOMMON	*	*	1.0<	1.0<	1.0<				
HIGH	KENT	8.4d	5.6	2.8	3.6	6.8	5.4	5.6	2.3	47
MDEQ						8.6				
MDEQ/Rep						9.7				
HOUGHTON	ROSCOMMON	3.6	5.1	3.2	1.0<	1.0	2.7	3.2	1.9	42
HUBBARD	ALCONA	1.0<	2.0	1.5	2.7	1.2	1.6	1.5	0.8	35
INCHWAGH	LIVINGSON	*	*	*	*	*				
INDIAN	KALAMAZOO	1.7	3.3	3.9	*	3.3	3.1	3.3	0.9	42
INDIAN	OSCEOLA	1.6	2.7	6.4	5.5	6.2	4.5	5.5	2.2	47
ISLAND	GR. TRAVERSE	1.4	1.4	1.0<	1.6	2.3	1.4	1.4	0.6	34
JEWELL	ALCONA	4.3	2.1	3.6	4.8	4.2	3.8	4.2	1.0	45
JUNO	CASS	4.7	7.1	5.9	11.0	13.0	8.3	7.1	3.5	50
KEELER	VAN BUREN	*	*	*	*	*				
KLINGER	ST. JOSEPH	1.0<	1.0<	4.1	4.7	3.3	2.6	3.3	2.0	42
LAKEVILLE	OAKLAND	1.0<	1.0<	2.2	1.9	2.5	1.5	1.9	1.0	37
LANCELOT	GLADWIN	2.4	6.0	2.3d	2.8	3.8	3.5	2.8	1.5	41
LANCER	GLADWIN	7.2	3.9	3.6d	8.6	5.6	5.8	5.6	2.1	47
LANSING	INGHAM	1.5	2.1	8.2	6.8	5.9	4.9	5.9	3.0	48
MDEQ						5.8				
MDEQ/Rep						6.0				
LILY	CLARE	1.0<	1.7	2.0	1.0<	*	1.2	1.1	0.8	32
LIMEKILN	LIVINGSTON	*	16.0	15.0	*	8.4				
LONG	GR. TRAVERSE	1.0<	1.0<	1.0<	1.0<	1.7	<1.0	<1.0	0.5	<31
LONG	IOSCO	j	j	j	3.7c	2.4				
LONG	MONTMORENCY				1.0<,g					
MAGICIAN	CASS	e	1.0	3.9	3.3	2.8	2.8	3.1	1.3	42
MARGRETHE	CRAWFORD	1.0<	1.0	1.7	2.2	2.0	1.5	1.7	0.7	36
MECOSTA	MECOSTA	1.3	1.6	1.8	2.1	1.7	1.7	1.7	0.3	36
MOON	GOGEBIC	3.2	2.0	3.3	2.2	2.3	2.6	2.3	0.6	39
MULLETT	CHEBOYGAN	1.0<	1.0<	1.0<	1.0<	1.0<	<1.0	<1.0	0.0	<31
MURRAY	KENT	3.9	1.0<	2.3	3.0	4.5	2.8	3.0	1.6	41
NEPESSING	LAPEER	1.5	1.2	2.0	2.6	1.7	1.8	1.7	0.5	36

APPENDIX 3
2004 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) May	June	July	Aug	Sept	Mean	Median	Std. Devia-tion	Carlson TSICHL
ORE	LIVINGSTON	3.1	1.0<	1.0<	5.7	6.5	3.3	3.1	2.8	42
MDEQ						7.1				
MDEQ/Rep						6.6				
ORION	OAKLAND	1.0<	*	1.1	2.1	1.8	1.4	1.5	0.7	34
OSTERHOUT	ALLEGAN	4.9	9.8	5.3	*	*				
OXBOW	OAKLAND	1.8a	*	2.4a	3.4	2.6	2.6	2.5	0.7	40
PAINTER	CASS	4.0	2.5	71.0	38.0	32.0	29.5	32.0	28.2	65
PENTWATER	OCEANA	1.7	4.4	5.3	10.0	5.6	5.4	5.3	3.0	47
Vol/Rep				4.7						
PERCH	HILLSDALE	2.8	8.5	1.0<	11.0	2.1	5.0	2.8	4.5	41
PRETTY	MECOSTA	*	*	*	4.3	4.8				
MDEQ					4.5					
MDEQ/Rep					4.6					
ROBINSON	NEWAYGO	11.0	14.0	23.0	12.0	7.4	13.5	12.0	5.8	55
ROUND	CLINTON	2.1	6.7	26.0	7.8	5.3	9.6	6.7	9.4	49
ROUND	LENAWEE	*	1.9	2.5	2.0	3.9	2.6	2.3	0.9	39
ROUND	MECOSTA	2.0	7.7	2.3	2.2	4.2	3.7	2.3	2.4	39
SANDY BOTTOM	LIVINGSTON	*	6.3	7.2	*	3.7				
SANFORD	BENZIE	4.5	f	3.4*	*	4.4				
SAPPHIRE	MISSAUKEE	*	4.5	3.6	3.1	3.2	3.6	3.4	0.6	43
SCHOOL SEC.	MECOSTA	1.3	1.4	2.1	3.5	2.6	2.2	2.1	0.9	38
MDEQ					4.1					
MDEQ/Rep					4.3					
SHINGLE	CLARE	3.5	4.2	9.2	5.9	17.0	8.0	5.9	5.5	48
SILVER	GR. TRAVERSE	1.0<	1.0<	1.5	2.0	1.8	1.3	1.5	0.7	35
SMALLWOOD	GLADWIN	1.0<	2.0	6.9	3.6d	2.5	3.1	2.5	2.4	40
SPIDER	GR. TRAVERSE	1.2	1.7	2.9	2.9	2.8	2.3	2.8	0.8	41
MDEQ						3.7				
MDEQ/Rep						3.7				
STONEY	OCEANA	9.7	3.3	8.0	8.0	8.8	7.6	8.0	2.5	51
MDEQ				9.6						
MDEQ/Rep				9.1						
STRAWBERRY	LIVINGSTON	2.2	5.0	4.5	7.1	5.1	4.8	5.0	1.8	46

APPENDIX 3
2004 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) May	June	July	Aug	Sept	Mean	Median	Std. Devia-tion	Carlson TSI_{CHL}
TORCH, SOUTH	ANTRIM	1.0<,d	1.0<	1.0<	g,e	1.0<,g	<1.0	<1.0	0.0	<31
TORCH, NORTH	ANTRIM	1.0<	1.0<,d	1.0<	1.0<,g	1.0<,g	<1.0	<1.0	0.0	<31
TWIN, BIG	CASS	1.0	3.6	2.6	2.5	2.8	2.5	2.6	0.9	40
TWIN, LITTLE	CASS	1.4	3.8	*	3.8	1.9	2.7	2.9	1.3	41
TWIN, EAST	MONTMORENCY	1.3d	1.5d	1.6d	1.8	3.6	2.0	1.6	0.9	35
TWIN, WEST	MONTMORENCY	1.8d	1.4d	3.0d	2.1	2.8	2.2	2.1	0.7	38
VAN ETTAN	IOSCO	6.9	2.3	7.2	3.0	2.5	4.4	3.0	2.5	41
VIKING	OTSEGO	53.0	13.0	2.8	5.6	8.7	16.6	8.7	20.7	52
VINEYARD	JACKSON	3.5	1.7	2.4	1.9	2.0	2.3	2.0	0.7	37
MDEQ						1.3				
MDEQ/Rep						1.4				
WALLED	OAKLAND	1.3	1.5	5.4	3.0	1.5	2.5	1.5	1.7	35
Vol/Rep				5.6						
WELLS	OSCEOLA	4.2	1.6	3.6	2.3	4.2	3.2	3.6	1.2	43
WHITE	OAKLAND	2.7	1.7	2.4	1.5	1.3	1.9	1.7	0.6	36
WINDOVER	CLARE	2.2c	2.0c	2.6c	c,h	c,h				
WOODS	KALAMAZOO	2.9d	6.9	16.0	8.3	12.0c	9.2	8.3	5.0	51

< Sample value is less than limit of quantification (1 ug/l)
* No sample received
a Label not properly filled out
b Label and data sheet sample dates do not agree
c No data sheet submitted with sample
d Sample not collected within the designated sampling window
e Sample vile contained blue separator sheet instead of white filter
f Sample unfrozen for 24 hours
g Sample poorly covered by aluminum foil
h No MgCO3 used to preserve the sample
I Sample not collected at proper time
j Vile not covered by aluminum foil

APPENDIX 4
2004 COOPERATIVE LAKES MONITORING PROGRAM
DISSOLVED OXYGEN AND TEMPERATURE RESULTS

County	Participating Lake
Alcona	Hubbard Lake
	Jewell Lake
Antrim	Lake Bellaire
	Clam Lake
Benzie	Lake Ann
Cass	Big Twin Lake
	Little Twin Lake
Cheboygan	Mullet Lake
Clare	Lake George
	Shingle Lake
Grand Traverse	Arbutus Lake
	Silver Lake
Ingham	Lake Lansing
Kalamazoo	Indian Lake
Kent	Bostwick Lake
	Cowan Lake
	High Lake
Lenawee	Devils Lake
	Round Lake
Livingston	Lake Chemung
	Strawberry Lake
Mason	Hamlin Lake
Mecosta	Blue Lake
	Mecosta Lake
	Round Lake

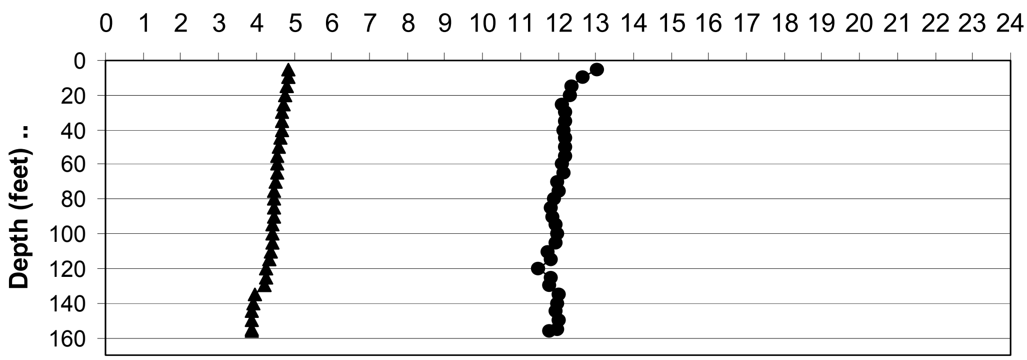
County	Participating Lake
Newaygo	Crystal Lake Hess Lake Robinson Lake
Oakland	Lake Orion Oxbow Lake
Osceola	Indian Lake Wells Lake
St. Joseph	Fisher Lake Little Fisher Lake
Van Buren	Cedar Lake Magician Lake

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 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.

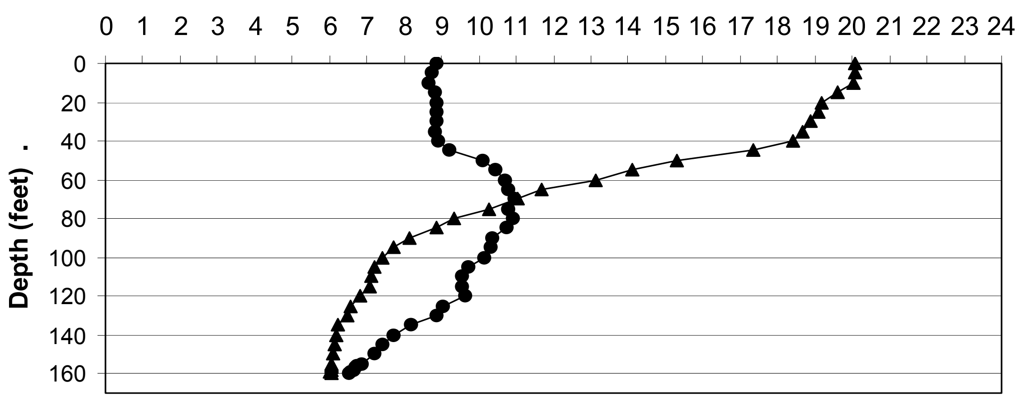
Oligotrophic Lake with a Very Large Volume Hypolimnion

Crystal Lake in Benzie 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.

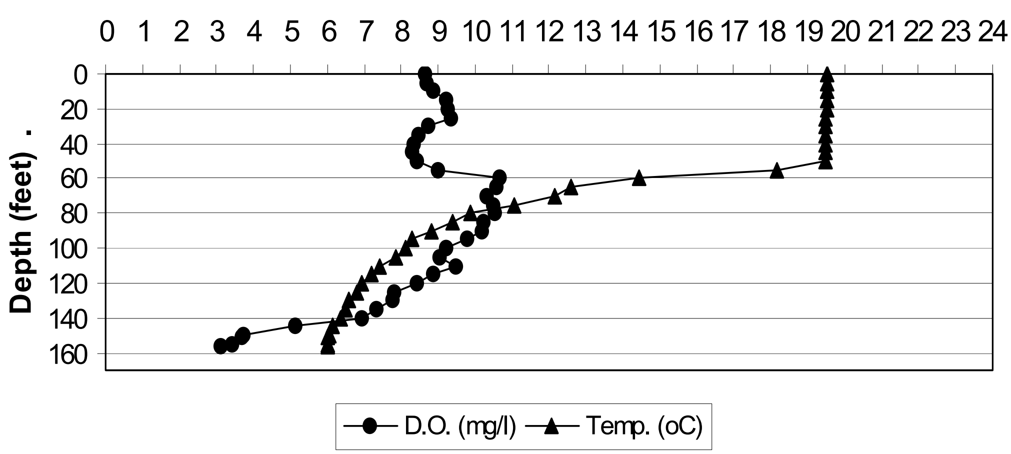
April 23, 2004



July 16, 2004



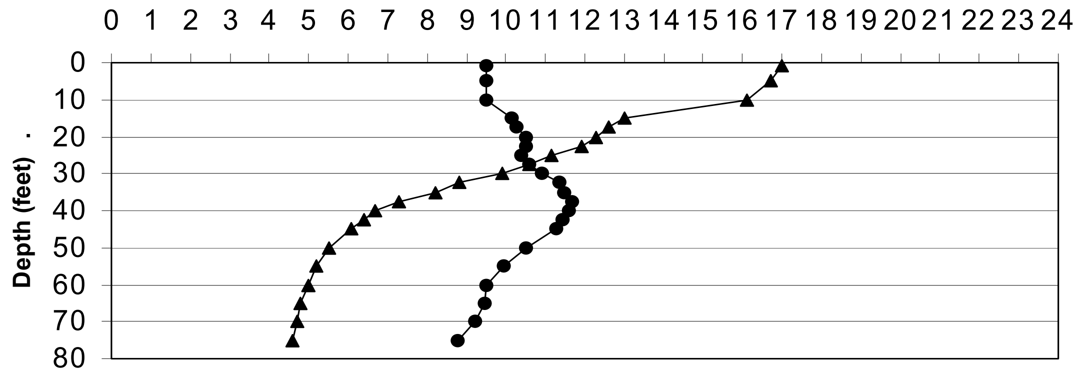
August 21, 2004



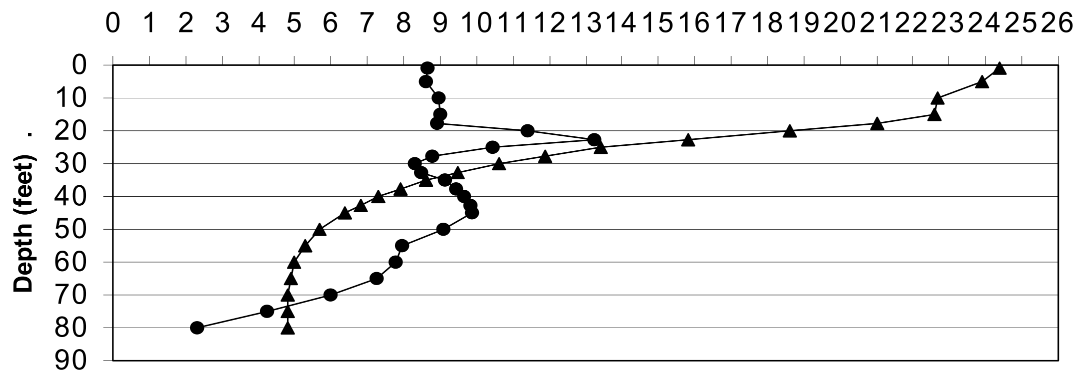
Oligotrophic/Mesotrophic Lake with a Large Volume Hypolimnion

Derby Lake in Montcalm 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.

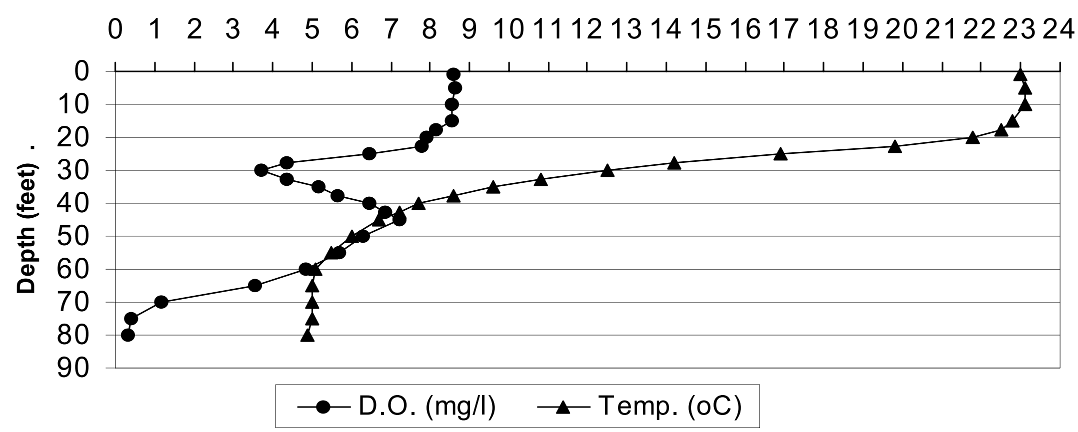
May 12, 2004



July 16, 2004



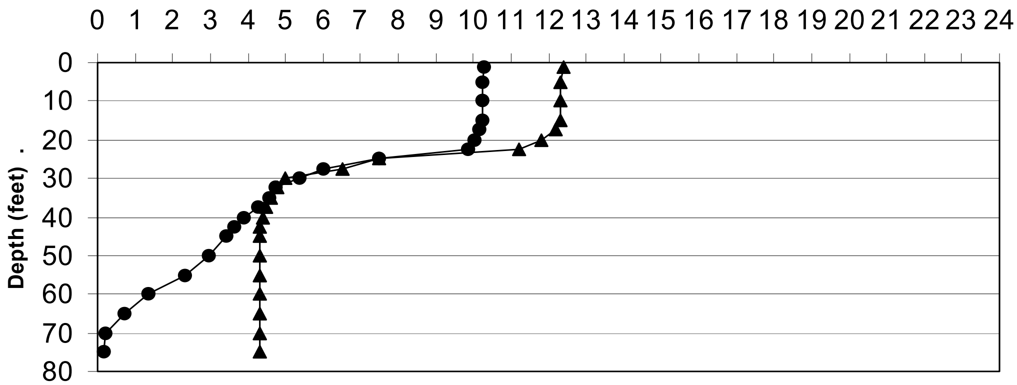
September 4, 2004



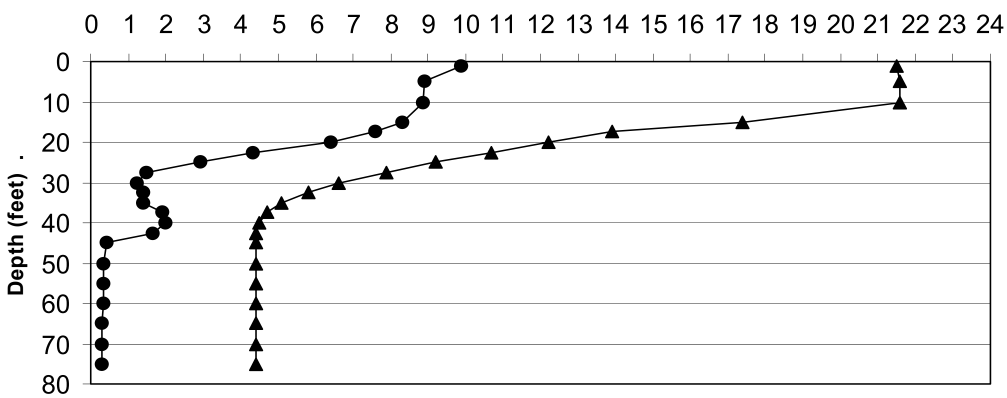
Oligotrophic/Mesotrophic Lake with a Small Volume Hypolimnion

Wells Lake in Osceola 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 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.

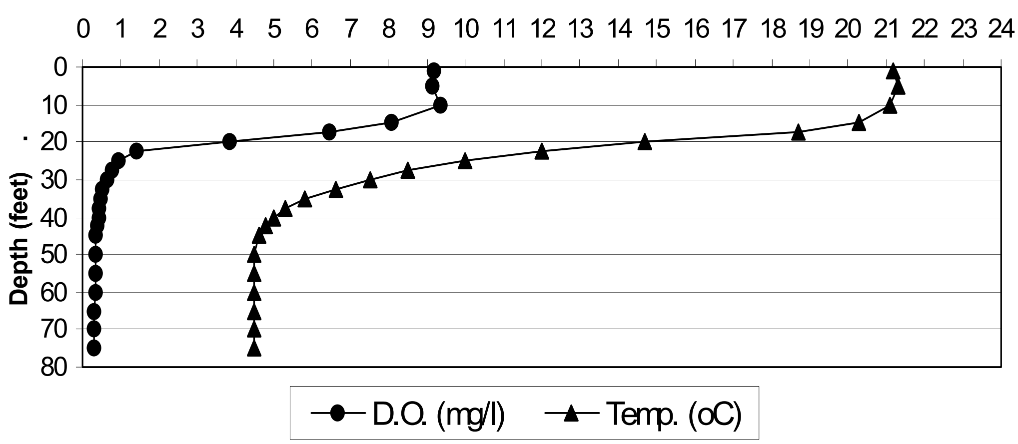
May 1, 2004



July 7, 2004



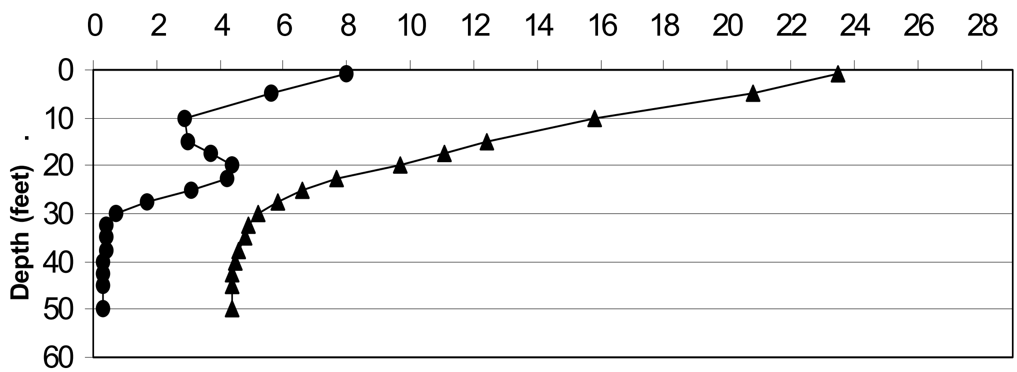
September 1, 2004



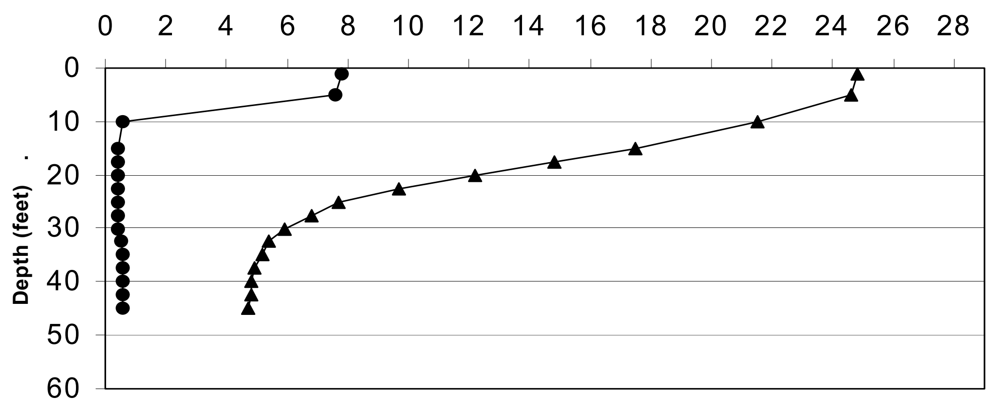
Eutrophic Lake with a Small Volume Hypolimnion

Cowan Lake in Kent County is a eutrophic lake with a small volume hypolimnion. As a productive 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.

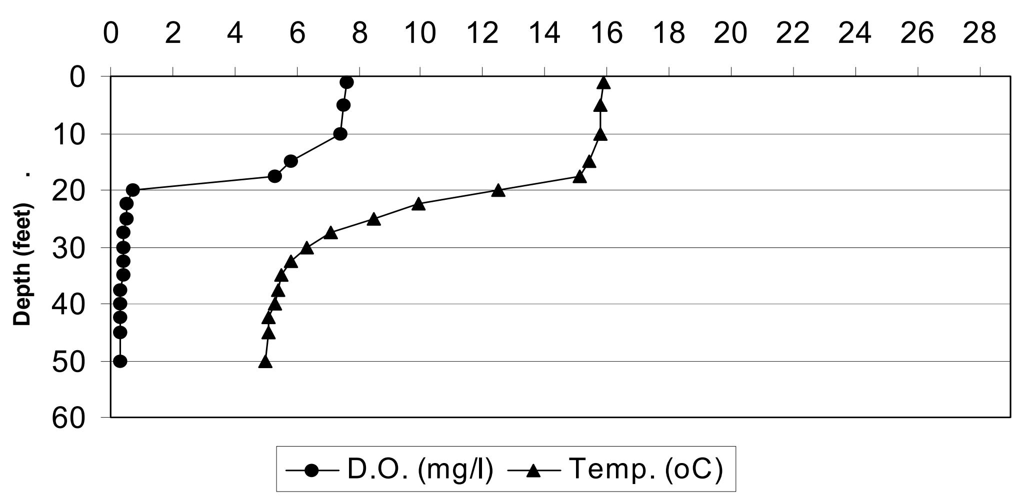
June 10, 2004



August 6, 2004



October 9 2004



Shallow Eutrophic Lake that does not Maintain Summer Stratification

Hess Lake in Newaygo 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-supplying the deep water with oxygen. In the calm periods between storms, dissolved oxygen is again quickly lost.