MI/DEQ/WB-07/003

COOPERATIVE LAKES MONITORING PROGRAM

Michigan's Citizen Volunteer Partnership for Lakes

"MI Lakes - Ours to Protect"

ANNUAL SUMMARY REPORT

2006

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

Michigan Clean Water Corps

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 often 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.

Cooperative Lakes Monitoring Program

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DATA CORRECTIONS FROM PREVIOUS REPORTS

There were no reported data or classification errors for the 2005 Annual Report.

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 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 monitored water quality by measuring water clarity with a Secchi disk.

In 1992, the DEQ (then the Department of Natural Resources) and the ML&SA entered into a cooperative agreement to expand the program. An advanced Self-Help program was initiated 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 citizens an opportunity to learn and participate in lake management. Currently, the CLMP supports monitoring components for Secchi disk transparency, total phosphorus, chlorophyll *a*, dissolved oxygen/temperature and aquatic plants.

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

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- Michigan Clean Water Corps
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  http:// www.micorps.net

CLMP and MiCorps

The CLMP is also a principal program within the Michigan Clean Water Corps (MiCorps), a network of volunteer monitoring programs in Michigan. It was created through an executive order by Governor Granholm to assist the DEQ in collecting and sharing water quality data for use in management programs and to foster water resource stewardship. MiCorps provides volunteer monitoring programs with many services including:

- Training programs,
- A web site-*www.micorps.net*,
- A data exchange network,
- A listserv,
- An annual conference, and
- A monitor's newsletter.

The mission of MiCorps is to network with and to support and expand volunteer water quality monitoring organizations across the state. To learn more about MiCorps visit their web site (www.micorps.net).

Michigan Clean
Water Corps

LAKE QUALITY

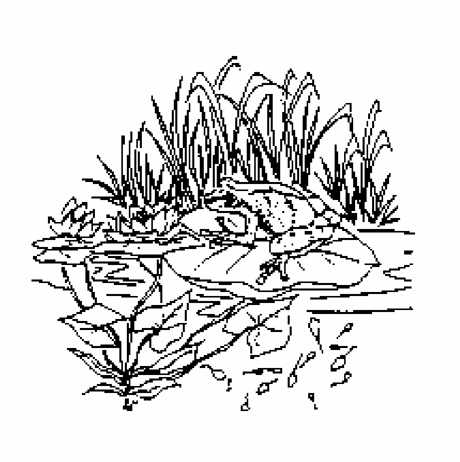
A lake's condition is influenced by many factors, such as the amount of recreational use it receives, shoreline development, and water quality. Lake *water quality* is a general term covering many aspects of chemistry and biology. The health of a lake is determined by its water quality.

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



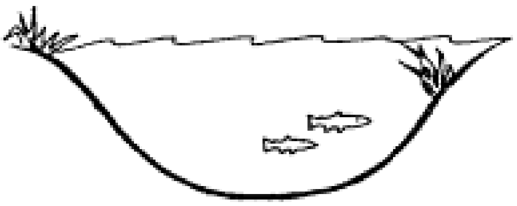
Increasing lake productivity can impact water quality and result in problems such as excessive weed growth, algal blooms, and mucky bottom sediments. *Productivity* refers to the amount of plant and animal life that can be produced within the lake.

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.



Oligotrophic

Mesotrophic

Eutrophic

(Source: Hamlin Lake Improvement Board)

EUTROPHICATION

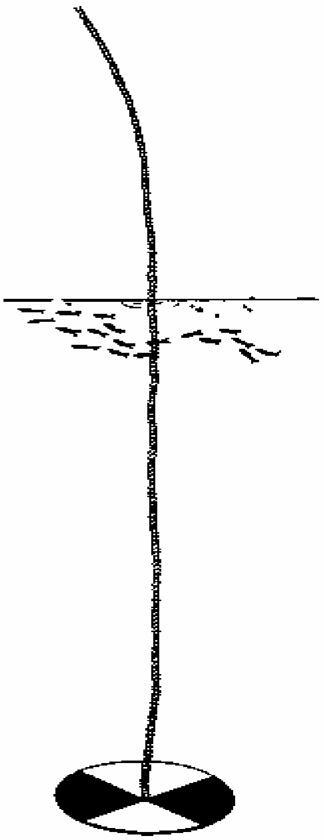
The gradual increase of lake productivity from oligotrophy to eutrophy is called lake aging or *eutrophication*. Lake eutrophication is a natural process resulting from the gradual accumulation of nutrients, increased productivity, and a slow filling in of the lake basin with accumulated sediments, silt, 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. Warm water fish, such as sunfish, bass, bullheads, and carp are 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)

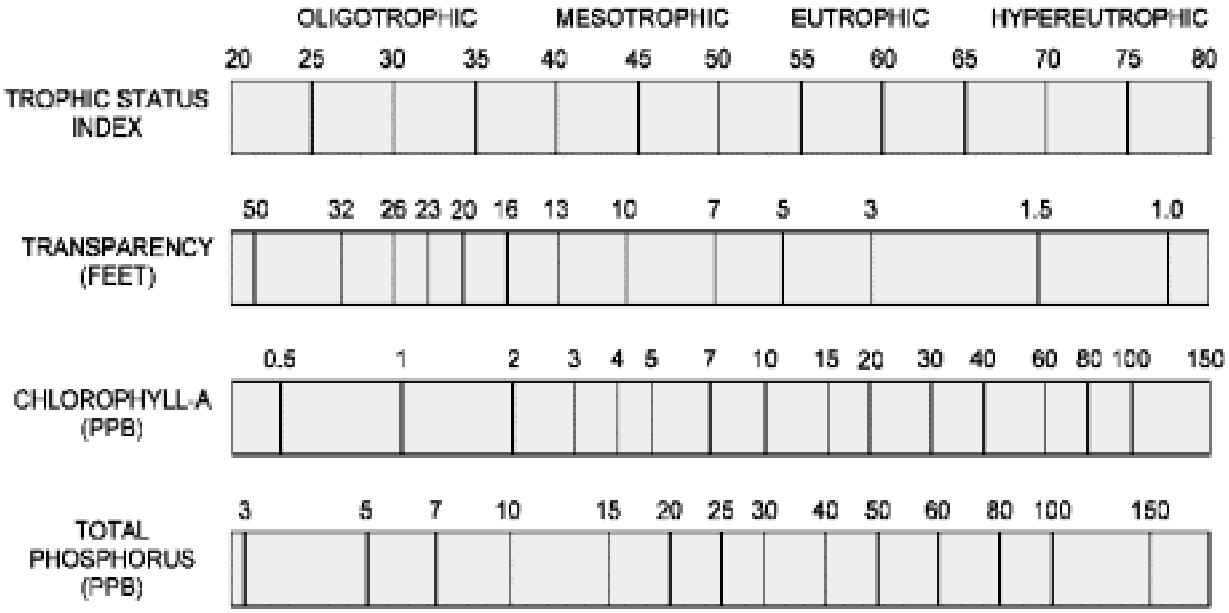
evaluate changes within the lake over time, and to estimate other water quality parameters within the lake.

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)

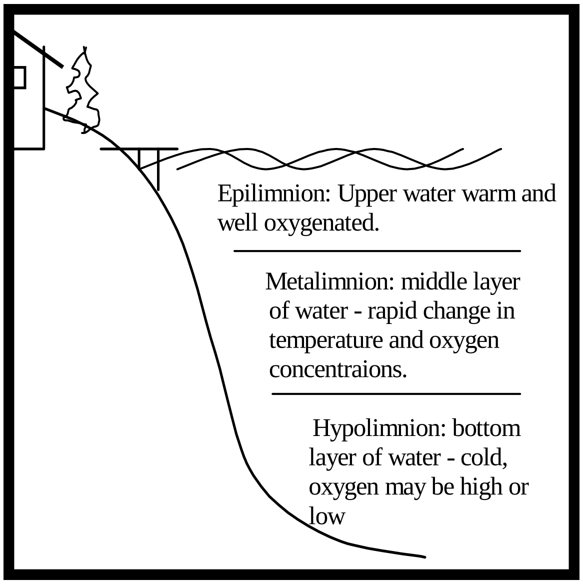
OTHER MEASURES OF LAKE PRODUCTIVITY

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 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 matter 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 35 feet maximum deep) can stratify, lose their 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

--IMPORTANT--

CLMP monitoring results for participating lakes are now available on the web in addition to being presented in summary form here in the annual report. To view current year and past results (through 2004 at this time), please visit MiCorps' Data Exchange Network at www.micorps.net/data/view/search/ and follow the instructions to find data on your lake of interest. On the site, you may search the database for lakes by lake name, county or watershed. You can also limit the data delivered to you by date or monitoring parameter(s). In 2007, monitoring data will appear on the Data Exchange well in advance of the annual report. CLMP volunteers may also find instructions on the website about how to enter their own data into the Data Exchange.

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.

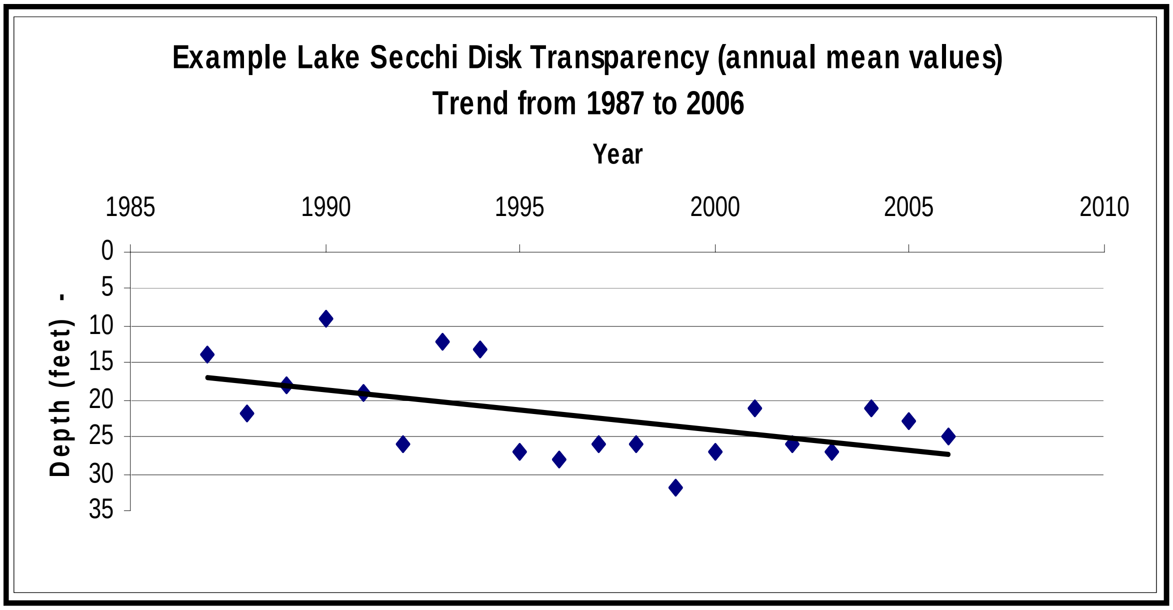
A summary of the transparency data collected by the lake volunteers during 2006 is included in Appendix 1. The number of measurements, or readings, made between mid-May and mid-September and the minimum and maximum Secchi disk transparency values are included for each lake that participated in the program. 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 2006, Secchi disk transparency data were reported for 201 lakes



(236 basins). Over 3850 transparency measurements were reported, ranging from 0.5 to 43.5 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 12.6 feet and the median value was 11.0 feet. The Carlson TSI_{SD} values ranged from 28 to 73 for these lakes with a mean value of 42. A Carlson TSI value of 42 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 2006 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 2006, samples for total phosphorus measurements were collected on 213 lakes. The spring overturn total phosphorus results ranged from <5 to 85 ug/l with a mean (average) of 12 ug/l and a median value of 10 ug/l. The late summer total phosphorus results ranged from <5 to 103 ug/l with 13 ug/l as the mean and 11 ug/l as the median. The Carlson TSI_{TP} values ranged from <27 to 71 for these lakes with a mean value of 39. A Carlson TSI value of 39 is generally indicative of a good quality mesotrophic lake (see page 8).

For the spring overturn sampling, 168 total phosphorus samples were turned in from 192 lakes registered in the program, for a participation rate of 87.5 percent. For the late summer sampling period 200 samples were received from 224 lakes for a participation rate of 89 percent.

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 2006 volunteers collected a minimum of four samples on 114 lakes.

Results from the chlorophyll monitoring for 2006 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 20 percent of the lakes.

About 600 chlorophyll samples were collected and processed in 2006. The chlorophyll *a* levels ranged from <1 to 42 ug/l over the five-month sampling period. The overall mean (average) was 3.9 ug/l and the median was 2.8 ug/l. The Carlson TSI_{CHL} values ranged from <31 to 58 with a mean value of 40. A Carlson TSI value of 40 is generally indicative of a good quality mesotrophic lake (see page 8).

During 2006, a total of 128 lakes (131 basins) registered for chlorophyll sampling. A total of 121 lakes participated minimally by turning in at least one sample, for a minimum participation rate of 95 percent. A total of 114 lakes turned in at least four samples for a complete participation rate of 88 percent. Ten samples were turned in, but not processed because of quality control issues for a 1.8 percent quality control rejection rate.

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}.

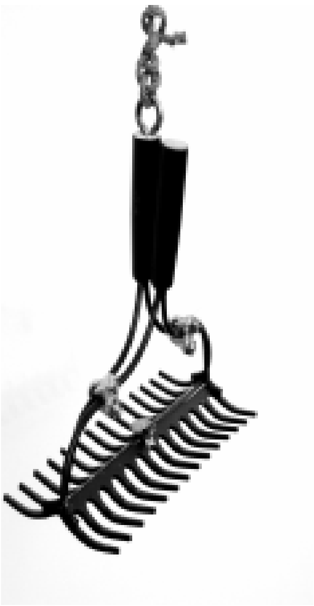
Dissolved Oxygen and Temperature

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 or 550A) 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 2006, CLMP participants in the dissolved oxygen/temperature project sampled 41 lakes. A total of 266 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 2006 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 eutrophic lake which weakly stratifies during the summer. A sixth pattern not represented is the very shallow lake, with a maximum depth of less than 22 feet. These lakes usually have the same temperature and dissolved oxygen concentrations from surface-to-bottom as a result of frequent mixing.



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.

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.

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 2006, CLMP participants in the aquatic plant project sampled two lakes for aquatic plants. The community at Glen Lake employed their modified plant sampling program to address the specific concern for exotic species introduction to the lake. Their monitoring would allow for early detection and rapid response to any introduced exotic aquatic plant.

The community at Beaver Lake, Alpena County did the standard plant survey.

In 2006, Beaver Lake had TSI values of 38 for Secchi disk, 32 for Total Phosphorus and 37 for Chlorophyll. These values would suggest that the lake is oligotrophic. Given this trophic state or productive level the lake should have a limited aquatic plant population. Indeed, except for Stonewort, which is common to oligotrophic lakes, all plant species had limited distribution and low densities. (See the results of the Beaver Lake survey in Appendix 5)

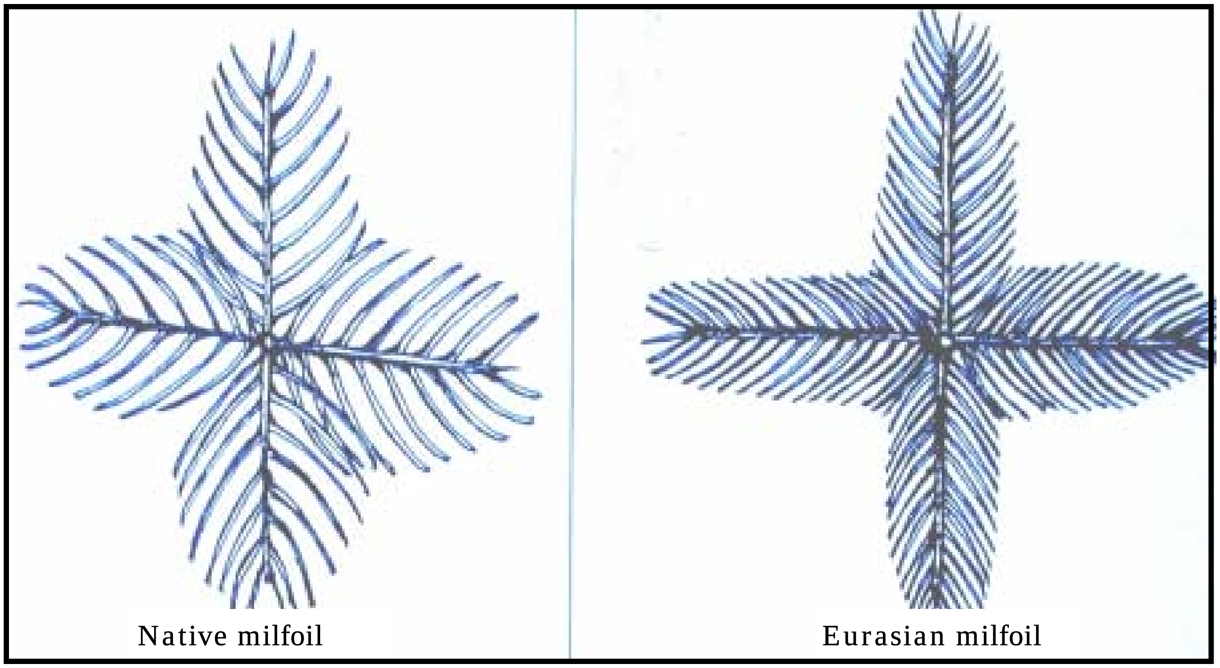
The Beaver Lake survey found no exotic plant species. The lake is susceptible to infestation and nuisance populations of aggressive exotic species. The lake community should continue to monitor for exotic species.

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

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

on a lake's condition. The DEQ and the ML&SA may be able to help you obtain additional information on your lake.

CLMP Data in Research

In 2005, researchers from Michigan State University (Bruhn and Soranno, 2005) published the results of a scientific evaluation of CLMP data in the Lake and Reservoir Management Journal. They looked to see if there where any long-term changes in water quality in Michigan lakes and if there was any relationship to area and land use with changes in quality. For their study they used Secchi disk water clarity data collected by CLMP volunteers as the measure for change in quality.

They found that most lakes' water quality (clarity) had remained the same or improved (clarity increased) since the 1970s . Thirty-one percent of the lakes increased in water clarity, 63% had no change and 6% declined in clarity. From the limited data, they find no significant relationship between land uses and water quality change, but did note that lakes in the northern part of the state had better clarity than lakes in the southern part of the state.

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

MANAGEMENT OF THE CRYSTAL LAKE WATERSHED

The Crystal Lake watershed (Benzie Co.) contains many diverse and unique environmental niches, including sand dunes, forested heights, wetlands, tributaries, and Crystal Lake, the 9th largest lake in Michigan - a body of pristine water of exceptional clarity, sandy shorelines, mixed sand and rock perimeter, and deep marl bottom. These unique features demand responsible stewardship and watershed management by its riparian owners and visitors.

The Crystal Lake & Watershed Association (**CLWA**), formed in 2004 upon merger of the Crystal Lake Association and the Crystal Lake Watershed Fund, builds on more than 50 years of history to protect and promote the natural qualities of Crystal Lake and its surrounding watershed. CLWA is working to preserve the lake and watershed beauty and recreational resources for future generations by monitoring water quality, providing educational programs, promoting harmonious land development, and ensuring safe use.

Water quality monitoring is understanding lake and watershed processes. The CLWA has conducted water quality monitoring in cooperative programs with many organizations, including the Cooperative Lakes Monitoring Program. Water quality monitoring of Crystal Lake dates from the 1940's and several major reports have been published. Vertical profiles of temperature, dissolved oxygen, pH, conductivity, redox, and turbidity have been measured since 1994 with a Hydrolab® H_2O multiprobe. Nitrogen, phosphorus, chlorophyll a, and Secchi disk depth are also determined.

The CLWA is proactive in addressing issues of land and water use. In 1989, Benzie County was one of the first counties in the U.S. to adopt an ordinance to require upgrading of onsite wastewater treatment systems prior to sale of any properties. Several hundred individual systems within the Crystal Lake watershed and elsewhere in Benzie County, have been upgraded. Benzie and Leelanau Counties have adopted new standards for Alternative Treatment Units using "innovative" or "advanced" treatment technologies to provide a higher degree of treatment to protect water quality of lakes and groundwater. More recent issues with potential impacts on water quality include: enforcement of the Crystal Lake Watershed Overlay District ordinance; litigation of the boat launch design; control of runoff from State Highway M-22; and reviewing the "Benzie Corridor" being considered in the management plan by the Sleeping Bear National Lake Shore.

The **Crystal Lake *"Walkabout"***, an educational program coordinated by the CLWA and cosponsored with 17 other organizations, is directed at students, property owners, and visitors of the Crystal Lake watershed. The program focuses on hydrology - how water moves about the watershed. Participants "walk about" Interpretive Sites in the watershed - the lake, and its tributaries, wetlands, dunes, and high ridges - as environmental professionals describe features and conduct activities associated with watershed management. Each participant receives a T-shirt and a 42 page Interpretive Manual containing maps, facts, descriptions of the Interpretive Sites, a chronology of the Crystal Lake history, and listing of watershed concerns and actions. Since 1994, the ***"Walkabout"*** has been presented to over 3,000 participants. In 2002, it became a biennial event for all 6th and 8th grade students in Benzie County. There is also a special program in mid-summer open to the public.

By Dr. Stacy L. Daniels,
CLWA, PO 89, Beulah, MI 49617

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. Mr. Ralph Bednarz Telephone: 517-335-4211 or bednarzr@michigan.gov

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. Additionally, those also involved in coordinating the CLMP include Donald Winne and Pearl Bonnell of the Michigan Lake and Stream Associations, Inc., and MiCorps staff, Ric Lawson and Jo Latimore of the Huron River Watershed Council.

Thank you to the dedicated volunteers who have made the CLMP one of the nations most successful citizen volunteer lakes monitoring programs. Also a special thank you to Ralph Vogel for constructing the Secchi disks for the CLMP, to Jean Roth for handling numerous administrative tasks, and to Bruce Bonnell, Mary Mueller and volunteer samplers who compiled data.

APPENDIXES

Appendix 1

2006 Secchi Disk Transparency Results

Appendix 2

2006 Total Phosphorus Results

Appendix 3

2006 Chlorophyll Results

Appendix 4

2006 Dissolved Oxygen and Temperature Participating Lakes and Example Results

Appendix 5

2006 Aquatic Plant Mapping Participating Lakes and Example Results

APPENDIX 1
2006 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)
Ann	Benzie	17	10	30	16.7	13	6.81	37
Antoine	Dickinson	12	10	15	12.8	12	1.53	40
Arbutus 1	Gr Traverse	17	8	13	11.7	12	1.57	42
Arbutus 2	Gr Traverse	17	13	26	17.7	17	4.58	36
Arbutus 3	Gr Traverse	17	13	26	17.1	16	4.36	36
Arbutus 4	Gr Traverse	17	11	24	15.5	15	3.78	38
Arbutus 5	Gr Traverse	17	11	19	13.8	13	2.24	39
Arnold	Clare	14	15	18	16.4	16.5	1.29	37
Baldwin	Montcalm	14	8.5	13.5	10.5	9.75	1.66	43
Bankson	Van Buren	16	9	19	11.8	9.75	3.50	42
Barlow	Barry	15	7	18	10.9	10	3.45	43
Base Line	Livingston	11	9.5	18.5	14.6	14.5	2.86	38
Bass	Kalkaska	6	7.5	19.5				
Bear	Manistee	13	7	23	9.3	8	4.17	45
Bear 1	Kalkaska	18	15	30	25.5	27	4.82	30
Bear 2	Kalkaska	18	17	29	25.7	27.5	4.00	30
Beatons 1	Gogebic	9	13.5	16.5	14.9	15.5	1.27	38
Beatons 2	Gogebic	9	17.5	21.5	19.2	18.5	1.46	34
Beatons 3	Gogebic	9	16.5	19.5	18.2	18.5	1.09	35
Beatons 4	Gogebic	6	14.5	21.5				
Beaver	Alpena	10	10	22.5	14.9	14	3.77	38
Bellaire	Antrim	17	10	20	12.9	12	2.76	40
Big	Osceola	16	20	33	25.3	24.5	3.66	31
Bills 1	Newaygo	17	7	20	11.7	9.5	4.01	42
Bills 2	Newaygo	12	7	21	14.2	12.5	4.93	39
Birch	Cass	18	12	38	21.7	18.5	9.32	33
Blue	Mason	14	22	36	25.7	23.75	4.57	30
Blue (Big)	Kalkaska	17	21	30	25.0	24.5	3.14	31
Blue 1	Mecosta	18	10	19	12.6	11.75	2.64	41
Blue 2	Mecosta	17	10	23	12.7	12	3.31	40
Bostwick	Kent	8	4.5	17.5	9.1	8.5	3.97	45
Brace, Lower	Calhoun	15	6.5	13	9.4	9	1.98	45
Brace, Upper	Calhoun	15	7	14	9.9	9.5	2.49	44
Bradford, Big	Otsego	8	15	22	17.8	17.75	2.10	36

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2006 COOPERATIVE LAKES MONITORING PROGRAM
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Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min	Max	Mean	Median	Standard Deviation	Carlson TSI$_{SD}$ (transparency)
Brooks	Leelanau	16	5.5	14.5	9.0	8.5	2.25	45
Brooks	Newaygo	9	2	4	2.5	2.5	0.66	64
Buck	Livingston	13	7.5	13.5	9.2	8.5	2.10	45
Buckhorn (North)	Oakland	18	9	14	11.6	11	1.38	42
Byram 1	Genesee	18	13	17	14.4	14	1.09	39
Byram 2	Genesee	18	12	16	13.5	13	1.20	40
Byram 3	Genesee	18	12	16	13.4	13	1.20	40
Canadian	Mecosta	12	6	17.5	10.4	9	3.85	43
Canadian, West	Mecosta	12	7	15	11.1	10.5	2.53	42
Cedar	Van Buren	18	9.5	18	12.7	11.75	2.65	40
Cedar (Briarwood)	Alcona	14	9.5	12.5	11.5	11.5	0.82	42
Cedar (Schmidts)	Alcona	14	6.5	10.5	8.6	8.5	1.32	46
Center	Osceola	9	15	20	15.9	15	1.63	37
Chain	Iosco	9	10	14	11.6	11	1.13	42
Christiana	Cass	14	5	10.5	7.0	7	1.48	49
Clam	Antrim	16	14	25	18.8	18.25	3.44	35
Clark 1	Jackson	13	7.5	33	13.2	10	7.25	40
Clark 2	Jackson	10	6	26.5	12.9	11.5	6.63	40
Clear	Jackson	13	7.5	13.5	9.5	9	1.98	45
Clear	St. Joseph	5	14.5	15.5				
Clifford	Montcalm	17	9	11.5	10.0	10	0.72	44
Cobb	Barry	18	5	24.5	12.0	9	5.69	41
Corey	St. Joseph	18	7.5	26.5	13.6	11.75	5.38	39
Cowan	Kent	18	4	8.5	5.9	6	1.32	51
Cowboy Lake	Dickinson	16	6	12	8.7	8.75	1.68	46
Crooked	Kalamazoo	18	10	22	14.3	12.5	4.01	39
Crooked (N)	Kalkaska	3	5.5	6.5				
Crooked, Big	Van Buren	18	9	14.5	12.6	12.75	1.79	41
Crooked, Little	Van Buren	14	9.5	20	12.7	12.25	3.24	40
Crooked, Upper 1	Barry	18	6	17	8.7	7.5	3.32	46
Crooked, Upper 2	Barry	18	6	18	9.0	7.25	3.76	45
Crystal	Dickinson	14	0.5	3	1.4	1.25	0.79	73
Crystal	Hillsdale	18	10.5	22	13.6	13	2.69	40
Crystal	Newaygo	10	7	18	13.8	13.5	3.65	39

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2006 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)
Crystal	Oceana	14	7.5	12.5	10.0	9.5	1.78	44
Cub	Kalkaska	15	13	23	17.5	18	3.44	36
Deer	Alger	10	6	9	7.3	7	1.03	48
Deer	Oakland	13	7.5	27	11.7	9.5	5.70	42
Derby	Montcalm	17	14	27	19.1	18	4.44	35
Diamond	Cass	18	5.5	20	11.4	10.5	4.73	42
Diamond	Newaygo	11	7.5	14.5	11.1	10.5	2.43	42
Dinner	Gogebic	16	11	15	13.0	12.5	1.55	40
Eagle	Allegan	16	9	13.5	11.2	11	1.62	42
Earl	Livingston	18	4.5	9.5	6.6	6.5	1.30	50
Emerald	Kent	18	4.5	20.5	11.7	11.5	4.13	42
Emerald	Newaygo	14	7	15	10.7	10.5	2.41	43
Fair	Barry	16	8.5	14	10.9	10.5	1.62	43
Farewell	Jackson	14	6	21	11.1	9	4.67	42
Fenton	Genesee	6	16	22				
Fish	Van Buren	18	5	15	10.1	10	2.51	44
Fisher	St. Joseph	18	7.5	35	17.2	15	8.50	36
Fisher, Big	Leelanau	12	14	16	15.0	15	1.04	38
Fisher, Little	Leelanau	12	13	14	13.6	14	0.51	40
Fisher, Little	St. Joseph	17	8	15	11.7	11	2.65	42
Ford	Mason	17	14.5	25.5	19.4	19	2.82	34
Freska	Kent	10	7.5	9.5	9.0	9.25	0.69	46
Gallagher	Livingston	7	9.5	12				
Glen (Big)	Leelanau	17	14	28.5	20.0	20	3.44	34
Glen, Little	Leelanau	18	4.5	12	8.4	8.25	1.98	46
Goshorn	Allegan	18	3.5	11	6.2	5.5	1.91	51
Gourdneck	Kalamazoo	16	6	19	12.4	13	3.92	41
Gratiot	Keweenaw	14	11.5	27.5	21.3	20	4.40	33
Gravel	Van Buren	18	9	15	10.8	10	1.89	43
Gut	Livingston	12	8.5	14.5	11.0	10.5	1.69	43
Hamburg	Livingston	18	13.5	24	17.0	16.5	2.64	36
Hamilton	Dickinson	16	9.5	14	11.6	11	1.32	42
Hamlin, Lower	Mason	17	10	18	13.0	13.5	2.02	40
Hamlin, Upper	Mason	17	4.5	13	9.2	9	2.19	45

APPENDIX 1
2006 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)
Harper	Lake	17	15	22	18.2	18	2.02	35
Hawk	Oakland	14	8.5	12	9.6	9.5	1.18	44
Hess	Newaygo	11	2	4.5	3.0	3	0.88	61
Hicks	Osceola	17	5	9	6.6	6.5	1.04	50
Higgins (N)	Roscommon	8	19.5	43.5	30.4	31.5	8.69	28
Higgins (S)	Roscommon	8	18	40.5	30.8	32.25	8.22	28
Horsehead	Mecosta	18	9	18.5	12.3	11	3.41	41
Houghton	Roscommon	12	4.5	8	5.2	5	0.96	53
Hubbard 1	Alcona	13	10	22	16.0	16	3.96	37
Hubbard 2	Alcona	14	11	22	16.8	17	3.99	36
Hubbard 3	Alcona	10	11	20	15.6	15	3.13	38
Hubbard 4	Alcona	10	12	23	16.3	14	3.85	37
Hubbard 5	Alcona	10	11	21	16.0	16.5	3.06	37
Hubbard 6	Alcona	18	10.5	21	15.7	15	3.49	37
Hubbard 7	Alcona	13	11	21	16.7	17	3.77	37
Hunter	Gladwin	15	7.5	17.5	12.0	11	3.03	41
Hutchins	Allegan	17	6.5	12.5	8.5	8	1.50	46
Indian	Kalamazoo	13	8	25.5	14.1	13.5	5.75	39
Indian	Kalkaska	14	7.5	17.5	10.8	10	3.11	43
Indian	Osceola	18	16	25	20.3	20	3.16	34
Island	Gr Traverse	13	12	25	18.0	18	3.87	35
Jewell	Alcona	15	6.5	10	8.4	8.5	1.32	46
Juno	Cass	14	5.5	10	6.7	6.5	1.25	50
Kimball	Newaygo	13	3.5	8.5	6.6	7	1.41	50
Klinger	St. Joseph	18	6	19	11.0	9.5	4.77	43
Lakeville	Oakland	16	12	21	14.6	13	3.05	38
Lancelot 1	Gladwin	10	6	10	8.2	8	1.06	47
Lancelot 2	Gladwin	9	7	10	8.2	8	1.00	47
Lancelot 3	Gladwin	10	7	11.5	9.4	9.5	1.58	45
Lancer 1	Gladwin	13	7	8.5	7.7	8	0.48	48
Lancer 2	Gladwin	13	9	14.5	11.6	12	2.09	42
Lancer 3	Gladwin	13	7	11	8.6	9	1.00	46
Lancer 4	Gladwin	13	2.5	5	4.0	4	0.66	57
Lancer 5	Gladwin	13	4	6	5.0	5	0.43	54

APPENDIX 1
2006 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)
Lansing	Ingham	16	5	7.5	6.0	6	0.61	51
Little	Marquette	14	12.5	21	16.8	15.75	2.76	36
Long	Iosco	15	10	15	12.0	12	1.43	41
Long	Oakland	18	11.5	19.5	13.6	13.5	1.81	39
Long	Washtenaw	8	8	12	9.8	9.5	1.49	44
Long 1	St. Joseph	12	10	27	16.0	13.5	5.95	37
Long 2	St. Joseph	11	9	24	13.9	12	4.18	39
Long, Upper	Oakland	12	6	15.5	12.0	13.25	3.28	41
Magician	Cass	18	6.5	18.5	11.1	9.5	4.12	42
Margrethe	Crawford	17	8	24	12.8	10	5.83	40
Mary	Iron	18	19	28.5	24.7	24.75	2.37	31
Mecosta	Mecosta	10	8.5	15	11.0	11	1.71	43
Mehl	Marquette	14	10	15	12.6	12.75	1.65	41
Mill	Van Buren	10	10.5	15.5	13.4	14	1.71	40
Miner	Allegan	11	5.5	22.5	11.7	12.5	5.48	42
Moon	Gogebic	16	16	25	20.3	19.5	2.65	34
Mud	Jackson	9	8	12	9.9	10	1.27	44
Mullett	Cheboygan	7	11.5	22.5	16.7	15.5	4.97	37
Murray	Kent	17	4.5	10.5	8.1	8.5	2.00	47
Muskellunge	Montcalm	18	5.5	15.5	9.1	8.25	2.85	45
Nepessing	Lapeer	18	11	19	16.1	16.5	2.29	37
North Blue	Kalkaska	11	16	22	18.5	18	2.30	35
Oneida	Livingston	13	6.5	12	9.0	8.5	1.75	46
Ore	Livingston	18	4	15	9.1	8.75	3.97	45
Osterhout	Allegan	13	7	10	8.4	9	1.12	46
Otsego	Otsego	18	6.5	14	9.8	9.5	2.46	44
Oxbow	Oakland	11	12.5	17.5	14.0	14.5	1.49	39
Painter	Cass	14	3	6	4.5	4.5	0.89	55
Papoose	Kalkaska	9	28	30	29.1	29	0.60	29
Parke	Oakland	16	12	19	15.7	15	2.61	37
Paw Paw, Little	Berrien	16	3	6.5	4.5	4.5	1.04	55
Payne	Barry	8	6	20	9.1	7.75	4.48	45
Pentwater 2	Oceana	8	4.5	6.5	5.6	5.5	0.64	52
Pentwater 4	Oceana	8	5	7.5	6.3	6.5	0.92	51

APPENDIX 1
2006 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)
Perch	Hillsdale	18	7	9	8.8	9	0.57	46
Perch	Otsego	9	8	13.5	11.1	11.5	1.83	42
Pickerel	Newaygo	13	10	15	11.8	11	1.94	41
Platte (Big)	Benzie	18	8	14	11.3	11	1.58	42
Platte (Little)	Benzie	10	6.5	7.5	6.9	6.75	0.41	49
Pleasant	Jackson	18	5.5	10.5	8.4	8.5	1.70	46
Pleasant	Wexford	16	4.5	7	5.7	5.5	0.91	52
Ponemah	Genesee	18	7.5	12.5	9.9	10	1.40	44
Portage	Jackson	9	7	17.5	11.0	9.5	3.77	43
Portage	Livingston	17	7.5	18.5	12.3	12	3.93	41
Pretty	Mecosta	11	11.5	18.5	13.5	12.5	2.51	40
Puterbaugh	Cass	15	8	19.5	11.5	9.5	3.39	42
Reeds	Kent	10	2.5	11.5	5.9	6.25	2.54	52
Reynolds, Lower	Van Buren	15	9	16	13.2	14	2.20	40
Reynolds, Upper	Van Buren	15	12	17.5	14.5	14	1.86	39
Robinson	Newaygo	9	7	12	8.3	8	1.50	47
Round	Clinton	17	7.5	13.5	9.5	9.5	1.44	45
Round	Lenawee	8	8	22	13.8	13	4.80	39
Round	Mecosta	10	6	12	9.7	10	1.95	44
Sage	Ogemaw	10	13	13.5	13.1	13	0.16	40
Sanford	Benzie	17	7	31	15.5	13	7.98	38
Sanford	Midland	18	4.5	9.5	7.3	7.75	1.45	48
Sapphire	Missaukee	9	8	8.5	8.4	8.5	0.17	46
School Section	Van Buren	18	9	13.5	11.2	11.5	1.25	42
School Section 1	Mecosta	17	5.5	14	9.3	9.5	2.19	45
School Section 2	Mecosta	17	5	14.5	8.5	8.5	2.23	46
Shafer	Van Buren	14	9.5	20	15.1	14.5	3.19	38
Shingle	Clare	17	8.5	12	10.0	10	1.04	44
Silver	Gr Traverse	18	16	32	22.7	21.75	4.72	32
Silver	Livingston	14	8.5	23	15.8	16	4.86	37
Silver	Van Buren	16	10.5	13	11.8	11.75	0.75	42
Silver 1	Genesee	18	8	19	12.2	11	3.88	41
Silver 2	Genesee	18	7.5	18	11.7	10.25	3.80	42
Silver 3	Genesee	18	8	18	11.8	10.5	3.67	41

APPENDIX 1
2006 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)
Spider 1	Gr Traverse	17	12	22	15.5	14	3.39	38
Spider 2	Gr Traverse	16	11	20	14.8	14	2.72	38
Spider 3	Gr Traverse	17	9	18	13.9	13	3.33	39
Squaw	Kalkaska	6	6.5	14				
Star, Big	Lake	15	9	13	9.9	10	1.09	44
Starvation	Kalkaska	16	17.5	24.5	20.1	19.5	2.33	34
Stone Ledge	Wexford	18	7	11	9.0	9	1.18	45
Stony 1	Oceana	9	3.5	11.5	7.3	6.5	2.98	48
Stony 2	Oceana	16	3.5	15	8.4	8.25	3.84	46
Strawberry	Livingston	16	6.5	9.5	7.7	7.5	0.87	48
Sweezey	Jackson	18	5	13	8.2	8	2.00	47
Sylvan	Newaygo	14	5	18	9.8	9.5	3.67	44
Taylor	Oakland	18	16	18	17.2	17	0.52	36
Torch (N. Basin)	Antrim	17	18.5	40.5	28.5	30	7.30	29
Townline	Mecosta	18	7.5	13	9.9	9.5	1.75	44
Triangle	Livingston	9	10	15	11.6	10.5	1.85	42
Twin, Big	Cass	16	9	25	17.1	17	5.69	36
Twin, Big	Kalkaska	16	14	26	22.4	23	3.24	32
Twin, Little	Cass	18	5	21	12.1	12.25	4.41	41
Twin, Little	Kalkaska	8	14.0	21.5	16.1	15.5	2.40	37
Twin, West	Montmorency	10	7.5	10.5	9.1	9.0	1.17	45
Van Ettan	Iosco	17	2.5	8.5	5.2	4.5	1.86	53
Vaughn	Alcona	18	8.5	18.0	12.3	11.5	2.96	41
Viking	Otsego	18	7.0	14.0	11.1	12.0	2.49	42
Vineyard	Jackson	17	8.0	27.0	14.0	12.0	5.63	39
Wahbememe	St. Joseph	13	15.0	31.0	22.9	23.0	4.92	32
Wamplers	Jackson	11	7.0	12.0	9.5	9.0	1.86	45
Webinguaw	Newaygo	10	3.0	6.0	4.2	4.0	0.82	57
Wells	Osceola	18	14.0	21.0	17.3	17.3	2.35	36
Wildwood	Washtenaw	18	10.0	12.5	11.3	11.5	0.73	42
Windover	Clare	10	11.0	23.0	15.8	14.3	4.50	37
Woods	Kalamazoo	16	5.5	13.5	10.0	10.8	2.63	44

APPENDIX 2
2006 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

		Total Phosphorus (ug/l)								Carlson
Lake	**County**	**Spring Overturn**				**Late Summer**				**TSITP**
		Vol	Rep.	DEQ	Rep.	Vol	Rep	DEQ	Rep	(summer TP)
ANN	BENZIE	6				5				27
ANTOINE	GR TRAVERSE					12 f				40
ARBUTUS	GR TRAVERSE	5				6				30
ARNOLD	CLARE	9				9				36
AVALON	MONTMORENCY	6				5				27
BALDWIN	MONTCALM	16				*				
BANKSON	VAN BUREN					17				45
BARLOW	BARRY	7				10				37
BASELINE	LIVINGSTON	15				14				42
BASS	KALKASKA	9				6				30
BASS	LIVINGSTON	9				*				
BEAR	KALKASKA	11				6				30
BEATONS	GOGEBIC	8	11			*				
BEAVER	ALPENA	10	8			7	6			32
BELLAIRE	ANTRIM	8 b				4 T				<27
BIG	OSCEOLA	17				13				41
BIG STAR	LAKE	9				9 h				36
BILLS	NEWAYGO	6 b				9				36
BIRCH	CASS	3 W				10				37
BISHOP	LIVINGSTON					10				37
BLUE	MASON	13				9				36
BLUE	MECOSTA	5				8				34
BLUE, BIG	KALKASKA	7				5				27
BLUE (NORTH)	KALKASKA	7				4 T				<27
BOSTWICK	KENT	*				33		30		55
BRACE, LOWER	CALHOUN					17				45
BRACE, UPPER	CALHOUN					13				41
BRADFORD, BIG	OTSEGO					5				27
BRIGHTON	LIVINGSTON	27				45				59
BROOKS	LEELANAU	14				12				40
BUCK	LIVINGSTON	*								
BUCKHORN (NORTH)	OAKLAND	21	21			11		11		39
CANADIAN	MECOSTA					13				41
CANADIAN, WEST	MECOSTA					8				34

APPENDIX 2
2006 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)
CEDAR	ALCONA/IOSCO	8				11				39
CEDAR	VAN BUREN	6				13				41
CENTER	OSCEOLA	11				7				32
CHAIN	IOSCO	11				17				45
CHEMUNG	LIVINGSTON	10				15	19			43
CHILSON POND	LIVINGSTON					15				43
CHRISTIANA	CASS	13				18				46
CLAM	ANTRIM	6 b				7				32
CLARK	JACKSON	*				9				36
CLEAR	JACKSON	5				9	11			36
CLIFFORD	MONTCALM	7				10				37
COBB	BARRY	5				7				32
COREY	ST. JOSEPH	8				10				37
COWAN	KENT	44				20				47
COWBOY	DICKINSON					12	12			40
CROCKERY	OTTAWA	55				*				
CROOKED, UPPER	BARRY	16				18				46
CROOKED	KALAMAZOO	*				9				36
CROOKED, NORTH (N)	KALKASKA	10 c				15 c				43
CROOKED, NORTH (S)	KALKASKA					17 c				45
CROOKED, BIG	VAN BUREN					10				37
CROOKED, LITTLE	VAN BUREN					11				39
CROOKED, WEST	LIVINGSTON					16				44
CRYSTAL	BENZIE					4 T,a				<27
CRYSTAL	DICKINSON					103				71
CRYSTAL	HILLSDALE	10				11				39
CRYSTAL	NEWAYGO	13				11				39
CRYSTAL	OCEANA	8				12				40
CUB	KALKASKA	8				7				32
DEER	ALGER	13				10	9			37
DEER	OAKLAND	7				8		5		34
DERBY	MONTCALM	7	6			7	7			32
DEVILS	LENAWEE	*				9				36
DIAMOND	CASS	3 W				8				34

APPENDIX 2
2006 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)
DIAMOND	NEWAYGO					12				40
DINNER	GOGEBIC	21				11				39
EAGLE	ALLEGAN	12				16				44
EAGLE	CASS	*								
EAGLE	KALKASKA	4 T	5			6	6			30
EARL	LIVINGSTON	32				18				46
EMERALD	KENT	14	12			12		17		40
EMERALD	NEWAYGO	6				*				
EVANS	LENAWEE	5				13				41
FAIR	BARRY	7				9	11			36
FARWELL	JACKSON	5				7				32
FENTON	GENESEE	12				11				39
FISH	VAN BUREN	19				18				46
FISHER	ST. JOSEPH	5				8				34
FISHER (BIG)	LEELANAU	6	5			4 T				<27
FISHER (LITTLE)	LEELANAU	6				4 T				<27
FISHER (LITTLE)	ST. JOSEPH	7				9				36
FONDA	LIVINGSTON	7 e	10 e			13				41
FRESKA	KENT	20				11				39
GALLAGHER	LIVINGSTON	17				17				45
GEORGE	CLARE	11				13				41
GILL	LIVINGSTON	19				16				44
GILLETTS	JACKSON	14				17				45
GLEN (BIG)	LEELANAU	5				3 W				<27
GLEN (LITTLE)	LEELANAU	5				6				30
GOSHORN	ALLEGAN	21				31				54
GOURDNECK	KALAMAZOO	6				13		8		41
GRATIOT	KEWEENAW					8				34
GRAVEL	VAN BUREN	6				11	12			39
GUNN	MASON	11	12			*				
HAMBURG	LIVINGSTON	12				8				34
HAMILTON	DICKINSON	16				9				36
HAMLIN (LOWER)	MASON	13				21				48
HAMLIN (UPPER)	MASON	15				26				51

APPENDIX 2
2006 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)
HESS	NEWAYGO	34				33				55
HICKS	OSCEOLA	30				20				47
HIGGINS, (N)	ROSC/CRAWF	2 W				5				27
HIGGINS, (S)						7				32
HIGH	KENT	*				11				39
HORSEHEAD	MECOSTA	8	8			15		20		43
HOUGHTON	ROSCOMMON	*				23				49
HUBBARD	ALCONA	7				8				34
HUTCHINS	ALLEGAN	12				16				44
INDIAN	KALKASKA	7				9				36
INDIAN	KALAMAZOO					6				30
INDIAN	OSCEOLA	*				9				36
ISLAND	GR TRAVERSE	7				9	8			36
JEWELL	ALCONA	6				16				44
JUNO	CASS	16				22				49
KIMBALL	NEWAYGO	85	75			22				49
KLINGER	ST. JOSEPH	3 W				9				36
LAKEVILLE	OAKLAND	6				14				42
LANCELOT	GLADWIN					18		15		46
LANCER	GLADWIN					16	13	16		44
LANSING	INGHAM	17 a				17				45
LILY	CLARE					15	15			43
LITTLE	MARQUETTE	12				10				37
LONG	GOGEBIC	9				6				30
LONG	IOSCO	10				9				36
LONG	ST. JOSEPH	10	8			14				42
LONG	WASHTENAW	13	16			15				43
LONG, UPPER	OAKLAND					18				46
MAGICIAN	CASS	*				14				42
MARGRETHE	CRAWFORD	8				7				32
MARL	GENESEE	4 T				7	6			32
MARY	IRON	9				7				32
MECOSTA	MECOSTA	8				11				39
MEHL	MARQUETTE	10	12			8 c				34

APPENDIX 2
2006 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)
MILL	VAN BUREN	14 b	12 b			11				39
MOON	GOGEBIC	11				4 T				<27
MUD	JACKSON	15				14				42
MULLETT	CHEBOYGAN	5				5				27
MURRAY	KENT	34				14 g	14 g			42
MUSKELLUNGE	MONTCALM	21				17				45
NEPESSING	LAPEER	12	10			22				49
ONEIDA	LIVINGSTON	12	13			11				39
ORE	LIVINGSTON	12				15				43
ORION	OAKLAND	5				*				
OSTERHOUT	ALLEGAN	*				16				44
OTSEGO	OTSEGO	10				12				40
OXBOW	OAKLAND					11	11			39
OXBOW, NORTH	MASON	*								
PAINTER	CASS	18				38				57
PAPOOSE	KALKASKA	*				31	31			54
PARK	CLINTON	8				18				46
PARKE	OAKLAND	15				17				45
PAYNE	BARRY	12				9				36
PENTWATER	OCEANA	*				*				
PERCH	HILLSDALE	10	11			14				42
PERCH	OTSEGO	19				9				36
PICKERAL	KALKASKA	4 T				3 W				<27
PICKEREL	NEWAYGO	35				16				44
PLATTE (LITTLE)	BENZIE	12	11			14	15			42
PLEASANT (BIG)	ST. JOSEPH	5				*				
PLEASANT	JACKSON					11				39
PLEASANT	WEXFORD	10				9				36
PORTAGE (BIG)	JACKSON	*				17				45
PORTAGE	WASH/LIV	12				12				40
PRETTY	MECOSTA	*								
ROBINSON	NEWAYGO	32				16	11			44
ROUND	CLINTON	16				15				43
ROUND	LENAWEE	*				7				32

APPENDIX 2
2006 COOPERATIVE LAKES MONITORING PROGRAM
TOTAL PHOSPHORUS RESULTS

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)
ROUND	MECOSTA	14				18				46
SAGE	OGEMAW	7				15				43
SANFORD	BENZIE	16				9				36
SANFORD	MIDLAND	*				28				52
SAPPHIRE	MISSAUKEE	9 c				9				36
SCHOOL SEC.	MECOSTA	5 c,d				*				
SCHOOL SEC.	VAN BUREN	22				20				47
SHAFER	VAN BUREN					15				43
SHAN-GRI-LA	LIVINGSTON	23				*				
SHINGLE	CLARE	11				17				45
SILVER	GENESEE	4 T				6				30
SILVER	GR TRAVERSE	*				4 T				<27
SILVER	LIVINGSTON	5				12				40
SILVER	VAN BUREN	10	9			13				41
SMALLWOOD	GLADWIN	16 e				25				51
SMOKY	IRON	8 b				*				
SPIDER	GR TRAVERSE	6				7				32
SQUAW	KALKASKA	15				18				46
STARVATION	KALKASKA	6				6				30
STONE LEDGE	WEXFORD	16				30				53
STONY	OCEANA					15 i				43
STRAWBERRY	LIVINGSTON	16				19	18			47
SWEEZEY	JACKSON	9				10				37
SYLVAN	NEWAYGO	10				*				
TAYLOR	OAKLAND	13				12				40
TIMS	JACKSON					27	19			52
TORCH (N. BASIN)	ANTRIM	5 b				2 W				<27
TORCH (S. BASIN)	ANTRIM	4 b,T				1 W				<27
TOWNLINE	MECOSTA	14				11	12	15		39
TRIANGLE	LIVINGSTON	9	10			14				42
TWIN (BIG)	CASS	8				13				41
TWIN (LITTLE)	CASS	9				8	7			34
TWIN (BIG)	KALKASKA	10				6				30
TWIN (LITTLE)	KALKASKA	6				7				32

APPENDIX 2
2006 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)
TWIN (WEST)	MONTMORENCY	*				15				43
TWIN (EAST)	MONTMORENCY	*				*				
VAN ETTAN	IOSCO	18	20			36				56
VAUGHN	ALCONA	15				25	21			51
VIKING	OTSEGO	14				25				51
VINEYARD	JACKSON	9				11				39
WAHBEMEME	ST. JOSEPH	10				6				30
WEBINGUAW	NEWAYGO	18				19				47
WELLS	OSCEOLA	*				8				34
WEST	KALAMAZOO	12 b	13 b			17		14	13	45
WHITEWOOD	LIVINGSTON	*								
WILDWOOD	CHEBOYGAN	14 a				*				
WILDWOOD	WASHTENAW	19				12				40
WINDOVER	CLARE	8				10				37
WOLF	LAKE	8				9				36
WOODS	KALAMAZOO	46				27				52

*	No sample received or received too late to process.
T	Value reported is less than the reporting limit (5 ug/l). Result is estimated.
W	Value is less than the method detection limit (3 ug/l)
a	No field sheets received
b	Sampling date on field sheet does not correspond with date on sample bottle label
c	Improper sample collection - no replicate
d	Sample bottle overfilled
e	Used ink that ran on label
f	Sample not collected at proper sampling site
g	No labels on bottles
h	Laboratory holding time exceeded
i	Sample bottle not rinsed

APPENDIX 3
2006 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l)					Mean	Median	Std. Deviation	Carlson TSI$_{CHL}$
		May	June	July	Aug	Sept				
ANN	BENZIE	1.7	1.7	1.4	2.0	1.1	1.6	1.7	0.3	36
ARBUTUS	GR TRAVERSE	1.1	1.5	2.7	2.0	2.0	1.9	2.0	0.6	37
ARNOLD	CLARE	1.5	1.6	2.2	2.3	1.9	1.9	1.9	0.4	37
AVALON	MONTMORENCY	1.9a	1.0<,a	*	*	*				
BALDWIN	MONTCALM	1.9b	3.1	4.6	*	*				
BARLOW	BARRY	2.2	2.6	2.8	2.2	2.0	2.4	2.2	0.3	38
BEAR	KALKASKA	1.6	1.4	1.3	1.1	2.0	1.5	1.4	0.3	34
Vol/Rep				1.3						
BEAVER	ALPENA	1.0<	2.1	1.8	1.9	2.1	1.7	1.9	0.7	37
BELLAIRE	ANTRIM	1.6	1.2	1.2	1.0	1.7	1.3	1.2	0.3	32
BIG	OSCEOLA	1.0<	1.2	1.0<	1.1	2.0	1.1	1.1	0.6	32
BIG STAR	LAKE	1.8	4.2	2.1	1.9	3.7	2.7	2.1	1.1	38
BILLS	NEWAYGO	1.0<	2.9	2.3	2.2j	2.5j	2.1	2.3	0.9	39
BIRCH	CASS	1.0<	1.0<	2.5	2.1	2.1	1.5	2.1	1.0	38
Vol/Rep					2.0					
BLUE	MECOSTA	1.5	2.3	2.4	2.3j	1.7j	2.0	2.3	0.4	39
BOSTWICK	KENT	*	4.1	4.5	6.8j	9.4j	6.2	5.7	2.4	48
MDEQ						11.0				
MDEQ/Rep						11.0				
BROOKS	LEELANAU	10.0	9.5	3.6	16.0	23.0	12.4	10.0	7.4	53
Vol/Rep		12.0								
CEDAR	ALCONA/IOSCO	1.0<	1.7	3.5	2.2	2.5	2.1	2.2	1.1	38
CEDAR	VAN BUREN	1.0<	1.1	1.3	2.5i	1.1	1.3	1.1	0.7	32
CHEMUNG	LIVINGSTON	*	1.3	2.5	2.1	3.9	2.5	2.3	1.1	39
Vol/Rep			2.1							
CHRISTIANA	CASS	6.3	3.1	5.2	12.0	6.1	6.5	6.1	3.3	48
CLAM	ANTRIM	1.6	1.0<	3.1	2.2	1.9	1.9	1.9	0.9	37
CLARK	JACKSON	1.0<	1.5	2.6	1.8	1.1	1.5	1.5	0.8	35
MDEQ					2.2					
MDEQ/Rep					2.2					
COREY	ST. JOSEPH	2.4	1.9	2.5	2.6	3.8	2.6	2.5	0.7	40
COWAN	KENT	3.1	3.5	21.0	10.0j	9.9j	9.5	9.9	7.2	53
CROCKERY	OTTAWA	*	7.6	16.0	*	*				
CROOKED	KALAMAZOO	2.0	1.0<	4.5	2.8	3.9	2.7	2.8	1.6	41

APPENDIX 3
2006 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l)					Mean	Median	Std. Deviation	Carlson TSI$_{CHL}$
		May	June	July	Aug	Sept				
CROOKED, BIG	VAN BUREN	2.5	3.0	1.5	2.6	3.3	2.6	2.6	0.7	40
CROOKED, LITTLE	VAN BUREN	1.8	2.9	4.7	4.6	4.0	3.6	4.0	1.2	44
CROOKED, UPPER	BARRY	3.7	6.1	6.1	*	*				
CRYSTAL	BENZIE	*	*	*	*	*				
CRYSTAL	HILLSDALE	1.3	3.6	4.0	3.6	4.3	3.4	3.6	1.2	43
CRYSTAL	NEWAYGO	3.3	1.9	3.0	2.0j	3.2j	2.7	3.0	0.7	41
CRYSTAL	OCEANA	2.8	5.0	6.2	6.3j	8.1j	5.7	6.2	2.0	48
CUB	KALKASKAK	1.5	1.0<	*	2.8	1.1	1.5	1.3	1.0	33
DEER	ALGER	2.1b	3.7	4.5	4.8	6.0	4.2	4.5	1.4	45
DEER	OAKLAND	c	f	1.0<	1.4	1.1				
MDEQ						1.3				
MDEQ/Rep						1.1				
DERBY	MONTCALM	1.0<	1.8	1.0<	1.1	1.3	1.0	1.1	0.6	32
DEVILS	LENAWEE	1.8b	3.6g	3.2	1.9	2.6	2.6	2.6	0.8	40
DIAMOND	CASS	1.1	1.0<	1.0<	3.2	2.2	1.5	1.1	1.2	32
EAGLE	ALLEGAN	1.0<	1.4	3.8	3.4	5.9	3.0	3.4	2.1	43
EARL	LIVINGSTON	13.0	33.0	4.5	9.0	4.9	12.9	9.0	11.8	52
EVANS	LENAWEE	1.0<,b	2.3	3.4	3.1	10.0	3.9	3.1	3.6	42
MDEQ					3.1					
MDEQ/Rep					3.3					
FAIR	BARRY	c	4.1	26.0	18.0	2.1	12.6	11.1	11.4	54
FARWELL	JACKSON	1.0<	1.0<	1.2	1.1	1.4	0.9	1.1	0.4	32
Vol/Rep				1.3						
FENTON	GENESEE	1.4	1.0	1.1	2.3	2.5	1.7	1.4	0.7	34
FISH	VAN BUREN	10.0	10.0	11.0	19.0	8.9	11.8	10.0	4.1	53
FISHER	ST. JOSEPH	1.0<	1.1	2.2	2.5	1.7	1.6	1.7	0.8	36
FISHER, BIG	LEELANAU	1.5	1.0<	1.0<	1.0<	1.0<	0.7	0.5	0.4	<31
FISHER, LITTLE	LEELANAU	1.4	1.0<	1.0<	1.0<	1.0<	0.7	0.5	0.4	<31
FISHER, LITTLE	ST. JOSEPH	1.0<	2.0	2.0	1.0	1.0<	1.2	1.0	0.8	31
FRESKA	KENT	2.8	4.2	12.0	4.7j	5.4j	5.8	4.7	3.6	46
GEORGE	CLARE	2.5	3.3	4.6	4.5	3.8	3.7	3.8	0.9	44
GILLETTS	JACKSON	*	*	*	*	2.4*				
GLEN, BIG	LEELANAU	1.5	1.0<	1.0<	1.0<	1.0<	0.7	0.5	0.4	<31
GLEN, LITTLE	LEELANAU	1.0<	1.8	1.1	1.9	1.0	1.3	1.1	0.6	32

APPENDIX 3
2006 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	**County**	**Chlorophyll *a* (ug/l)**					**Mean**	**Median**	**Std. Deviation**	**Carlson TSI$_{CHL}$**
		May	**June**	**July**	**Aug**	**Sept**				
GOSHORN	ALLEGAN	18.0	14.0	32.0	16.0	15.0	19.0	16.0	7.4	58
GOURDNECK	KALAMAZOO	2.3	7.1	3.3	3.7	4.2	4.1	3.7	1.8	43
MDEQ						4.4				
MDEQ/Rep						4.3				
GUNN	MASON	*	*	*	*	*				
HAMLIN, LOWER	MASON	1.5a	2.3a	6.2a	3.7	2.0	3.1	2.3	1.9	39
HAMLIN, UPPER	MASON	5.0e	5.5e	5.4e	8.9	5.7	6.1	5.5	1.6	47
HESS	NEWAYGO	11.0b	6.9	6.6	10.3j	9.7j	8.9	9.7	2.0	53
HICKS	OSCEOLA	2.8	7.8	7.0	12.0	11.0	8.1	7.8	3.6	51
HIGGINS/NORTH	ROSCOMMON	1.0<	1.0<	1.0<	1.0<	1.0<	0.5	0.5	0.0	<31
HIGGINS/SOUTH	ROSCOMMON	1.0<	1.0<	1.0<	1.0<	1.0<	0.5	0.5	0.0	<31
HIGH	KENT	2.6	3.0	3.0	4.0j	9.7j	4.5	3.0	3.0	41
Vol/Rep		5.2								
HORSEHEAD	MECOSTA	2.0	3.6	3.2	4.2j	5.3j	3.7	3.6	1.2	43
MDEQ						5.6				
MDEQ/Rep						5.4				
HOUGHTON	ROSCOMMON	4.5	4.0	4.4	2.4	2.5	3.6	4.0	1.0	44
HOUGHTON - # 2	ROSCOMMON	8.0	6.4	5.0	4.0	4.8	5.6	5.0	1.6	46
Vol/Rep					4.3					
HUBBARD	ALCONA	1.0<	1.2	2.5	1.0<	1.0<	1.0	0.5	0.9	<31
INDIAN	KALAMAZOO	1.0<	*	1.0	1.4	1.5	1.1	1.2	0.5	32
INDIAN	OSCEOLA	1.2	2.6	5.5	6.5	3.3	3.8	3.3	2.2	42
ISLAND	GR. TRAVERSE	1.4	1.0<	1.4	6.2	7.2	3.3	1.4	3.1	34
JEWELL	ALCONA	2.2	3.9	4.7	3.9	3.6	3.7	3.9	0.9	44
JUNO	CASS	6.6	7.1	9.8	15.0	4.5	8.6	7.1	4.0	50
KIMBALL	NEWAYGO	12.0	20.0	5.2	5.2j	9.5j	10.4	9.5	6.1	53
KLINGER	ST. JOSEPH	2.1	1.0<	4.7	5.8	4.0	3.4	4.0	2.1	44
Vol/Rep						4.9				
LAKEVILLE	OAKLAND	1.0	1.0<	1.7	3.0	4.3	2.1	1.7	1.5	36
LANCELOT	GLADWIN	2.0	2.3	3.6	5.2	4.2	3.5	3.6	1.3	43
MDEQ						4.8				
MDEQ/Rep						4.8				
LANCER	GLADWIN	1.0<	1.7	1.0<	1.5	1.2	1.1	1.2	0.6	32
MDEQ						1.5				
MDEQ/Rep						1.5				

APPENDIX 3
2006 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l)					Mean	Median	Std. Deviation	Carlson TSI$_{CHL}$
		May	June	July	Aug	Sept				
LANSING	INGHAM	7.6	*	6.5	4.4	4.3	5.7	5.5	1.6	47
MDEQ				6.8						
MDEQ/Rep				7.2						
LILY	CLARE	1.0<	1.1	2.0	1.5	1.0	1.2	1.1	0.6	32
LITTLE	MARQUETTE	1.1b	1.5	4.2	2.2	3.5	2.5	2.2	1.3	38
LONG	IOSCO	2.6	2.0	1.8	1.9	1.8	2.0	1.9	0.3	37
LONG	MONTMORENCY	*	*	*	*	*				
LONG, UPPER	OAKLAND	5.4	1.8	2.0	4.3	14.0	5.5	4.3	5.0	45
Vol/Rep						13.0				
MAGICIAN	CASS	1.0<,b	1.0<	2.8	2.5	3.2	1.9	2.5	1.3	40
MARGRETHE	CRAWFORD	1.8	1.0<	2.3	4.1	3.5	2.4	2.3	1.4	39
MECOSTA	MECOSTA	1.2	1.0<	3.5	1.0<,j	2.2j	1.6	1.2	1.3	32
MEHL	MARQUETTE	1.4b,h	2.4	2.2	2.9	3.2	2.4	2.4	0.7	39
Vol/Rep			2.4							
MOON	GOGEBIC	1.9	2.5	3.0	3.1	3.8	2.9	3.0	0.7	41
Vol/Rep						4.8				
MULLETT	CHEBOYGAN	*	1.0	1.1	*	1.0<				
MURRAY	KENT	4.0	1.1	2.6	3.9j	4.1j	3.1	3.9	1.3	44
NEPESSING	LAPEER	1.3	1.6	4.6	1.4	3.9	2.6	1.6	1.6	35
ORE	LIVINGSTON	d	d	d	4.7	4.3	4.5	4.5	0.3	45
ORION	OAKLAND	*	*	*	*	1.0<				
OSTERHOUT	ALLEGAN	2.1	5.0	3.2	*	2.5	3.2	2.9	1.3	41
OTSEGO	OTSEGO	2.2	3.6	4.8	8.3	4.1	4.6	4.1	2.3	44
OXBOW	OAKLAND	1.3	6.8	3.2	2.9	2.4	3.3	2.9	2.1	41
PAINTER	CASS	9.6	10.0	14.0	12.0	3.6	9.8	10.0	3.9	53
PARKE	OAKLAND	1.0<	1.2	4.3	2.1	2.5	2.1	2.1	1.4	38
PENTWATER	OCEANA	5.7	9.3	8.2	21.0	10.0	10.8	9.3	5.9	52
PERCH	HILLSDALE	2.1	5.9	1.0<	1.0<	1.0<	1.9	0.5	2.3	<31
PICKEREL	NEWAYGO	3.8	2.8	4.1	2.1j	4.2j	3.4	3.8	0.9	44
Vol/Rep			4.2							
PLATTE, LITTLE	BENZIE	3.2	2.4	4.3	2.9	3.6	3.3	3.2	0.7	42
PRETTY	MECOSTA	a,c	4.0a	4.4a	6.5	6.9	5.5	5.5	1.5	47
ROBINSON	NEWAYGO	14.0	5.9	6.0	*	17.0j	10.7	10.0	5.6	53

APPENDIX 3
2006 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Chlorophyll *a* (ug/l) May	June	July	Aug	Sept	Mean	Median	Std. Deviation	Carlson TSI$_{CHL}$
ROUND	CLINTON	3.8	7.1	9.2	11.0	5.7	7.4	7.1	2.8	50
Vol/Rep				9.0						
ROUND	LENAWEE	1.0<,b	2.0	3.0	2.0	1.0<	1.6	2.0	1.1	37
ROUND	MECOSTA	2.3	1.5	5.3	9.6j	7.1j	5.2	5.3	3.4	47
SAGE	OGEMAW	1.0<	1.5	2.5	2.1	3.0	1.9	2.1	1.0	38
SAPPHIRE	MISSAUKEE	*	1.8	3.7	4.1	3.2b	3.2	3.5	1.0	43
SCHOOL SEC.	MECOSTA	*	*	*	*	*				
SHINGLE	CLARE	2.2	2.8	3.9	6.7	4.9	4.1	3.9	1.8	44
SILVER	GR. TRAVERSE	1.7	2.2	1.7	1.6	1.7	1.8	1.7	0.2	36
SMALLWOOD	GLADWIN	*	2.8	4.4	3.4	2.7	3.3	3.1	0.8	42
Vol/Rep					4.0					
SPIDER	GR. TRAVERSE	1.4	3.4	3.5	4.3	3.2	3.2	3.4	1.1	43
STONY	OCEANA	*	4.1	8.3	13.0j	5.6j	7.8	7.0	3.9	50
STRAWBERRY	LIVINGSTON	2.2	10.0	7.7	9.7	3.7	6.7	7.7	3.5	51
SWEEZEY	JACKSON	1.0<	2.1	2.4	1.9	1.2	1.6	1.9	0.8	37
TORCH/NORTH	ANTRIM	1.0<	1.0<	1.0<	1.0<	*	0.5	0.5	0.0	<31
TORCH/SOUTH	ANTRIM	*	*	*	1.0<	1.0<				
TWIN, EAST	MONTMORENCY	*	*	*	*	*				
TWIN, WEST	MONTMORENCY	2.6	2.9	2.7	4.0	5.6	3.6	2.9	1.3	41
Vol/Rep		3.2								
VAN ETTAN	IOSCO	1.8	2.7	7.8	42.0	20.0	14.9	7.8	16.8	51
VIKING	OTSEGO	9.9	9.5	3.1	11.0	4.3	7.6	9.5	3.6	53
VINEYARD	JACKSON	1.2	1.5	2.2	2.1	2.5	1.9	2.1	0.5	38
WEBINGUAW	NEWAYGO	f	f	f	1.5j	1.3j				
WELLS	OSCEOLA	1.0<	2.7	3.1	1.6	1.6	1.9	1.6	1.0	35
Vol/Rep			1.7							
WILDWOOD	CHEBOYGAN	*	*	*	*	*				
WINDOVER	CLARE	1.0<	1.1	3.1	2.8	2.7	2.0	2.7	1.2	40
WOODS	KALAMAZOO	*	*	*	*	*				

< Sample value is less than limit of quantification (1 ug/l)

* No sample received

a No data sheet submitted with sample

APPENDIX 3

2006 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}

b Sample not collected within the designated sampling window

c Sample not collected at proper time - sample not processed

d Sample poorly or not covered by aluminum foil - sample not processed

e Dates on field sheet and vile labels do not match

f Separator sheets used instead of filter - sample not processed

g No information for sample on lab sheet

h Procedures not followed - two different sampling sites

i Extra magnesium carbonate added to sample

j Samples shipped from collection point with minimal ice - laboratory results appear normal.

APPENDIX 4
2006 COOPERATIVE LAKES MONITORING PROGRAM
DISSOLVED OXYGEN AND TEMPERATURE RESULTS

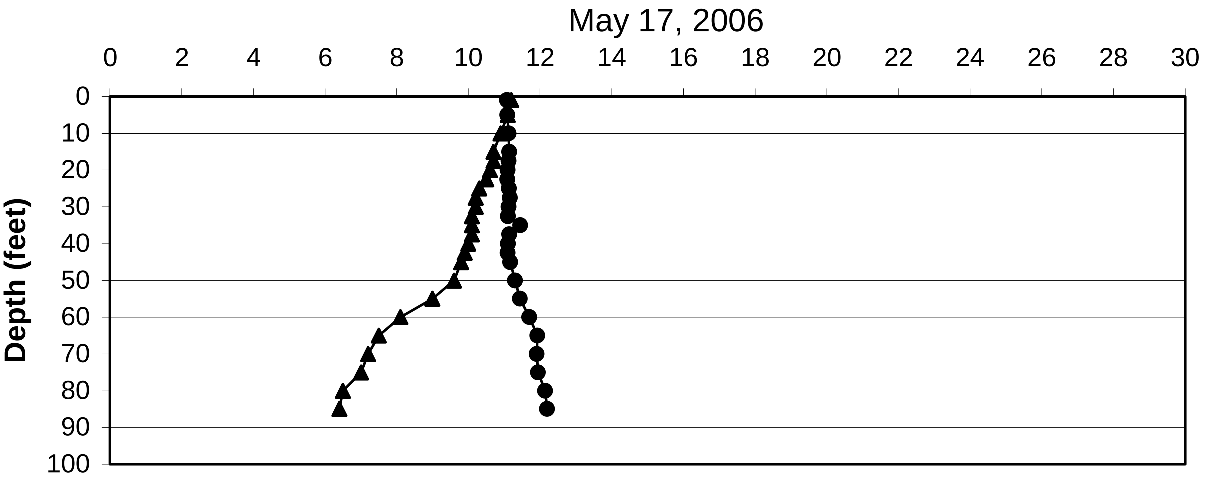
County	Participating Lakes
Alcona	Hubbard Lake Jewell Lake
Alpena	Beaver Lake
Barry	Upper Crooked Lake
Benzie	Lake Ann
Cass	Magician Lake
Cheboygan	Mullet Lake
Clare	Lake George Shingle Lake
Grand Traverse	Arbutus Lake Silver Lake
Kalamazoo	Gourdneck Lake Crooked Lake
Kalkaska	Bear Lake Cub Lake
Kent	Bostwick Lake Cowan Lake Freska Lake
Lenawee	Devils Lake Round Lake
Livingston	Strawberry Lake
Marquette	Little Lake Mehl Lake
Mason	Hamlin (Upper) Lake Hamlin (Lower) Lake
Mecosta	Blue Lake Mecosta Lake Round Lake

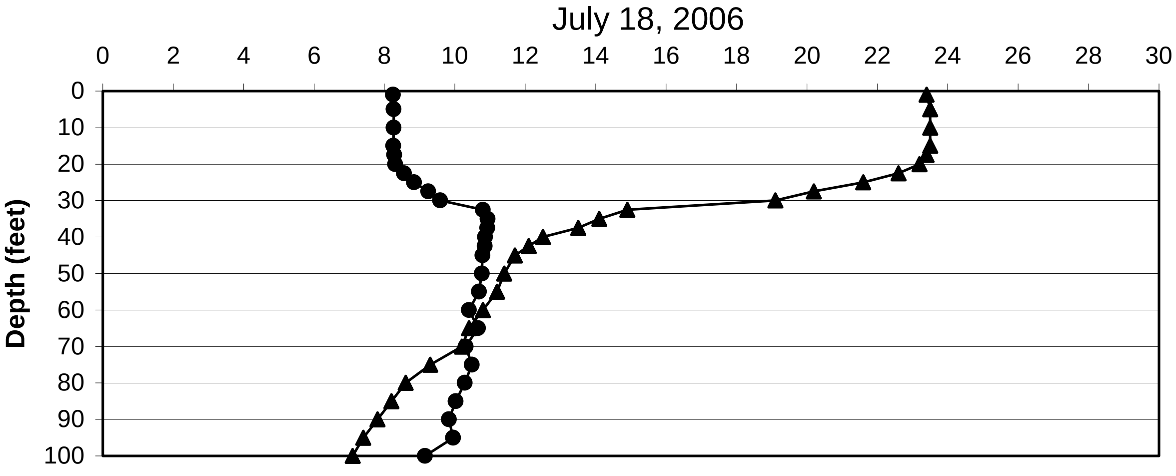
County	Participating Lakes
Montcalm	Baldwin Lake Derby Lake
Newaygo	Crystal Lake Hess Lake Pickerel Lake Kimball Lake
Oakland	Deer Lake Oxbow Lake Parke Lake
Osceola	Big Lake Hicks Lake
Roscommon	Higgins (North) Lake Higgins (South) Lake
St. Joseph	Fisher Lake Little Fisher Lake

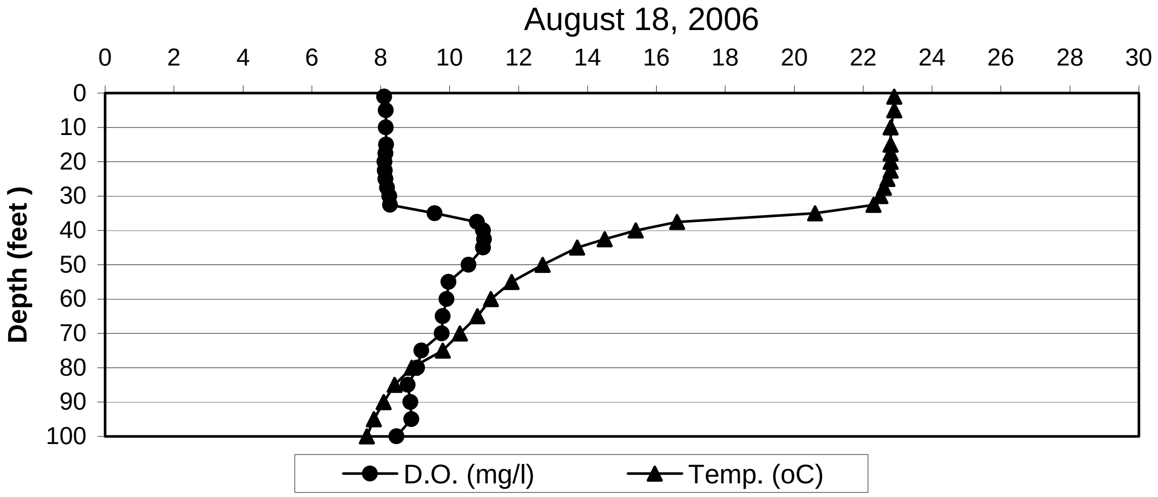
On the following pages five representative dissolved oxygen/temperature patterns are illustrated. The first is of a high quality oligotrophic lake, which has a very large hypolimnion volume. The lake maintains high oxygen levels in the hypolimnion all summer. The second pattern represents a good quality 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

Higgins Lake in Roscommon 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.

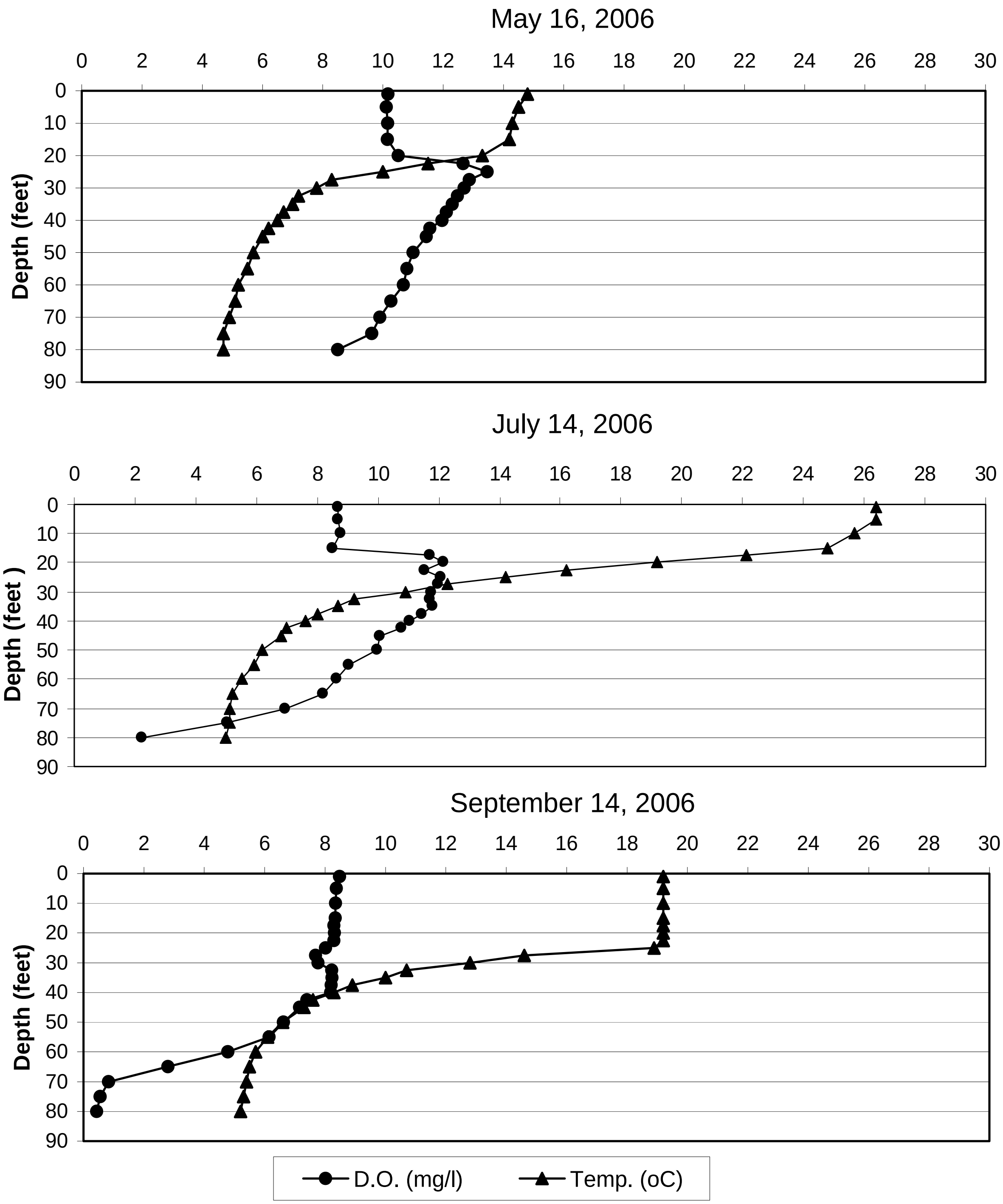






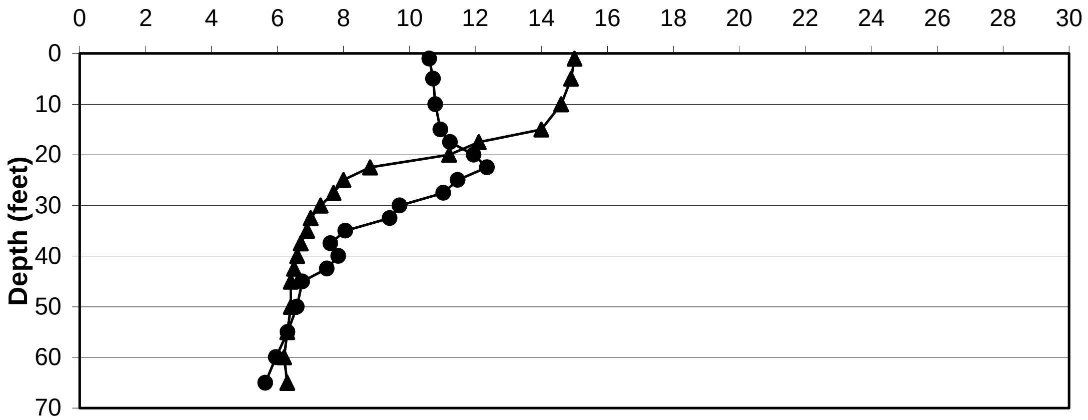
Oligotrophic/Mesotrophic Lake with a Large Volume Hypolimnion

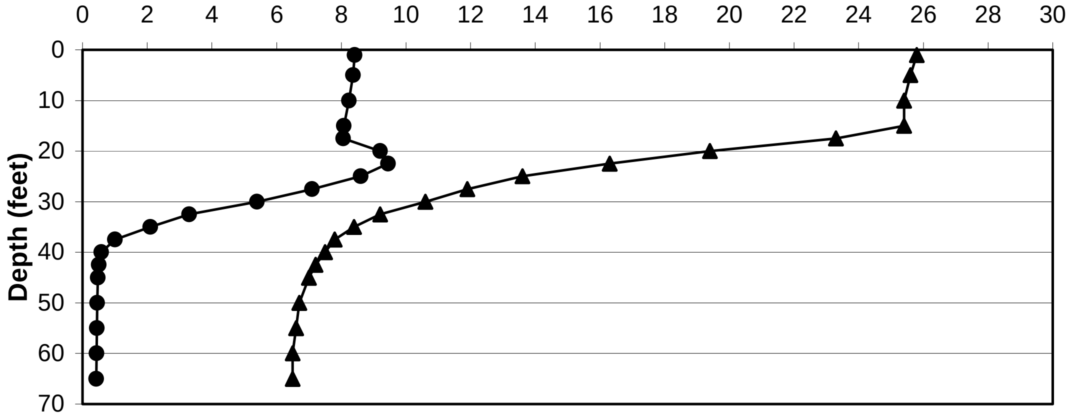
Derby Lake in Montcalm County is an oligotrophic/mesotrophic lake with a large hypolimnion. It produces minor amounts of organic material that must be decomposed. Its hypolimnion has a substantial oxygen supply that is gradually depleted by the decomposition of the organic material. Dissolved oxygen 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.

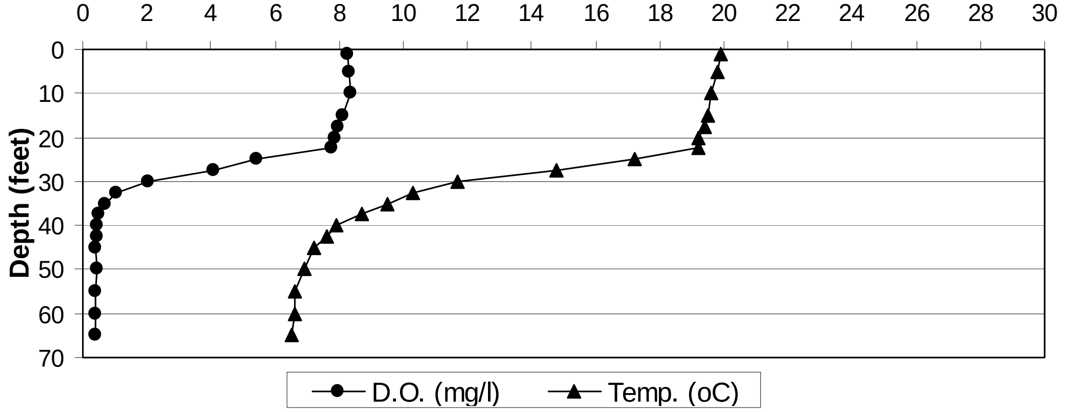


Oligotrophic/Mesotrophic Lake with a Small Volume Hypolimnion

Crystal Lake in Newaygo 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 4, 2006

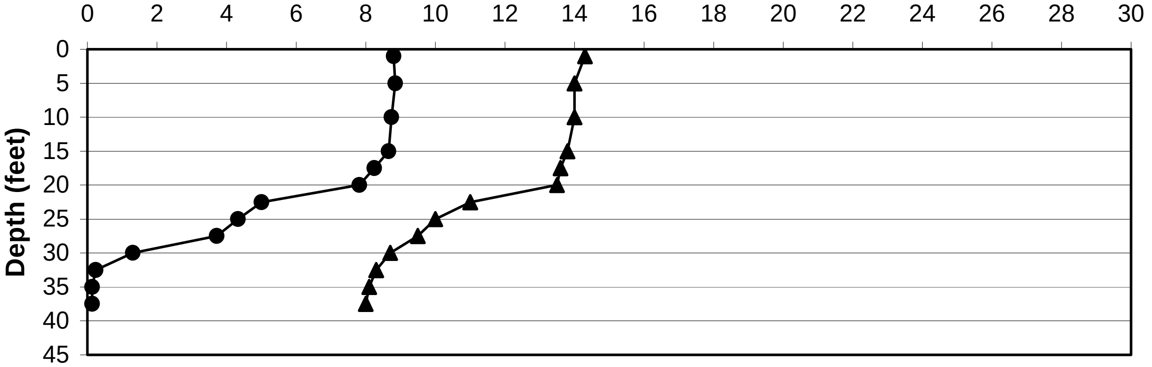

July 27, 2006


September 16, 2006

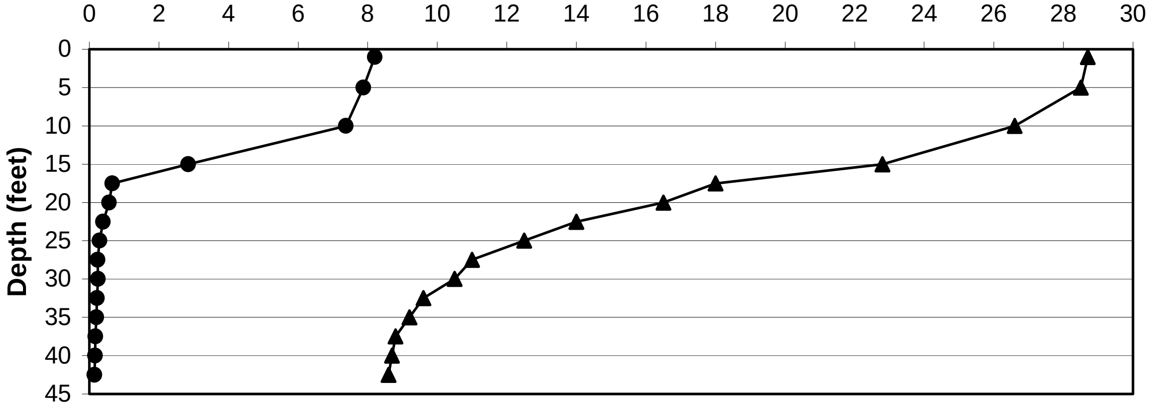
Eutrophic Lake with a Small Volume Hypolimnion

Upper Crooked Lake in Barry 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.

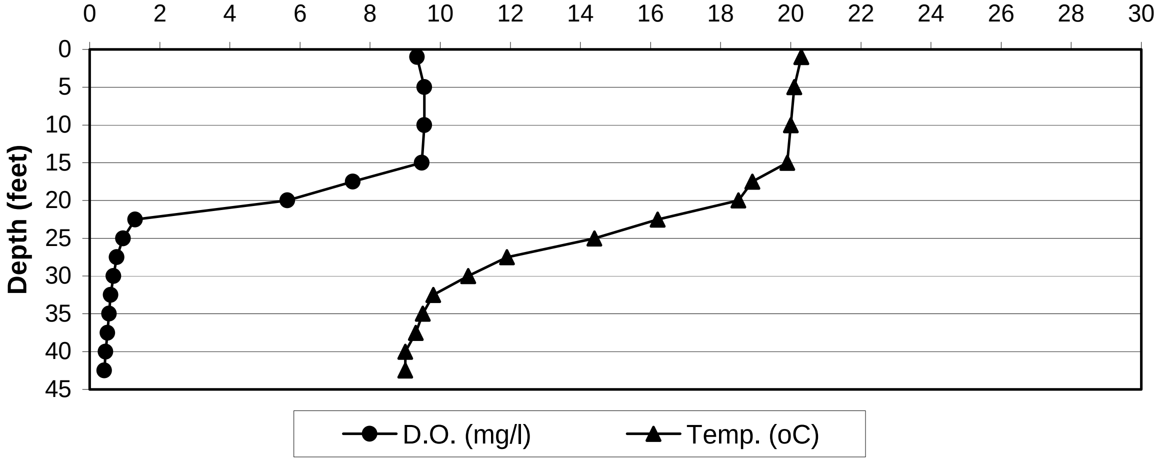
May 14, 2006



July 19, 2006



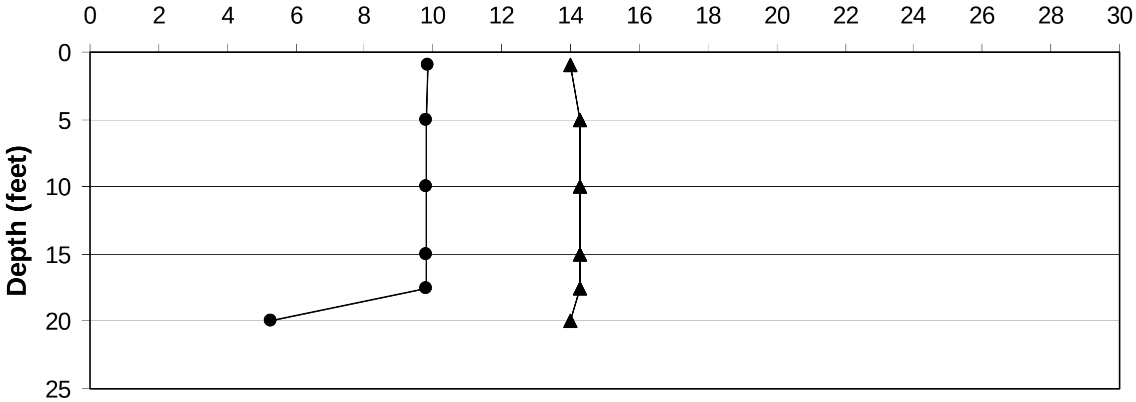
September 17, 2006



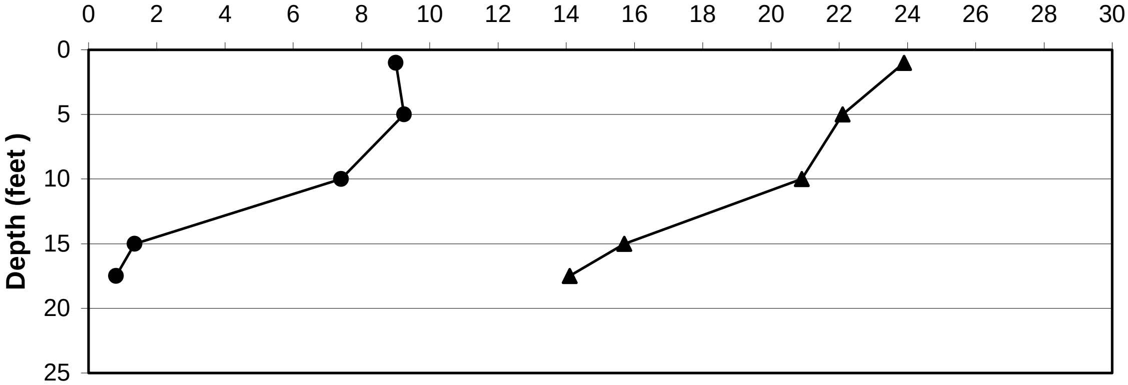
Shallow Eutrophic Lake that does not Maintain Summer Stratification

Hess Lake in Newaygo County is a shallow eutrophic lake with insufficient depth to maintain stratification all summer. As a eutrophic lake it produces abundant 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.

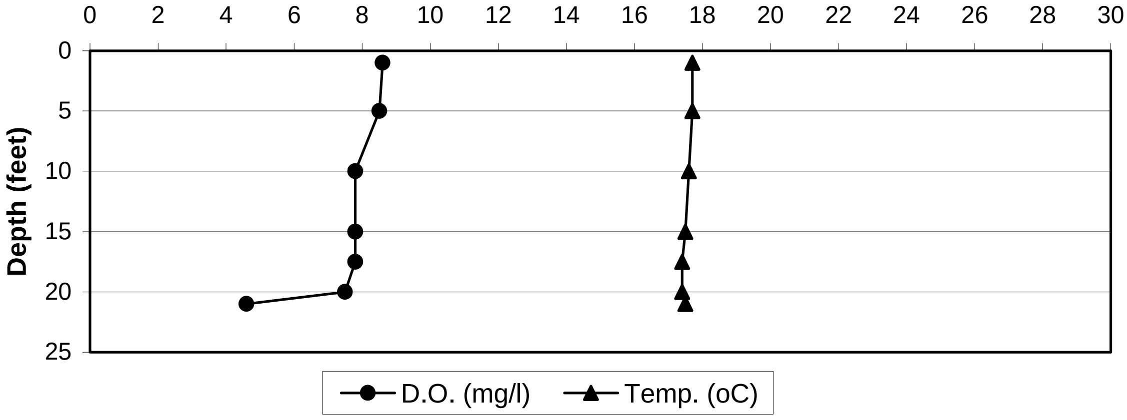
May 21, 2006



June 14, 2006



September 15, 2006



APPENDIX 5
2006 COOPERATIVE LAKES MONITORING PROGRAM
AQUATIC PLANT MAPPING RESULTS

Two lakes participated in the 2006 CLMP aquatic plant mapping project. They were Glen Lake in Leelanau County and Beaver Lake in Alpeana County. Both Lakes have similar productivity, with TSI values generally in the 30's. The CLMP plant mapping project revealed that both lakes had limited plant populations consisting of a good diversity of species, none of which dominated. Both lakes have shallow areas of water less than ten feet deep, which if conditions are appropriate could make the lakes susceptible to exotic species infestations.

As an example of the work completed in the CLMP aquatic plant mapping project the whole lake reporting data sheet for Beaver Lake is presented below. These data are from a survey done on the lake in July. In addition to the data sheet each lake monitoring team produced aquatic plant maps for their lake.

Plant Number	Plant Name	Distribution (# of sites where observed)	Average Density
20	Stonewort	79	2.25
48	Bladderwort	44	0.89
34	Wild Celery	15	0.42
37	Illinois pondweed	11	0.17
7	Bulrushes	10	0.23
31	Variable pondweed	8	0.15
21	Bushy pondweed (Najas)	7	0.11
12	White water lily	4	0.15
6	Cattails	2	0.05
45	American pondweed	1	0.04
13	Yellow water lily	2	0.03
43	Floating-leaf pondweed	2	0.04
36	Waterweed	1	0.01
44	Whitestem pondweed	1	0.01
32	Flat-stemmed pondweed	1	0.01