COOPERATIVE LAKES MONITORING PROGRAM

Michigan's Citizen Volunteer
Lakes Monitoring Program

ANNUAL SUMMARY REPORT

2001

a partnership for Michigan's lakes

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

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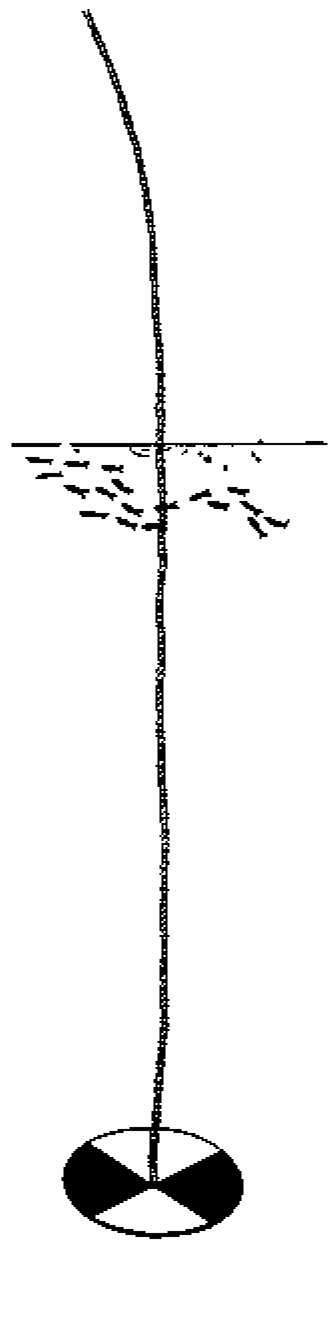

INTRODUCTION

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

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

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

Michigan's abundant water resources...

...include over 11,000 inland lakes.

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

THE SELF-HELP LEGACY

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

"working together
to protect lakes"

Michigan Department of
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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

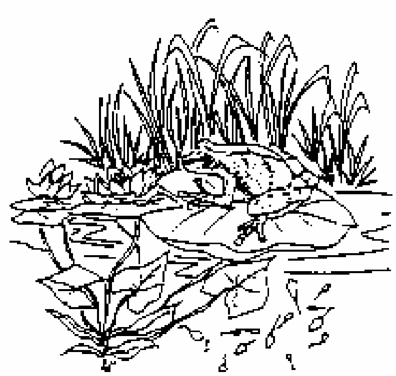
A lake's condition is influenced by many factors, such as the amount of recreational use it receives, shoreline development, and water quality. Lake *water quality* is a general term covering many aspects of lake chemistry and biology. The health of a lake is determined by its water quality.

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



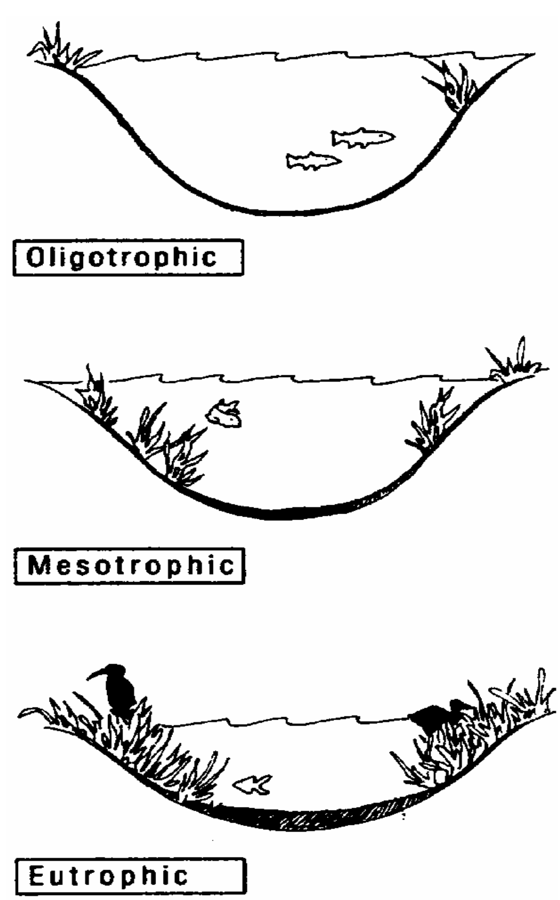
Increasing lake productivity can impact water quality and result in problems such as excessive weed growth, algal blooms, and mucky bottom sediments. *Productivity* refers to the amount of plant and animal life that can be produced within the lake.

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

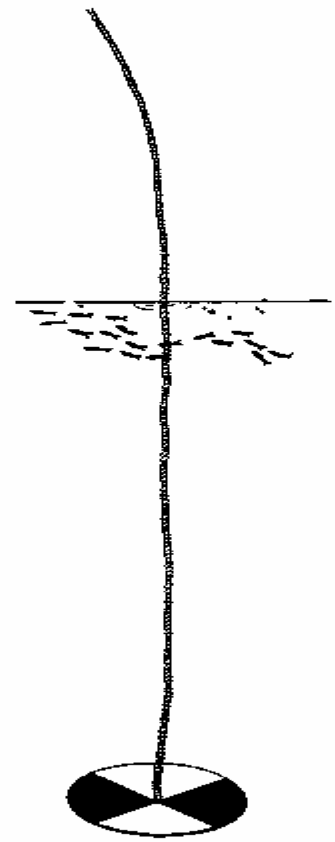
A lake's ability to support plant and animal life defines its level of productivity, or *trophic state.* Lakes are commonly classified based on their productivity. Low productive *oligotrophic* lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient *dissolved 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 progressing from very good to very poor conditions. A more precise method of describing the productivity of a lake is to use a numerical index which can be calculated directly from water quality data. A variety of indexes are available with Carlson's (1977) *Trophic State Index*, or TSI, being the most widely used.

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

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

Carlson's TSI Equations

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

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

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

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

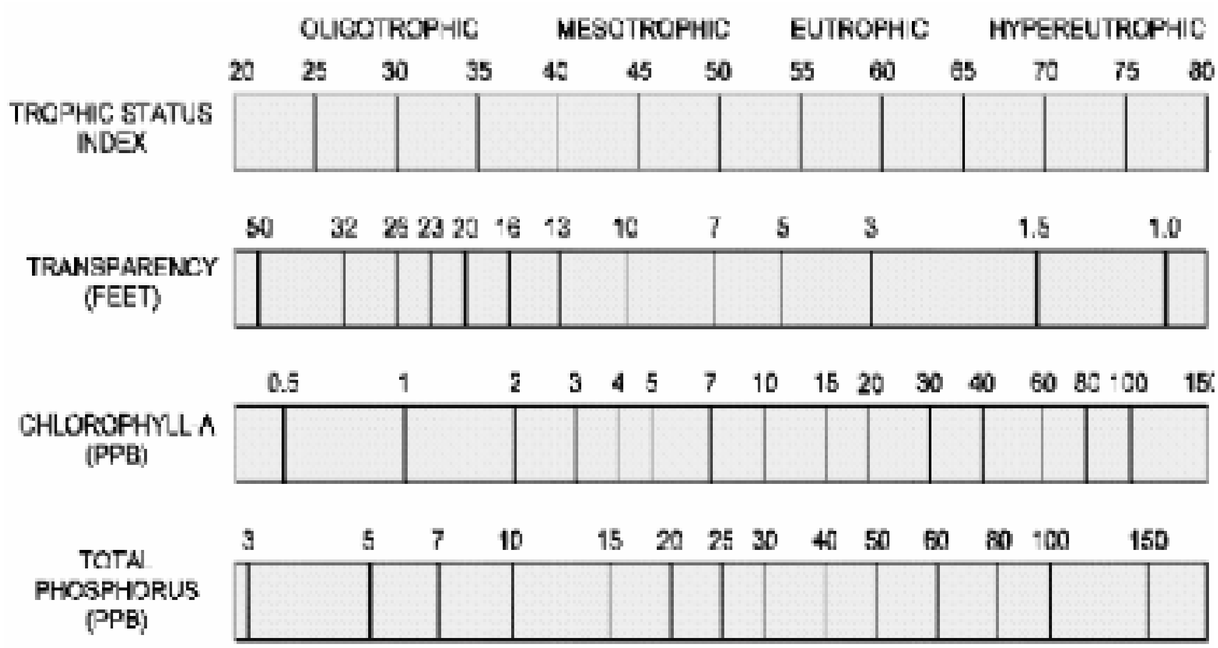
evaluate changes within the lake over time, and to estimate other water quality parameters within the lake.

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

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

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

CARLSON'S TROPHIC STATE INDEX



(Source: Minnesota Pollution Control Agency)

OTHER MEASURES OF LAKE PRODUCTIVITY

Dissolved Oxygen (DO) and Temperature

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

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

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

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

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

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

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

Rapid Algal Assay

Algae are a diverse group of photosynthetic organisms, growing in the water column and on submerged surfaces in ponds, lakes, and streams. Because they use nutrients dissolved in the water and reproduce on the order of a few hours to a few days, algae respond very quickly to changes in the lake environment. Algae are also an important food source for invertebrates, like zooplankton, as well as herbivorous and larval fish. It's their contribution to both water quality (e.g. presence or lack of noxious blooms or toxic species) and their critical position in the food web that makes the algal data so important and useful.

Algae often are the first biological indicator to respond to environmental change, so monitoring the algal populations can provide accurate feedback on the increasing or decreasing water quality in a lake and short-term perturbation. A rapid algal assessment of a lake can provide initial algal data on dominant species and indicate the presence of nuisance species. The combination of rapid algal data with chlorophyll *a* data can provide a meaningful description of lake algal populations. Additionally slide mounts used for the algal analysis are a permanent archive which can be referenced anytime in the future.

Aquatic Plant Mapping

The other 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.

Fish Age and Growth

The growth rate of fish should reflect the movement of energy and nutrients through the aquatic food web into a final culmination of growth in predator fish. Thus it is reasonable to expect that nutrient-poor lakes (oligotrophic) should have relatively slow growth rates for fish and that nutrient-rich lakes (eutrophic) should have relatively rapid growth rates for fish. The growth rate of fish can then be expected to follow and confirm those parameters that reflect Carlson's trophic indices, namely Secchi disk readings, summer phosphorus concentrations and chlorophyll *a* concentrations.

It is possible that some eutrophic lakes could have slow growth rates, especially in panfish such as bluegill or yellow perch. Given this situation, an interpretation could be that there is an over-population of the panfish. Thus the fish age and growth may also give insight to fish management needs for a given lake.

The age of fish can be determined by studying the scales of the fish. The scales have annual rings somewhat similar to the growth rings of trees. Scales can be removed without harm to a fish and the fish can be returned safely to the water. The length of the captured fish is measured to complete the growth rate analysis. Since the annual growth in length is proportional to the distance between the annual growth rings on the scales, it is possible to calculate the length of the fish at each year of its life. The growth rate, once determined, can be compared to the average growth for that species for Michigan. Thus it can be determined if that species of fish, for a given lake, is growing faster, about the same, or slower than the average for Michigan lakes. To obtain a meaningful measure of fish growth it is best to study two species of fish; a panfish and a top predator. For most lakes these would be bluegill (or yellow perch) and largemouth bass (or smallmouth bass).

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 2001 is included in Appendix 1. The number of measurements, or readings, made between mid-May and mid-September and the minimum and maximum Secchi disk transparency values are included for each lake that participated in the program. For those lakes with eight or more evenly spaced readings over this time period, the mean, median, standard deviation, and Carlson TSI_{SD} values were calculated and listed.

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

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

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

During 2001, Secchi disk transparency data were reported for 184 lakes (233 basins). Over 3,100 transparency measurements were reported, ranging from 1.4 to 62 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 11.4 feet. The Carlson TSI_{SD} values ranged from 28 to 67 for these lakes with a mean value of 42. A Carlson TSI value of 42 is generally indicative of a good quality mesotrophic lake (see page 8).

Total Phosphorus

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

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

Total phosphorus results for the 2001 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 2001, samples for total phosphorus measurements were collected on 150 lakes. The spring overturn total phosphorus results ranged from <5 to 107 ug/l with a mean (average) of 17 ug/l and a median value of 13 ug/l. The late summer total phosphorus results ranged from <5 to 95 ug/l with 14 ug/l as the mean and 11 ug/l as the median. The Carlson TSI_{TP} values ranged from <27 to 70 for these lakes with a mean value of 40. A Carlson TSI value of 40 is generally indicative of a very good quality mesotrophic lake (see page 8).

Chlorophyll *a*

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

Chlorophyll monitoring was added to the CLMP in 1998 and expanded in subsequent years. Chlorophyll samples were collected on 107 lakes in 2001. For each lake, the volunteers were asked to collect and process five sets of chlorophyll *a* samples, one set per month from May through September.

Results from the chlorophyll monitoring for 2001 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 600 chlorophyll samples were collected and processed in 2001. The chlorophyll *a* levels in these lakes ranged from <1 to 98 ug/l over the five-month sampling period. The overall mean (average) was 5.8 ug/l and the median was 4 ug/l. The Carlson TSI_{CHL} values ranged from <31 to 65 with a mean value of 44. A Carlson TSI value of 44 is generally indicative of a mesotrophic lake (see page 8).

TSI Comparisons

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

Dissolved Oxygen and Temperature

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

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

During 2001, CLMP participants in the dissolved oxygen/temperature project sampled 51 lakes. A total of 344 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 2001 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.

Rapid Algal Assay

Rapid algal assay data were still being evaluated at the time of this report's publication. The extensive amount of data submitted for analysis and refining analytical techniques required more time than anticipated. However, all participants in the rapid algal project will receive an individualized report of their data, as soon as the analysis is complete.

Aquatic Plant Mapping

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

During 2001, CLMP participants in a pilot project sampled 3 lakes for aquatic plants. The lakes involved in the pilot project are identified in Appendix 5. The results of aquatic plant sampling varies depending upon the size, depth, volume and productivity of the lake sampled. Because of these varied results and the amount of individual data collected, each lake's results are not included in this report. Each participating lake community will have their individual aquatic plant distribution maps and data sheets. Instead of individual results, a representative data sheet is illustrated in Appendix 5 for one of the lakes. All three lakes in the 2001 pilot project were similar in productivity, with TSI values in the high 30's to low 40's. All three lakes had only moderate plant populations, none had Eurasian milfoil and only sparse populations of curly-leaf pondweed were identified in any of the lakes.

Fish Age and Growth

Two lakes participated in the CLMP's fish age and growth pilot project. Both lakes collected scales from largemouth bass and bluegill. The scales were analyzed at Michigan State University to determine the size and age of the fish at capture. From these data a growth pattern was constructed for the bass and bluegill population in each lake. The results of these analyses are in Appendix 6.

In both lakes the largemouth bass population growth pattern did not differ from established Michigan state averages (see Appendix 6). The age at which bass reach legal capture size (14 inches) is about 5 1/2 years.

The results for bluegill were different. One lake has a bluegill growth pattern similar to the state average. The second lake's bluegill growth pattern was well below the state average suggesting a stunted population.

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.

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APPENDIXES

Appendix 1

2001 Secchi Disk Transparency Results

Appendix 2

2001 Total Phosphorus Results

Appendix 3

2001 Chlorophyll Results

Appendix 4

2001 Dissolved Oxygen and Temperature Participating Lakes and Example Results

Appendix 5

2001 Aquatic Plant Mapping Participating Lakes and Example Results

Appendix 6

2001 Fish Age and Growth Results

APPENDIX 1
2001 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSI SD
		Readings	Min.	Max.	Mean	Median	Deviation	(transparency)
Ann	Benzie	14	10.0	23.0	17.4	18.5	4.20	36
Arbutus 1	Grand Traverse	18	11.0	13.0	12.4	13.0	0.78	41
Arbutus 2	Grand Traverse	18	12.0	21.0	17.3	18.5	2.67	36
Arbutus 3	Grand Traverse	18	12.0	21.0	16.6	17.0	2.55	37
Arbutus 4	Grand Traverse	18	12.0	20.0	16.9	17.5	2.22	36
Arbutus 5	Grand Traverse	18	11.0	16.0	13.8	14.0	1.15	39
Arnold	Clare	17	14.0	23.0	18.1	17.0	2.66	35
Austin	Osceola	16	9.0	15.0	12.2	12.0	1.91	41
Avalon	Montmorency	12	17.0	30.0	23.9	26.5	4.78	31
Baldwin	Montcalm	18	9.0	19.5	12.5	11.3	3.22	41
Baldwin 1	Cass	14	7.1	14.5	10.4	10.0	2.59	43
Baldwin 2	Cass	14	7.3	14.3	10.6	10.9	2.05	43
Baldwin 3	Cass	14	8.4	17.0	11.6	10.6	2.86	42
Baldwin 4	Cass	14	7.8	15.8	11.0	10.6	2.42	43
Barlow	Barry	11	6.0	12.0	10.2	11.0	1.77	44
Baseline	Livingston	18	10.5	19.0	15.3	15.5	2.27	38
Bass	Livingston	10	8.0	12.5	10.4	10.3	1.61	43
Bass	Kent	17	8.0	17.5	10.7	9.0	3.12	43
Bear	Manistee	14	6.5	13.5	8.0	7.2	1.90	47
Bear 1	Kalkaska	15	25.0	38.0	30.7	29.0	4.45	28
Bear 2	Kalkaska	15	25.0	38.0	30.7	29.0	4.45	28
Beaton	Gogebic	10	8.5	22.0	14.5	14.5	3.41	39
Beaver	Alpena	17	10.6	14.8	12.8	13.0	1.15	40
Big	Osceola	18	11.0	17.0	12.8	12.0	1.80	40
Big Bradford	Otsego	14	15.0	24.0	18.9	18.8	2.60	35
Big Crooked	Kent	3	12.5	18.0				
Big Fish	Lapeer	18	10.0	13.7	12.1	12.1	0.96	41
Big Meyers	Kent	9	5.0	11.6	8.5	7.5	2.41	46
Big Platte	Benzie	18	4.0	15.0	11.1	12.8	3.74	42
Big Twin North	Cass	16	9.5	20.0	13.2	13.5	3.33	40
Bills 1	Newaygo	17	6.0	14.0	9.5	9.0	2.45	45
Bills 2	Newaygo	15	6.0	14.0	8.9	8.0	2.27	46

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min.	Max.	Mean	Median	Standard Deviation	Carlson TSISD (transparency)
Birch	Cass	18	12.0	29.0	19.1	17.5	4.76	35
Blue	Mason	14	15.0	31.5	21.7	21.3	5.40	33
Blue 1	Mecosta	18	8.0	25.0	14.2	12.5	4.51	39
Bostwick	Kent	9	3.5	17.0	10.5	10.5	4.76	43
Brooks	Newaygo	15	3.0	4.0	3.3	3.0	0.37	60
Burkhart	Washtenaw	18	10.2	21.4	14.7	14.5	3.14	38
Byram 1	Genesee	18	7.0	15.0	10.7	11.0	2.45	43
Byram 2	Genesee	18	7.0	15.0	10.6	11.0	2.55	43
Byram 3	Genesee	18	7.0	15.0	10.6	11.0	2.55	43
Camelot	Isabella	13	6.5	10.8	8.6	8.5	1.36	46
Campau	Kent	18	7.0	10.0	8.8	9.0	1.15	46
Campbell	Kent	1	13.2	13.2				
Cascade Dam	Kent	3	2.7	4.0				
Cedar	Van Buren	18	8.0	17.5	12.1	12.5	2.59	41
Cedar (Briarwood)	Alcona/Iosco	7	9.0	10.5				
Cedar (Schmidt's)	Alcona/Iosco	7	4.4	7.2				
Center	Osceola	12	9.0	15.0	10.7	10.0	1.85	43
Chain	Iosco	10	10.0	13.0	11.4	11.0	0.84	42
Christiana	Cass	14	5.5	16.0	8.3	7.5	2.79	47
Clear	Berrien	15	12.0	17.5	14.0	13.5	1.45	39
Clear	Jackson	13	8.0	12.0	9.6	9.0	1.19	44
Clifford 1	Montcalm	18	11.0	25.0	14.9	13.0	3.86	38
Coldwater	Branch	13	2.5	17.5	7.6	7.0	4.05	48
Coon (M)	Livingston	18	5.0	9.0	7.1	7.5	1.21	49
Coon (N)	Livingston	18	5.4	9.0	7.2	7.0	1.20	49
Coon (S)	Livingston	18	5.2	9.6	7.2	7.6	1.23	49
Corey	St. Joseph	16	8.5	18.0	11.3	10.5	2.80	42
Cowan	Kent	17	1.5	8.0	5.2	5.5	2.05	53
Cranberry	Kent	5	1.4	4.3				
Crockery	Ottawa	16	2.0	7.1	4.7	4.3	1.51	55
Crooked	Alcona	17	11.5	20.5	15.5	15.5	2.98	38
Crooked	Clare	12	10.1	13.6	11.9	12.1	1.08	41

APPENDIX 1
2001 COOPERATIVE LAKES MONITORING PROGRAM
SECCHI DISK TRANSPARENCY RESULTS

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSI_{SD}
		Readings	Min.	Max.	Mean	Median	Deviation	(transparency)
Crooked (Big)	Van Buren	17	13.0	23.0	16.7	16.6	3.24	36
Crooked (Little)	Van Buren	10	12.0	19.0	15.6	15.7	1.99	38
Crystal	Benzie	5	17.0	26.0				
Crystal	Hillsdale	18	6.0	19.0	12.9	13.5	3.63	40
Cub	Kalkaska	15	16.0	25.0	19.8	20.0	2.60	34
Dean	Kent	6	8.5	13.3				
Deer	Alger	6	7.0	10.5				
Derby	Montcalm	16	10.0	22.0	17.2	17.8	3.46	36
Devils	Lenawee	5	8.5	12.0				
Diamond	Cass	18	5.0	18.0	10.6	10.5	4.02	43
Donnell	Cass	10	5.0	14.0	9.1	9.0	3.06	45
Duck 1	Grand Traverse	17	10.0	18.0	12.8	12.0	2.01	40
Duck 2	Grand Traverse	16	11.0	18.0	13.0	12.5	2.00	40
Eagle	Allegan/Van Buren	18	13.0	16.0	14.5	14.8	0.92	39
East Twin	Montmorency	11	8.5	13.5	11.9	12.5	1.39	41
Emerald	Newaygo	15	10.5	18.5	13.9	14.0	2.21	39
Evans	Lenawee	18	13.0	29.5	19.6	18.8	4.38	34
Fair	Barry	14	8.4	14.2	11.1	11.0	1.94	42
Fenton	Genesee	13	13.5	15.3	14.5	14.6	0.47	39
Fish	Van Buren	18	6.0	11.0	7.8	7.8	1.38	47
Fisher	St. Joseph	18	6.0	16.2	9.8	9.5	2.60	44
Fishhawk	Gogebic	10	7.5	10.0	8.6	8.5	0.70	46
Freska	Kent	13	7.7	12.3	9.8	10.1	1.35	44
Gill/Gut	Livingston	17	9.0	17.0	11.7	11.0	1.96	42
Glen (Big)	Leelanau	15	12.0	25.0	18.2	18.0	3.40	35
Gratiot	Keweenaw	15	8.7	16.0	13.0	13.8	2.60	40
Green	Oakland	18	9.0	16.0	12.5	12.0	1.86	41
Gulliver	Schoolcraft	11	11.2	12.6	12.0	12.2	0.48	41
Gunn	Mason	18	11.5	15.5	14.1	14.4	1.04	39
Hackert	Mason	11	8.0	17.0	10.8	10.0	3.43	43
Hamburg	Livingston	18	9.3	19.5	15.1	16.0	3.37	38
Hamilton	Dickinson	16	12.0	15.0	13.6	14.0	1.05	40

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min.	Max.	Mean	Median	Standard Deviation	Carlson TSI$_{SD}$ (transparency)
Harper	Lake	17	12.5	19.8	15.4	15.0	1.87	38
Hawk	Oakland	15	7.1	14.3	10.0	10.0	1.75	44
Hess	Newaygo	16	1.5	2.5	2.0	2.0	0.39	67
Higgins Lake 1	Roscommon	7	19.0	41.0				
Higgins Lake 2	Roscommon	2	21.0	29.0				
High	Kent	9	11.8	17.5	14.2	14.3	1.86	39
Horsehead	Mecosta	18	8.3	17.3	11.5	10.6	2.93	42
Horseshoe	Osceola	9	10.1	19.0	14.1	15.5	3.16	39
Hubbard	Alcona	18	13.0	21.0	17.2	17.0	2.24	36
Hunter 1	Gladwin	18	8.0	21.0	12.1	12.0	3.14	41
Hunter 2	Gladwin	18	7.5	13.5	10.9	11.0	1.54	43
Hunter's 1	Alcona	9	13.0	21.0	16.7	17.0	2.46	37
Hunter's 2	Alcona	9	13.0	19.0	16.4	17.0	2.15	37
Hutchins	Allegan	8	3.5	11.1	7.3	7.7	3.09	48
Indian	Montcalm	16	8.0	16.0	12.4	12.0	2.56	41
Indian 1	Osceola	17	15.0	21.5	18.4	18.0	2.39	35
Indian 2	Osceola	17	14.5	20.0	17.7	19.0	1.80	36
Indiana	Cass	18	5.5	19.5	13.6	13.5	3.51	39
Island	Grand Traverse	16	13.0	38.0	21.5	17.0	8.59	33
Jordan	Barry	18	3.4	9.6	5.5	5.2	1.81	53
Juno	Cass	14	5.5	13.0	7.4	7.5	1.96	48
K.P. Lake	Crawford	11	9.0	16.0	13.0	12.0	2.68	40
Kettle	Kent	18	7.0	16.0	10.9	10.5	2.45	43
Kirkwood	Oakland	18	4.2	9.0	6.7	6.6	1.69	50
Klinger	St. Joseph	17	5.5	20.0	12.6	10.0	4.99	41
Lake George	Clare	18	7.0	12.0	8.7	8.5	1.31	46
Lake Margrethe 1	Crawford	16	8.0	28.0	13.3	12.0	4.51	40
Lake Margrethe 2	Crawford	16	9.0	30.0	13.6	12.0	4.93	40
Lake Margrethe 3	Crawford	16	10.0	28.0	13.2	11.5	4.51	40
Lake Margrethe 4	Crawford	16	9.0	20.0	12.7	11.5	2.91	40
Lake Mud\Yellow R.	Genesee	18	3.0	6.5	4.6	4.5	1.04	55
Lake Nepessing	Lapeer	7	8.0	17.0				

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSISD
		Readings	Min.	Max.	Mean	Median	Deviation	(transparency)
Lake of the Woods	Van Buren	16	9.0	11.5	10.2	10.2	0.74	44
Lakeville	Oakland	18	10.0	20.0	13.4	12.5	3.20	40
Lancelot 1	Gladwin	4	4.4	10.0				
Lancelot 2	Gladwin	4	5.4	10.0				
Lancelot 3	Gladwin	4	6.0	10.0				
Lancer 1	Gladwin	4	7.0	8.0				
Lancer 2	Gladwin	4	7.0	10.0				
Lancer 3	Gladwin	4	7.0	9.0				
Lancer 4	Gladwin	4	5.0	8.0				
Lancer 5	Gladwin	4	5.0	6.0				
Lansing	Ingham	18	5.0	8.8	6.2	5.5	1.24	51
Leelanau (North)	Leelanau	14	8.0	27.0	17.9	20.0	7.76	36
Leelanau (South)	Leelanau	6	11.0	12.5				
Leisure	Shiawassee	17	3.5	16.3	11.5	12.5	3.27	42
Lily	Clare	13	8.0	13.5	10.8	10.5	1.87	43
Lime	Kent	13	11.4	18.0	14.4	14.3	2.40	39
Little Bradford 1	Otsego	9	13.0	15.0	13.8	14.0	0.67	39
Little Bradford 2	Otsego	6	13.0	14.0				
Little Glen	Leelanau	18	4.0	9.0	7.0	7.0	1.59	49
Little Long	Osceola	8	9.0	13.5	10.8	10.8	1.39	43
Little Paw Paw	Berrien	13	5.5	9.5	7.6	7.8	1.38	48
Little Pine Island 1	Kent	18	6.5	15.8	11.3	11.4	3.08	42
Little Pine Island 2	Kent	18	6.5	17.0	11.3	12.4	3.22	42
Little Twin	Cass	10	8.6	13.9	10.8	9.7	2.10	43
Long	Branch	13	4.5	10.0	7.8	7.5	1.82	48
Long	Grand Traverse	18	19.0	62.0	29.9	24.0	14.11	28
Long	Iosco	8	9.3	12.3	11.0	11.1	0.88	43
Long	Kent	5	10.8	17.5				
Long (Sylvania)	Gogebic	15	13.5	19.0	15.4	15.0	1.65	38
Long (West)	Gogebic	15	13.0	19.0	15.0	15.0	1.45	38
Louise	Dickinson	16	14.5	18.5	16.1	16.0	1.16	37
Marl 1	Genesee	17	4.0	9.5	7.1	7.5	1.81	49

Lake	County	Secchi Disk Transparency (feet)						Carlson
		Number of	Range				Standard	TSI$_{SD}$
		Readings	Min.	Max.	Mean	Median	Deviation	(transparency)
Marl 2	Genesee	17	4.4	11.4	8.0	8.6	2.40	47
Marl 3	Genesee	17	4.4	10.7	8.1	9.1	1.94	47
Mary	Dickinson	16	14.0	18.0	15.7	15.5	1.03	37
Mecosta	Mecosta	12	9.0	16.5	13.1	13.1	2.39	40
Middle	Kent	3	9.4	12.3				
Mill	Van Buren	10	8.5	17.5	12.5	12.5	2.54	41
Moon	Gogebic	16	19.0	30.0	23.1	23.0	3.05	32
Murray	Kent	16	7.0	10.3	8.7	8.6	1.00	46
North 1	Alcona	12	15.0	21.0	17.7	17.8	2.09	36
North 2	Alcona	12	14.0	20.0	17.0	16.8	1.99	36
Olin	Kent	4	7.6	13.6				
Ore	Livingston	16	5.0	18.0	11.1	9.0	4.64	42
Orion	Oakland	17	8.5	21.0	13.3	13.0	3.05	40
Osterhout	Allegan	14	6.5	9.0	7.8	8.0	0.75	48
Oxbow	Oakland	9	11.0	19.5	15.0	14.5	3.23	38
Painter	Cass	14	4.5	7.5	5.7	5.8	0.89	52
Pardee	Livingston	18	12.8	14.0	13.1	13.0	0.32	40
Paw Paw 1	Berrien	14	2.0	9.6	6.4	6.7	1.97	50
Paw Paw 2	Berrien	14	2.4	9.4	6.4	6.4	1.93	50
Paw Paw 3	Berrien	14	2.6	9.5	6.3	6.2	1.84	51
Perch	Hillsdale	18	3.3	10.0	7.5	7.3	1.98	48
Pleasant 1	Washtenaw	18	7.0	10.8	9.1	9.4	1.29	45
Pleasant 1	Wexford	6	5.0	5.8				
Pleasant 2	Washtenaw	18	7.0	10.8	9.1	9.2	1.22	45
Pleasant 2	Wexford	8	3.8	6.0	4.7	4.6	0.66	55
Pleasant 3	Washtenaw	18	6.9	10.9	9.2	9.1	1.16	45
Pleasant 1	St. Joseph	16	8.0	17.0	12.5	12.3	2.58	41
Pleasant 2	St. Joseph	16	9.0	16.0	12.8	13.0	1.99	40
Ponemah	Genesee	15	3.3	6.7	5.2	5.4	1.10	53
Pratt	Kent	2	2.0	3.0				
Puterbaugh 1	Cass	16	8.5	14.5	10.9	10.8	1.70	43
Puterbaugh 2	Cass	16	8.5	14.5	11.0	10.8	1.80	43

Lake	County	Secchi Disk Transparency (feet) Number of Readings	Range Min.	Range Max.	Mean	Median	Standard Deviation	Carlson TSI_{SD} (transparency)
Puterbaugh 3	Cass	16	8.5	14.5	11.0	10.8	1.79	43
Ratigan	Kent	7	3.2	9.8				
Reeds	Kent	12	3.6	10.7	6.8	7.4	2.58	49
Robinson	Newaygo	13	5.5	11.0	8.6	8.5	1.71	46
Round	Clinton	16	6.7	11.0	8.3	8.1	1.14	47
Round	Lenawee	11	5.5	15.0	10.0	9.5	3.70	44
Round 1	Mecosta	18	7.0	11.5	9.3	9.0	1.47	45
Sage 1	Ogemaw	18	10.5	14.5	12.1	12.3	1.13	41
Sanford	Benzie	13	13.0	20.0	16.1	16.0	1.61	37
Sapphire	Missaukee	18	7.5	8.0	7.8	8.0	0.26	48
Shan-gri-la	Livingston	11	6.5	7.0	6.6	6.5	0.17	50
Shingle	Clare	17	8.0	15.0	11.2	11.0	2.05	42
Silver	Kent	4	11.5	16.0				
Silver	Livingston	17	11.0	22.5	14.3	14.0	2.49	39
Silver 1	Genesee	11	13.0	20.0	17.3	18.0	2.37	36
Silver 2	Genesee	11	13.0	24.0	17.8	18.0	3.25	36
Silver 3	Genesee	11	10.0	22.0	17.4	19.0	3.50	36
Spider 1	Grand Traverse	17	13.0	30.0	18.4	17.0	5.11	35
Spider 2	Grand Traverse	17	13.0	25.0	17.9	17.0	3.45	35
Spider 3	Grand Traverse	17	12.0	22.0	16.3	16.0	2.87	37
Stone Ledge	Wexford	18	9.0	11.0	10.3	11.0	0.84	43
Stoners	Kent	4	3.3	5.2				
Strawberry	Livingston	18	5.4	9.0	7.6	7.4	0.79	48
Sylvan	Newaygo	15	7.0	21.5	13.6	15.0	4.07	39
Tan	Oakland	2	10.5	17.5				
Taylor	Oakland	18	16.0	23.0	18.8	19.0	2.38	35
Upper Sherwood 1	Oakland	16	3.8	8.1	6.6	7.0	1.27	50
Upper Sherwood 2	Oakland	16	4.0	8.8	6.9	7.1	1.28	49
Upper Sherwood 3	Oakland	16	4.0	8.2	6.6	7.1	1.31	50
Van Etten	Iosco	18	3.0	10.0	4.9	4.0	2.44	54
Vaughn	Alcona	9	6.5	15.0	10.7	11.0	2.72	43
Viking	Otsego	18	8.0	13.0	10.3	10.0	1.18	44

		Secchi Disk Transparency (feet)						Carlson
Lake	County	Number of Readings	Range Min.	Max.	Mean	Median	Standard Deviation	TSI_{SD} (transparency)
Vineyard	Jackson	17	5.5	32.5	12.6	10.5	7.57	41
Walled	Oakland	12	7.7	16.8	13.1	13.3	2.33	40
Wells	Osceola	15	10.5	19.0	14.7	15.0	2.51	38
West Londo	Iosco	18	7.2	14.5	9.6	9.3	2.17	44
West Twin	Montmorency	12	9.0	13.0	11.2	10.8	1.17	42
White 1	Oakland	10	14.0	28.0	19.0	17.8	4.88	35
Woods	Kalamazoo	17	6.0	15.0	11.6	13.0	3.06	42
Zukey 1	Livingston	8	4.0	12.0	7.8	7.5	3.28	48
Zukey 2	Livingston	16	6.4	21.7	11.0	8.0	5.12	43

APPENDIX 2
2001 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
Ann	Benzie	5				2 T				<27
Arbutus	Grand Traverse	6				5				27
Arnold	Clare	5				5				27
Avalon	Montmorency	2 T				7				32
Baldwin	Cass	5				11				39
Baldwin	Montcalm	22				13				41
Barlow	Barry	14				8				34
Baseline	Livingston	9				12				40
Bass	Kent	10	7	14		11				39
Bear	Kalkaska	0 W				5				27
Beatons	Gogebic	7 **				*				
Big Bear	Otsego	*				*				
Big Crooked	Kent	20				*				
Big Crooked	Van Buren	8				10				37
Big Fish	Lapeer	16				14				42
Big	Osceola	11		25		13	12	17		41
Big Meyers	Kent	19	21	22		18				46
Big Pine Island	Kent	21				*				
Big Pleasant	St. Joseph	*				9				36
Birch	Cass	9				7				32
Blue	Mason	18				6				30
Blue	Mecosta	7		9		8		8		34
Bostwick	Kent	16				31				54
Brooks	Newaygo	25				33				55
Burkhart	Washtenaw	15				10				37
Campbell	Kent	*				*				
Cascade Dam	Kent	*				*				
Cedar	Van Buren	7				11		9		39
Chain	Iosco	10				13				41
Christiana	Cass	25				16				44

APPENDIX 2
2001 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
Church	Kent	27 **				*				
Clear	Berrien	14	14			7				32
Clear	Jackson	5				11				39
Clifford	Montcalm	13				6				30
Corey	St. Joseph	9				8				34
Cowan	Kent	107				21				48
Cranberry	Kent/Ottawa	72				*				
Crockery	Ottawa	66				25				51
Crooked	Alcona					9				36
Crooked	Clare	8				10				37
Crystal	Benzie	3 T				3 T				<27
Crystal	Hillsdale	12	9			10				37
Cub	Kalkaska	0 W				5				27
Dean	Kent	18				*				
Deer	Alger					7	8			32
Derby	Montcalm	8	10	9		8				34
Devils	Lenawee	11				8				34
Dewey	Cass	18				*				
Diamond	Cass	8	8	11		7		5		32
Donnell	Cass	11								
Eagle	Allegan	10				*				
East Lake	Kalkaska	11				*				
East Twin	Montmorency	*				17		15	17	45
Evans	Lenawee	3 T				8				34
Fair	Barry	7				8				34
Fenton	Genesee	*				14				42
Fish	Van Buren	*				19	18	22		47
Fisher	St. Joseph	5				7				32
Freska	Kent	22				10				37
George	Clare	10		15		13				41

APPENDIX 2
2001 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
Gill/Gut	Livingston	20				17				45
Glen (Big)	Leelanau	7	5			5				27
Glen (Little)	Leelanau	5				4 T				<27
Gratiot	Keweenaw					10	10			37
Green	Oakland	16	17			9	11	14		36
Gulliver	Schoolcraft	9				11	18			39
Gunn	Mason	4 T				7	7			32
Hamburg	Livingston	*				11				39
Hamilton	Dickinson	14				14				42
Harper	Lake	5				7				32
Hess	Newaygo	*				54				62
Higgins	Roscommon	*				*				
High	Kent	16				14				42
Horsehead	Mecosta	10				10				37
Hubbard	Alcona	6	10			5				27
Hunters	Alcona	23				12				40
Hutchins	Allegan	16				*				
Indian	Montcalm	22				21				48
Island	Grand Traverse	3 T				7				32
Jordan	Barry/Ionia	94				23				49
Juno	Cass	40				19				47
Keeler	Van Buren	*				17				45
Kettle	Kent	*				19				47
Klinger	St. Joseph	5				6				30
KP	Crawford	5				10				37
Lakeville	0akland	12				12				40
Lancelot	Gladwin	11				26				51
Lancer	Gladwin	17				22				49
Lansing	Ingham	13				19				47
Lily	Clare	11				15				43

APPENDIX 2
2001 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 TSI TP Summer TP
Little Crooked	Van Buren	12				15				43
Little Pine Island	Kent	24				22				49
Long	Gogebic	9	9			6				30
Long	Grand Traverse	4 T				5				27
Long	Iosco	16	14	18		12		14		40
Long	Kent	10				14				42
Louise	Dickinson	11				13				41
Margrethe	Crawford	6				3 T	8			<27
Marl	Genesee	11				8				34
Mary	Dickinson	14				10				37
McGilvery	Gladwin	*				*				
Mecosta	Mecosta	9		8	7	8		6		34
Middle	Kent	14				*				
Moon	Gogebic	6				8				34
Mud	Genesee	40				95				70
Murray	Kent	37				13				41
Muskrat	Kent	*				*				
Nepessing	Lapeer	19				23				49
North	Alcona	15				9				36
North Twin	Cass	9		9	14	7		9		32
Olin	Kent	25				8				34
Ore	Livingston	18				18				46
Osterhout	Allegan	12				15	15			43
Oxbow	Oakland	16				7				32
Painter	Cass	25				44				59
Pardee	Livingston	*				*				
Park	0akland	14				18				46
Pentwater	Oceana	27				31				54
Perch	Hillsdale	23				11				39
Pleasant	Washtenaw	25				18				46

		Total Phosphorus (ug/l)								Carlson
Lake	County	Spring Overturn				Late Summer				TSITP
		Vol	Rep	DEQ	Rep	Vol	Rep	DEQ	Rep	Summer TP
Pleasant	Wexford	17				15				43
Ponemah	Genesee	23	23			*				
Pratt	Kent	22				*				
Ratigan	Kent	65				25	26			51
Reeds	Kent	42				43				58
Robinson	Newaygo	39				24				50
Round	Clinton	25	25			19				47
Round	Kent					18				46
Round	Lenawee	13				8				34
Round	Mecosta	18		17		13		13		41
Sage	Ogemaw	12				9	10	10		36
Sanford	Benzie	16				9				36
Sapphire	Missaukee	9				15				43
School Section	Mecosta	6				9		11		36
Shangrila	Livingston	14				11				39
Sherwood Upper	0akland	19				27				52
Shingle	Clare	12	12	23	21	12				40
Silver	Genesee	5				5	7			27
Silver	Livingston	*				*				
South Twin	Cass	6		10		6		9		30
Spider	Grand Traverse	5				7				32
Stoneledge	Wexford	16				14				42
Stoners	Kent	49				38				57
Strawberry	Livingston	15				17				45
Stringy (Tan)	Oakland	15				16				44
Taylor	Oakland	19								
Van Etten	Iosco	25				33				55
Vaughn	Alcona	24				20				47
Viking	Otsego	18	21			21				48
Vineyard	Jackson	4 T				7				32

Lake	County	Total Phosphorus (ug/l)								Carlson
		Spring Overturn				Late Summer				TSI$_{TP}$
		Vol	Rep	DEQ	Rep	Vol	Rep	DEQ	Rep	Summer TP
Wabasis	Kent	33				*				
Walled	Oakland	*				7				32
West Londo	Iosco	10		19		12				40
West Twin	Montmorency	*				8	10	30		34
White	Oakland	*				14		15	15	42
Windover	Clare	7				9				36
Woods	Kalamazoo	38				12				40
Zukey	Livingston	5				*				

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

** sample turned in unfrozen

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

W value observed is less than lowest value reportable under "T" code

APPENDIX 3
2001 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Sampling Event Chlorophyll (ug/l) May	June	July	Aug	Sept	Mean	Median	Standard Deviation	Carlson TSIchl
ANN	BENZIE	3	2	1 <	1	2	1.8	2	0.8	37
ARBUTUS	GRAND TR.	1	3	2	4	3	2.6	3	1.1	41
ARNOLD	CLARE	3	1	2	1 <	2	1.8	2	0.8	37
AVALON	MONTMORENCY	1 <	1 <	2	2	2	1.6	2	0.5	37
BALDWIN	MONTCALM	12 f	5 f	6 f	*	6	7.3	6	3.2	48
MDEQ				5						
BARLOW	BARRY	2	2	2	3	3	2.4	2	0.5	37
BASS	KENT	5	3	2	5	3	3.6	3	1.3	41
BIG	OSCEOLA	1	4	5	a	7	4.3	4.5	2.5	45
MDEQ						6				
BIG BEAR	OTSEGO	*	*	*	*	*				
BIG CROOKED	VAN BUREN	2	3	3	4	4	3.2	3	0.8	41
BIG CROOKED	KENT	*	*	*	*	*				
BIG MEYERS	KENT	2 d	7 d	4 d	5 d	6 d	4.8	5	1.9	46
Vol/Rep		2 d								
BIG PINE ISLAND	KENT	*	*	*	*	*				
BIRCH	CASS	5	2	2	2	3	2.8	2	1.3	37
BLUE	MECOSTA	2	2	4	3	2	2.6	2	0.9	37
MDEQ						2				
BOSTWICK	KENT	2	3 b	4	9	11	5.8	4	4.0	44
BROOKS	NEWAYGO	14	3	14	13	8	10	13	4.8	56
MDEQ		15								
BURKHART	WASHTENAW	5	3	4	5	12	5.8	5	3.6	46
CAMPBELL	KENT	*	*	*	*	*				
CASCADE DAM	KENT	*	*	*	*	*				
CEDAR	VAN BUREN	6	5	3	3	5	4.4	5	1.3	46
MDEQ						3				
CHRISTIANA	CASS	2	7	9	9	4	6.2	7	3.1	50
CHURCH	KENT	1 <	6	6	*	*				
CLEAR	BERRIEN	2	4	6	5	5	4.4	5	1.5	46
COREY	ST. JOSEPH	3	4	4	2	3	3.2	3	0.8	41
COWAN	KENT	3	31	3	42	16	19	16	17.3	58

Lake	County	Sampling Event Chlorophyll (ug/l) May	June	July	Aug	Sept	Mean	Median	Standard Deviation	Carlson TSIchl
MDEQ			44							
CRANBERRY	KENT/OTTAWA	15 d	2 d	40 d	*	*				
CROCKERY	OTTAWA	10	46	54	10	10	26	10	22.1	53
MDEQ				45						
CROOKED	ALCONA	2	2	1 <	4 b	6	3	2	2.0	37
CROOKED	CLARE	1	2	5	6	5	3.8	5	2.2	46
CRYSTAL	HILLSDALE	3	4	4	2	4	3.4	4	0.9	44
CRYSTAL	BENZIE	2 bc	1 bc	1 <bc	1 <de	1 <de	1.2	<1	0.4	<31
DEAN	KENT	1 <c	1 c	2 c	*	*				
DEER	ALGER	5	3	5	5	1	3.8	5	1.8	46
Vol/Rep					4					
DERBY	MONTCALM	2	1	2	3	2	2	2	0.7	37
MDEQ				2						
DEVILS	LENAWEE	*	6	5	4 b	3 b	4.5	4.5	1.3	45
DEWEY	CASS	*	*	*	*	*				
DIAMOND	CASS	3	1 <	2	5	5	3.2	3	1.8	41
MDEQ						5				
EAGLE	ALLEGAN	4	7	6	*	*				
Vol/Rep		1 <								
EAST TWIN	MONTMORENCY	*	2	*	*	8				
MDEQ						6				
EVANS	LENAWEE	1	2	4	6	6	3.8	4	2.3	44
FAIR	BARRY	4	14 b	6	3	5	6.4	5	4.4	46
Vol/Rep		3 I								
FISH	VAN BUREN	6	12	6	11	12	9.4	11	3.1	54
MDEQ						12				
FISHER	ST. JOSEPH	1	6	3	2	3	3	3	1.9	41
Vol/Rep				3						
FRESKA	KENT	11	9	24	14	10	14	11	6.1	54
GEORGE	CLARE	*	6	7	8	7	7	7	0.8	50
GLEN - BIG	LEELANAU	2	1 <	1 <	1 <	1 <	1.2	<1	0.4	<31
Vol/Rep			1 <							

APPENDIX 3
2001 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Sampling Event Chlorophyll (ug/l) May	June	July	Aug	Sept	Mean	Median	Standard Deviation	Carlson TSIchl
GLEN - LITTLE	LEELANAU	2	2	2	2	2	2	2	0.0	37
GREEN	OAKLAND	4	2	3	2	6	3.4	3	1.7	41
Vol/Rep				3						
MDEQ						10				
GULLIVER	SCHOOLCRAFT	2	2	4	5 d	7 d	4	4	2.1	44
Vol/Rep		2								
GUNN	MASON	2	4	4	4	3	3.4	4	0.9	44
Vol/Rep					3					
MDEQ					4					
HARPER	LAKE	2	3	3	2	5	3	3	1.2	41
HESS	NEWAYGO	18	12	18	30	19	19	18	6.5	59
MDEQ		18								
HIGGINS	ROSCOMMON	*	*	*	*	*				
HIGH	KENT	7 f	7 f	4 f	11	8	7.4	7	2.5	50
Vol/Rep				5 l						
HORSEHEAD	MECOSTA	3	3	6	5	4	4.2	4	1.3	44
HUBBARD	ALCONA	3	3	1 <	2	2	2.2	2	0.8	37
INDIAN	MONTCALM	1	2	5	2	5	3	2	1.9	37
ISLAND	GRAND TR.	2	1	2	5	2	2.4	2	1.5	37
JORDAN	IONIA/BARRY	2	8	21	12	18	12	12	7.6	55
MDEQ					16					
JUNO	CASS	2	6	5	11	7	6.2	6	3.3	48
KEELER	VAN BUREN	3	3	16	3	4	5.8	3	5.7	41
KETTLE/CAMPAU	KENT	9	7	7	5	6	6.8	7	1.5	50
MDEQ			7							
KLINGER	ST. JOSEPH	1 <	2	3	4	4	2.8	3	1.3	41
KP	CRAWFORD	1 <	1 <	3 b	1	1	1.4	1	0.9	31
Vol/Rep			1 <							
LAKEVILLE	OAKLAND	1 <	2	3	3	2 b	2.2	2	0.8	37
LANCELOT	GLADWIN	*	1	4	5	17	6.8	4.5	7.0	45
LANCER	GLADWIN	*	2	2	6	5	3.8	3.5	2.1	43
LANSING	INGHAM	3	6	6	7	7	5.8	6	1.6	48

APPENDIX 3
2001 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Sampling Event Chlorophyll (ug/l)					Mean	Median	Standard Deviation	Carlson TSIchl
		May	June	July	Aug	Sept				
LILY	CLARE	1 b	3 b	2	2	2	2	2	0.7	37
LITTLE CROOKED	VAN BUREN	2	4	4	7	5	4.4	4	1.8	44
LITTLE PINE IS.	KENT	1	7	10	2	8	5.6	7	3.9	50
LONG	KENT	2	2	3	2 b	3	2.4	2	0.5	37
LONG	GRAND TR.	1 <f	2 f	2 f	2	2	1.8	2	0.4	37
LONG	IOSCO	6	6	5	4	6	5.4	6	0.9	48
MDEQ						5				
MARGRETHE	CRAWFORD	3 b	2	3	3	4	3	3	0.7	41
Vol/Rep					4					
MCGILVERY	GLADWIN	*	*	*	*	*				
MECOSTA	MECOSTA	1	2	4	4	3	2.8	3	1.3	41
MDEQ						2				
MIDDLE	KENT	8 b	*	4	*	*				
MOON	GOGEBIC	5	2	3	7	8	5	5	2.5	46
MUD/YELLOW	GENESEE	13	7	25	h	28	18	19	9.9	59
Vol/Rep						30				
MURRAY	KENT	5	5	4	5	5	4.8	5	0.4	46
MUSKRAT	KENT	*	*	*	*	*				
NEPESSING	LAPEER	4 b	5 b	5	*	8 d	5.5	5	1.7	46
NORTH	ALCONA	1 <	2	a	3	2	2	2	0.8	37
NORTH TWIN	CASS	1	6	4	3	2	3.2	3	1.9	41
MDEQ						4				
OLIN	KENT	6	4	4	*	4	4.5	4	1.0	44
ORE	LIVINGSTON	3	2	1 <	6	8	4	3	2.9	41
OSTERHOUT	ALLEGAN	10	12	6	5	6	7.8	6	3.0	48
OXBOW	OAKLAND	3	5	4	6 bd	5 d	4.6	5	1.1	46
PAINTER	CASS	12	7	13	29	35	19	13	12.1	56
PARDEE	LIVINGSTON	*	*	*	*	*				
PENTWATER	OCEANA	*	*	*	*	*				
PERCH	HILLSDALE	3	12	2	5	2	4.8	3	4.2	41
Vol/Rep						3				
PRATT	KENT	*	7 bd	*	*	*				

APPENDIX 3
2001 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Sampling Event Chlorophyll (ug/l) May		June		July		Aug		Sept		Mean	Median	Standard Deviation	Carlson TSIchl
RATIGAN	KENT	4			*	45		60	dg	24	d	33	35	24.5	65
REEDS	KENT	4		3		2			a	22		7.8	3.5	9.5	43
ROBINSON	NEWAYGO	8		8		13		12		21		12	12	5.3	55
ROUND	KENT		*		*		*		*		*				
ROUND	LENAWEE	2		2		5		3		3		3	3	1.2	41
ROUND	MECOSTA	2		8		8		6		8		6.4	8	2.6	51
MDEQ										9					
ROUND	CLINTON	5		6		5		6		6		5.6	6	0.5	48
SAGE	OGEMAW	1		3		2		5		5		3.2	3	1.8	41
MDEQ										4					
SAPPHIRE	MISSAUKEE		*	5		4		5		4		4.5	4.5	0.6	45
SCHOOL SEC.	MECOSTA	1	<	2		3		3		4		2.6	3	1.1	41
MDEQ										4					
SHINGLE	CLARE		*	4		4		7		7		5.5	5.5	1.7	47
SOUTH TWIN	CASS	3		3			*	1		1	<	2	2	1.2	37
MDEQ										4					
SPIDER	GRAND TR.	1		3		3		4		4		3	3	1.2	41
STONE LEDGE	WEXFORD	2		5		3		2		1		2.6	2	1.5	37
STONERS	KENT	4		4		14			*	10		8	7	4.9	50
STRAWBERRY	LIVINGSTON	4		5		8		7		7		6.2	7	1.6	50
VAN ETTAN	IOSCO	6		4		3		2		8		4.6	4	2.4	44
VIKING	OTSEGO	20		31		6		98		57		42	31	36.3	64
VINEYARD	JACKSON	1	<	1	<	3		4		1	<	2	<1	1.4	<31
WABASIS	KENT		*		*		*		*		*				
WALLED	OAKLAND	1		2		3		2		2		2	2	0.7	37
WEST TWIN	MONTMORENCY	4		4		4		1		5		3.6	4	1.5	44
MDEQ										5					
WHITE	OAKLAND	2		1	<	3		3	b	3		2.4	3	0.9	41
MDEQ										2					

APPENDIX 3
2001 COOPERATIVE LAKES MONITORING PROGRAM
CHLOROPHYLL RESULTS

Lake	County	Sampling Event Chlorophyll (ug/l) May	June	July	Aug	Sept	Mean	Median	Standard Deviation	Carlson TSIchl
WINDOVER	CLARE	4	3	4	5	4	4	4	0.7	44
WOODS	KALKASKA	1	6	18	3	16	8.8	6	7.7	48

< Sample value recorded was less than one.

* no sample received or sample turned in too late to process

a Improper sample collection/preservation. Sample not suitable for analysis.

b Sample not collected during the designated sampling period.

c Sample turned in not frozen or only partially frozen.

d Samples not wrapped in aluminum foil or very poorly wrapped in aluminum foil.

e Filters inside vials wrapped in aluminum foil.

f No field sheets were turned in with the sample.

g No labels on sample.

h Field sheets indicate there is a sample but none was received.

i Sample used as a replicate in place of another lake which did not turn in a sample.

County	Participating Lakes
Benzie	Ann Lake
Cass	Birch Lake
	Christiana Lake
	Diamond Lake
	Juno Lake
	Painter Lake
Clare	Lake George
	Shingle Lake
Grand Traverse	Island Lake
	Long Lake
Ionia/Barry	Jordan Lake
Kent	Big Crooked Lake
	Big Meyers Lake
	Bostwick Lake
	Campau Lake
	Campbell Lake
	Cascade Dam
	Cowan Lake
	Dean Lake
	Freska Lake
	High Lake
	Long Lake
	Middle Lake
	Murray Lake
	Olin Lake
	Pratt Lake
	Ratigan Lake
	Reeds Lake
	Stoners Lake
	Wabasis Lake
Kent/Ottawa	Cranberry Lake
Leelanau	Glen Lake (Big)
	Glen Lake (Little)

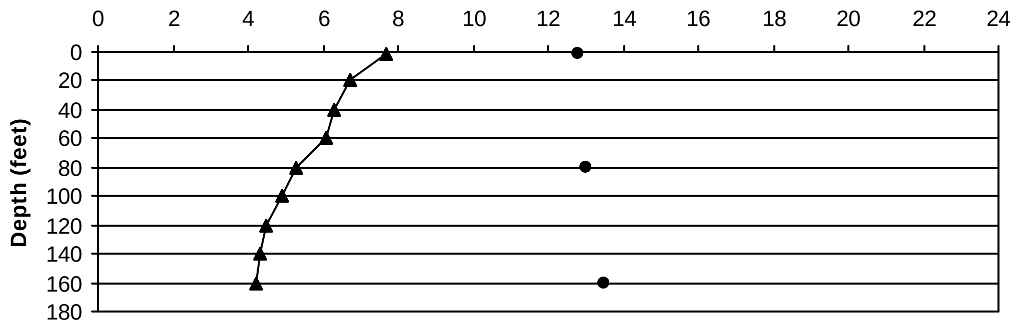
County	Participating Lakes
Lenawee	Devils Lake Round Lake
Livingston	Strawberry Lake
Mecosta	Blue Lake Horsehead Lake Mecosta Round Lake School Section Lake
Montcalm	Baldwin Lake
Montmorency	Twin Lakes (East) Twin Lakes (West)
Newaygo	Brooks Lake Hess Lake Robinson Lake
Oakland	Green Lake Walled Lake White Lake
St. Joseph	Corey Lake
Van Buren	Cedar Lake

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

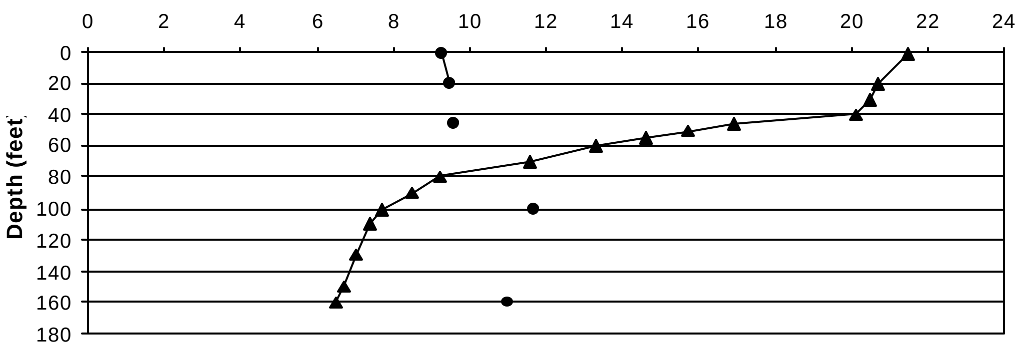
Oligotrophic Lake with a Very Large Volume Hypolimnion

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

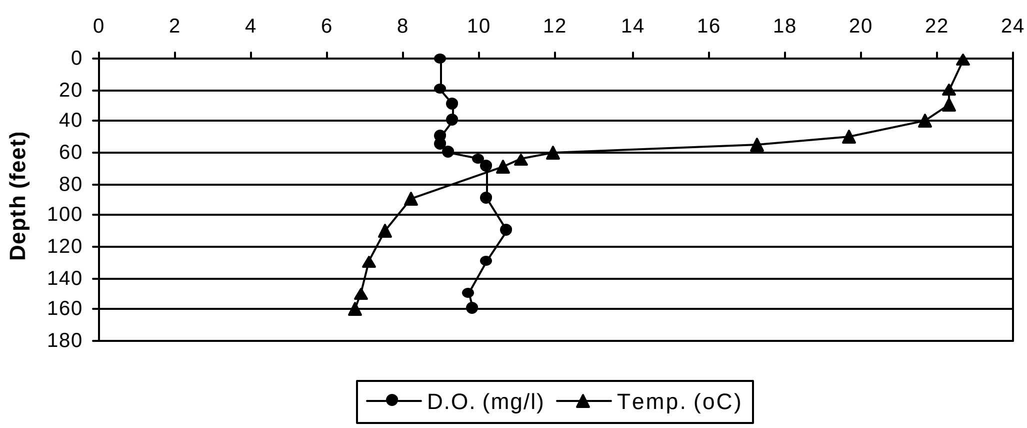
May 2, 1990



July 11, 1990



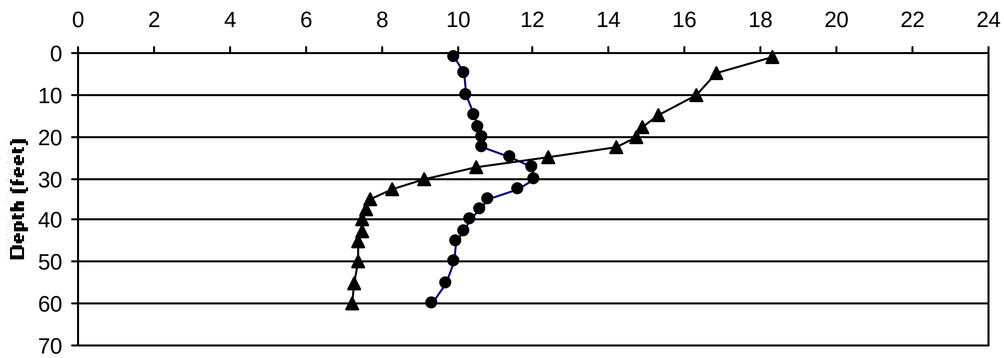
September 5, 1990



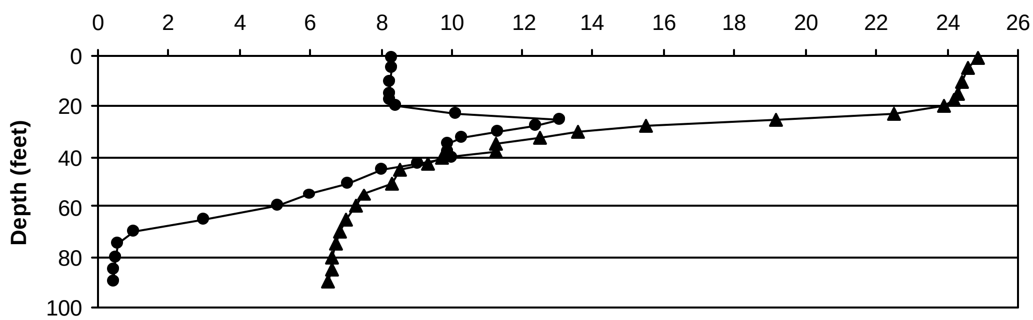
Oligotrophic/Mesotrophic Lake with a Large Volume Hypolimnion

Lake Ann in Benzie 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.

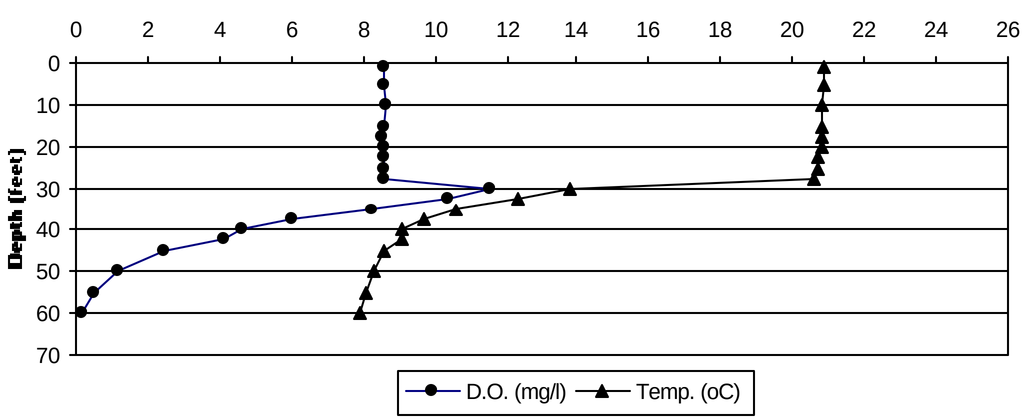
May 19, 2001



August 11, 2001



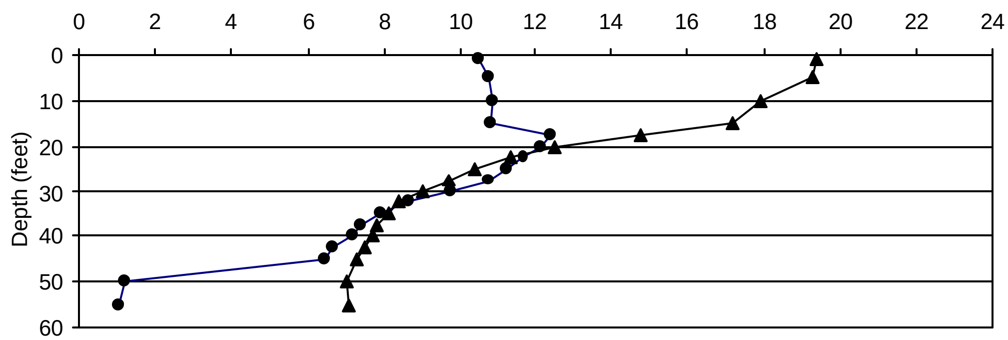
September 10, 2001



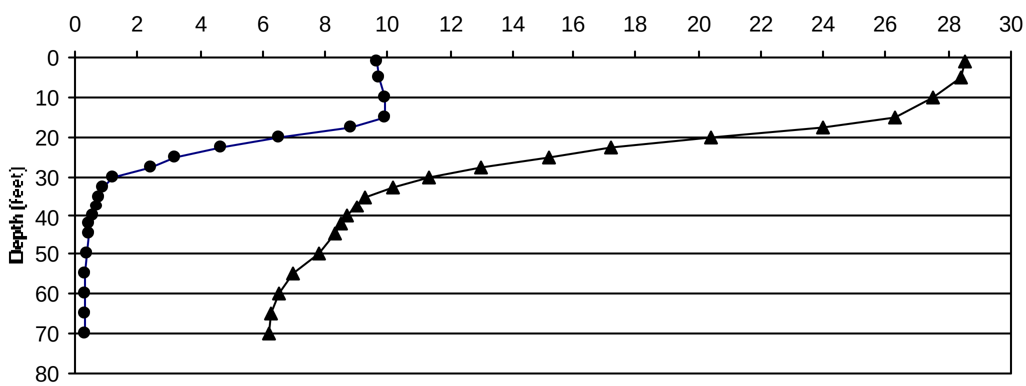
Oligotrophic/Mesotrophic Lake with a Small Volume Hypolimnion

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

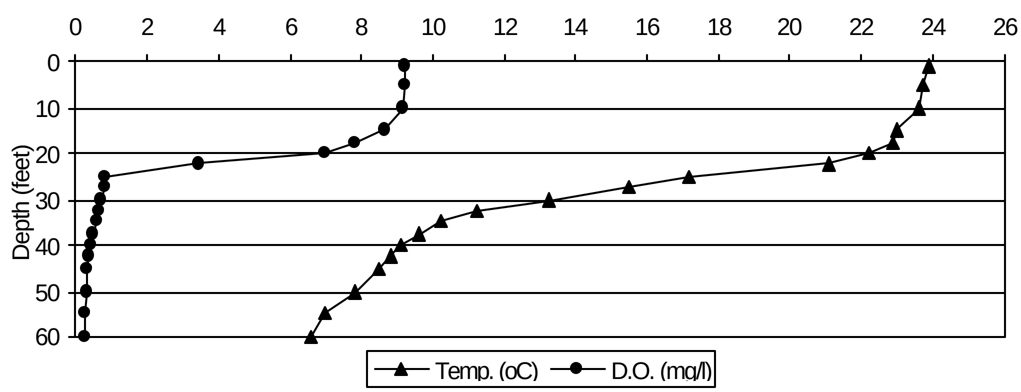
May 14, 2001



August 7, 2001



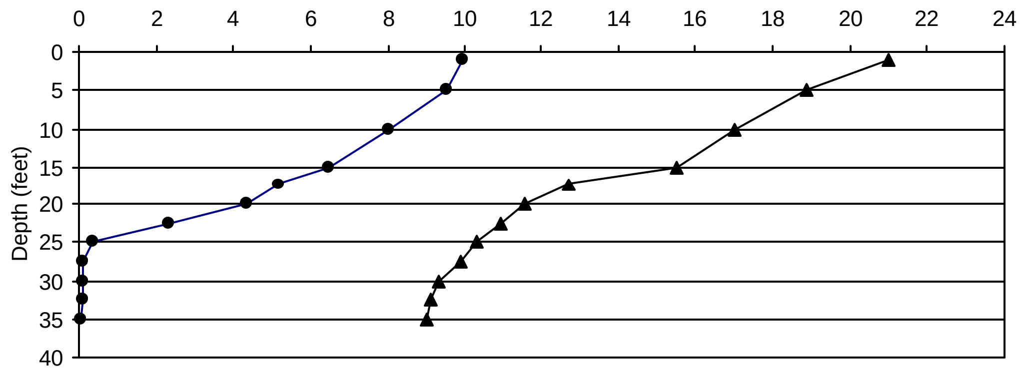
September 3, 2001



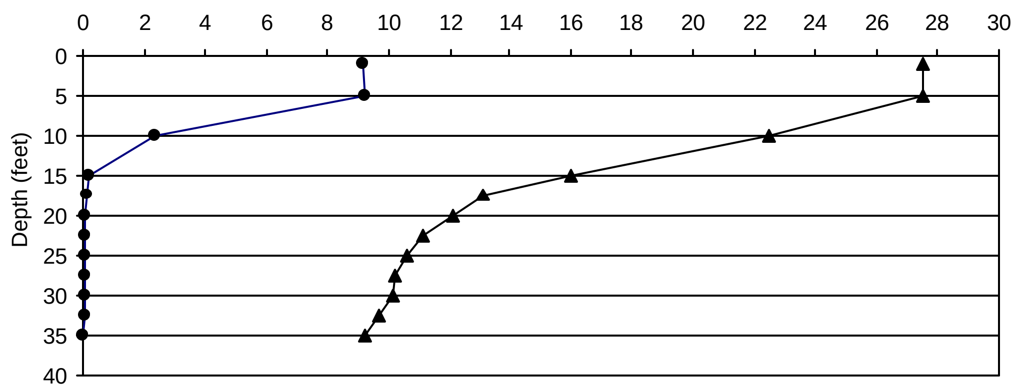
Eutrophic Lake with a Small Volume Hypolimnion

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

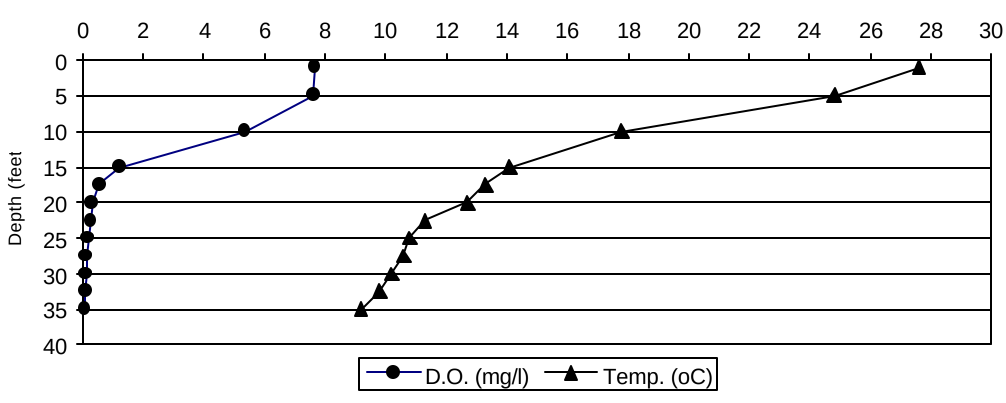
May 19, 2001



July 23, 2001



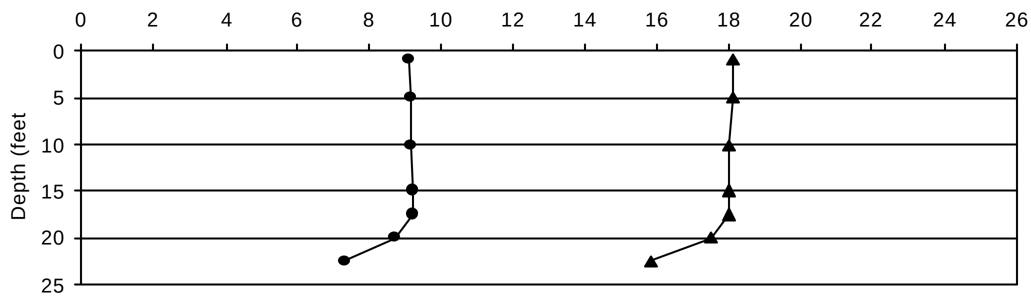
August 28, 2001



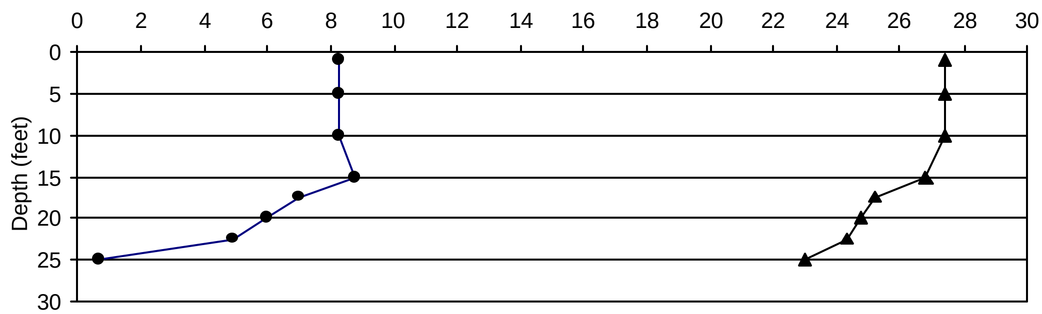
Shallow Mesotrophic Lake that does not Maintain Summer Stratification

White Lake in Oakland 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.

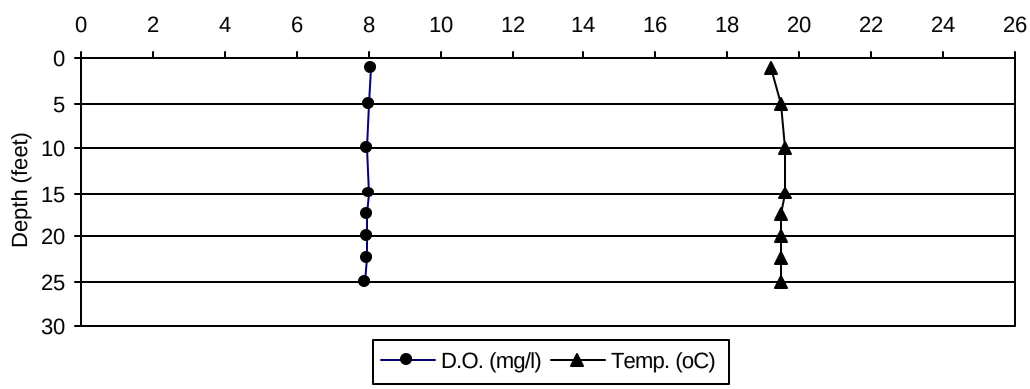
May 10, 2001



August 3, 2001



September 21, 2001



APPENDIX 5
2001 COOPERATIVE LAKES MONITORING PROGRAM
AQUATIC PLANT MAPPING

Three lakes participated in the 2001 CLMP aquatic plant mapping pilot project. They were Corey Lake in St. Joseph County, Birch Lake in Cass County and Gunn Lake in Mason County. All three lakes have similar productivity, with TSI values in the high 30's to low 40's. The CLMP plant mapping project revealed that all three lakes had moderate plant populations consisting of a good diversity of species, none of which dominated. Additionally, none of the lakes had Eurasian milfoil and only sparse populations of curly-leaf pondweed were identified in any of the lakes. As an example of the work completed in the CLMP aquatic plant mapping pilot project the whole lake reporting data sheet for Birch Lake is presented below. In addition to the data sheets each lake monitoring team produced a map of the lake showing aquatic plant distribution and density for each plant type identified.

Plant Number	Plant Name	Distribution (# of sites where observed)	Average Density
20	Stonewort	49	2.13
40	Native milfoil	20	0.79
34	Wild celery	17	0.47
36	Waterweed	11	0.44
32	Thin-leaf pondweed	10	0.44
43	Floating-leaf pondweed	13	0.41
33	Flat-stemmed pondweed	11	0.40
46	Illinois pondweed	12	0.33
48	Bladderwort	9	0.25
52	Sago pondweed	10	0.22
9	Arrowhead	4	0.22
47	Water marigold	6	0.18
45	American pondweed	2	0.05
51	Curly-leaf pondweed	3	0.04
37	A small leafed pondweed	2	0.02
12	White water lily	1	0.02
7	Bulrush	2	0.02
21	Bushy pondweed	1	0.01

APPENDIX 6
2001 COOPERATIVE LAKES MONITORING PROGRAM
FISH AGE AND GROWTH ANALYSIS

Two lakes participated in the 2001 CLMP fish age and growth pilot project. They were Gunn Lake in Mason County and Osterhout Lake in Allegan County.

Gunn Lake

Comparisons of Gunn Lake largemouth bass and bluegill to Michigan's state averages suggest growth of these fish species in the lake do not differ significantly from the state averages (Figure 1). For instance, the estimated age at which largemouth bass reach legal capture size (14 inches) in Gunn Lake is estimated to be nearly identical to that of the state average (approximately 5 1/2 years). Based on these results it is concluded that the growth rates of bass and bluegill in Gunn Lake are typical for Michigan, and conditions controlling fish growth are also expected to be typical of a Michigan lake.

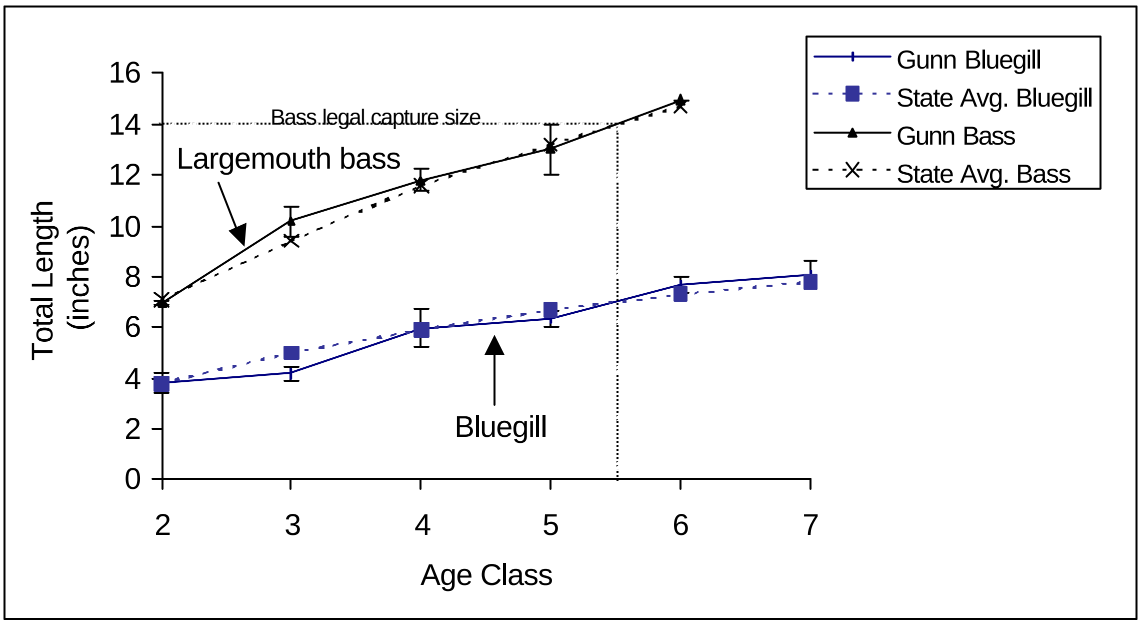


Figure 1. Gunn Lake largemouth bass and bluegill length-at-age (spring 2001) compared to the historic state averages. Values indicate sample means ±1 standard deviation where applicable. No error estimates are associated with state averages. Only age classes of fish captured are represented.

Osterhout Lake

Comparisons of Osterhout Lake largemouth bass to the Michigan average suggests only minor deviations, particularly in the youngest and oldest age classes (Figure 2). However, small sample sizes for individual age classes limit the ability and confidence to conclude significant differences. These results suggest that Osterhout Lake bass reach legal capture size (14 inches) at approximately the same age as a typical bass in Michigan (approximately 5 1/2 years). These results also suggest that conditions controlling bass growth may be typical for a Michigan lake.

However, comparisons of Osterhout Lake bluegill to the Michigan average suggests bluegill growth is well below the state average (Figure 2). These results are consistent with a 1990 Michigan Department of Natural Resources Fisheries Division survey that suggested a stunted bluegill population existed at that time. Such stunting occurs most commonly in small, shallow lakes. If rooted plants are dense bass predation on bluegill is limited allowing bluegill populations to be high. The resulting high abundance of bluegill increases competition for resources and results in poor bluegill growth. But plants don't need to be dense to have stunted bluegill. Some small, shallow lakes with sandy bottoms have a limited food base of insects and other invertebrates. Excellent spawning habitat allows bluegill to reproduce large numbers of young but there is insufficient food to allow good growth. Bass in these situations may show poorer growth in young age groups while they compete with bluegill for insect food. However, after reaching six to eight inches bass growth may improve significantly as they increase their consumption of fish and take advantage of the abundant bluegill population.

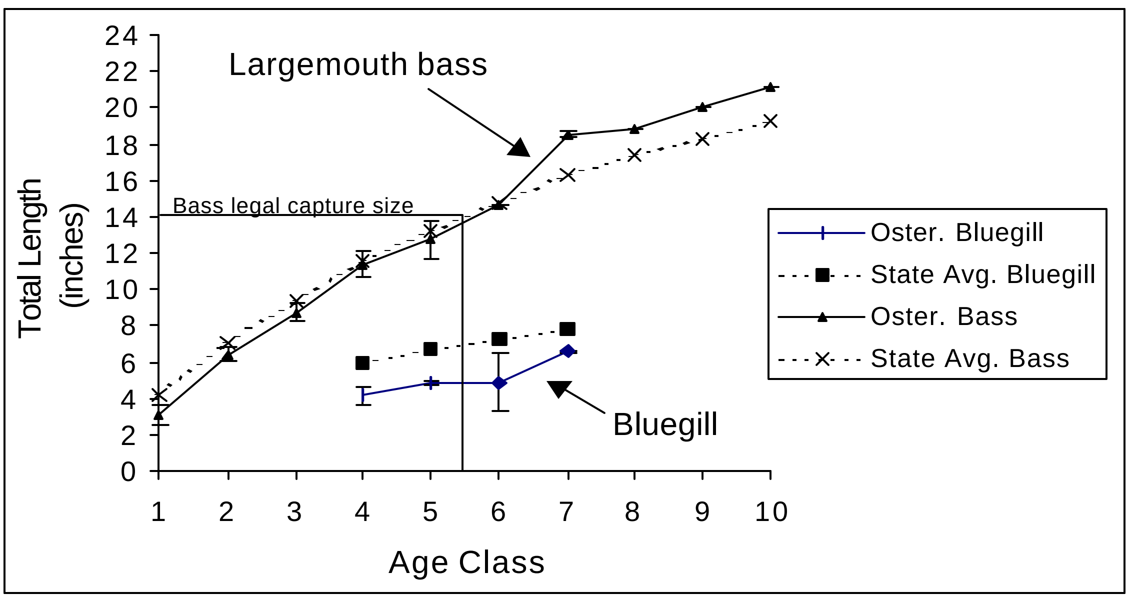


Figure 2. Osterhout Lake largemouth bass and bluegill length-at-age (spring 2001) compared to the historic state averages. Values indicate sample means ±1 standard deviation where applicable. No error estimates are associated with state averages. Only age classes of fish captured are represented.