
Picture 1. Lake Guardian for Shingle Lake, 29 August, 2009.

A Limnological and Fishery Survey for Lake George and Shingle Lake, 11 June and 29 August 2009

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INTRODUCTION

Freshwater Physicians performed an assessment of the limnology and fish community of Lake George and Shingle Lake. Water quality samples (for chlorides, soluble reactive phosphorus, ammonia, and nitrates) were collected once on 29 August 2009 from the surface, mid-depth, and bottom of each lake and a dissolved oxygen and temperature profile was measured at each 1-m depth interval in the deepest part of each lake on two occasions: 11 June and 29 August 2009. The temperature-depth relationships are important since they provide information on whether the habitat in a lake is suitable for cool water species (e.g., northern pike, walleyes) or just warm-water fishes and the nutrient and chloride data will indicate whether there is historical or continuing pollution and how eutrophic (nutrient enriched) a particular water body is by the amount of nutrients that accumulate in the bottom waters during stratification in the summer. Fishes were collected on 11 June 2009 using three gear types: small and large trap nets, gill nets, and a 50-ft bag seine. This information and a consideration of the entire ecosystem of each lake will be assembled and synthesized to provide a management plan for each lake.

METHODS

Our study involves physical, chemical, and biological measurements and observations by professional aquatic biologists who have conducted lake management studies since 1972; we incorporated in 1974. We use specialized samplers and equipment designed to thoroughly examine all components of an aquatic ecosystem. Shallow water, deep water, sediments, animal and plant life as well as inlet and outlet streams are intensively sampled and analyzed at several key stations (sites on the lake). Our SCUBA divers or snorkelers examine aquatic plants, sediments, and fish and assist in some other data collections. Some samples are analyzed in the field, while the balance is transported to our laboratory for measurements and/or identification of organisms found in samples.

After the field study, we compile, analyze, summarize, and interpret data. We utilize a comprehensive library of limnological studies, and review all the latest management practices in constructing a management plan. All methods used are standard limnological procedures, and most chemical analyses are according to Standard Methods for the Examination of Water and Wastewater. Water analyses were performed by Grand Valley State University.

STATION LOCATIONS

During any study we choose a number of places (stations) where we do our sampling for each of the desired parameters. We strive to have a station in any unusual or important place, such as inlet and outlet streams, as well as in representative areas in the lake proper. One of these areas is always the deepest part of the lake. Here we check on the degree of thermal and chemical stratification, which is extremely important in characterizing the stage of eutrophication (nutrient enrichment), invertebrates present, and possible threats to fish due to production of toxic substances due to decomposition of the bottom sediments. The number and location of these stations for this study are noted in that section.

PHYSICAL PARAMETERS

Acreage

Acreage figures, when desired, are derived from maps, by triangulation, and/or estimation. The percentage of lake surface area in shallow water (less than 10 feet) is an important factor. This zone (known as the littoral zone) is where light can penetrate with enough intensity to support rooted aquatic plants. Natural lakes usually have littoral zones around their perimeters. Man-made lakes and some reservoirs often have extensive areas of littoral zone.

Sediments

Bottom accumulations give good histories of the lake. The depth, degree of compaction, and actual makeup of the sediments reveal much about the past. An Ekman grab or dredge sampler or a coring device is used to sample bottom sediments for examination. It is lowered to the bottom, tripped with a weight, and it "grabs" a 1 square foot sample of the bottom. Artificial lakes often fill in more rapidly than natural lakes because disruption of natural drainage systems occurs when these lakes are built. Sediments are either organic (remains of plants and animals produced in the lake or washed in) or inorganic (non-living materials from wave erosion or erosion and run-off from the watershed).

Light Penetration

The clarity of the water in a lake determines how far sunlight can penetrate. This in turn has a basic relationship to the production of living phytoplankton (minute plants called algae), which are basic producers in the lake, and the foundation of the food chain. We measure light penetration with a small circular black and white Secchi disc attached to a calibrated line. The depth at which this disc just disappears (amount of water transparency) will vary between lakes and in the same lake during different seasons, depending on degree of water clarity. This reference depth can be checked periodically and can reflect the presence of plankton blooms and turbidity caused by urban run-off, etc. A regular monitoring program can provide an annual documentation of water clarity changes and also a historical record of changes in the algal productivity in the lake that may be related to development, nutrient inputs, or other insults to the lake.

Temperature

This is a physical parameter but will be discussed in the chemistry section with dissolved oxygen. Thermal stratification is a critical process in lakes which helps control the production of algae, generation of various substances from the bottom, and dissolved oxygen depletion rates.

Stream Flows from Inlets and Outlets

Estimation of flows in and out of a lake gives us information about ground water inputs, inputs of nutrients and toxic substances, and amount of water moving through the ecosystem. When tied to the chemical analyses described earlier, nutrient inputs and outputs can be calculated and amount of impact of these inputs evaluated. In addition these tributaries can be important spawning habitat for species such as northern pike and suckers.

CHEMICAL PARAMETERS

Water chemistry parameters are extremely useful measurements and can reveal considerable information about the type of lake and how nutrients are fluxing through the system. They are important in classifying lakes and can give valuable information about the kind of organisms that can be expected to exist under a certain chemical regime. All chemical parameters are a measure of a certain ion or ion complex in water. The most important elements--carbon (C), hydrogen (H), and oxygen (O) are the basic units that comprise all life, so their importance is readily obvious. Other elements like phosphorus (P) and nitrogen (N) are extremely important because they are significant links in proteins and RNA/DNA chains. Since the latter two (P and N) are very important plant nutrients, and since phosphorus has been shown to be critical and often times a limiting nutrient in some systems, great attention is given to these two variables. Other micronutrients such as boron, silicon, sulfur, and vitamins can also be limiting under special circumstances. However, in most cases, phosphorus turns out to be the most important nutrient.

Temperature Stratification

Temperature governs the rate of biological processes. A series of temperature measurements from the surface to the bottom in a lake (temperature profile) is very useful in detecting stratification patterns. Stratification in early summer develops because the warm sun heats the surface layers of a lake. This water becomes less dense due to its heating, and "floats" on the colder, denser waters below. Three layers of water are thus set up. The surface warm waters are called the epilimnion, the middle zone of rapid transition in temperatures is called the thermocline, and the cold bottom waters, usually around 39 F (temperature of maximum density), are termed the hypolimnion. As summer progresses, the lowest cold layer of water (hypolimnion) becomes more and more isolated from the upper layers because it is colder and denser than surface waters.

When cooler weather returns in the fall, the warm upper waters (epilimnion) cool to about 39 F, and because water at this temperature is densest (heaviest), it begins to sink slowly to the bottom. This causes the lake to "turnover" or mix, and the temperature becomes a uniform 39 F top to bottom. Other chemical variables, such as dissolved oxygen, ammonia, etc. are also uniformly distributed throughout the lake.

As winter approaches, surface water cools even more because water is most dense at 39 F, and the deep portions of the lake "fill" with this "heavy water". Water colder than 39 F is actually lighter and floats on the more dense water below, until it freezes at 32 F and seals the lake. During winter decomposition on the bottom can warm bottom temperatures slightly.

In spring when the ice melts and surface water warms from 32 to 39 F, seasonal winds will mix the lake again (spring overturn), thus completing the yearly cycle. This represents a typical cycle, and many variations can exist, depending on the lake shape, size, depth, and location. Summer stratification is usually the most critical period in the cycle, since the hypolimnion may go anoxic (without oxygen--discussed next). We always try to schedule our sampling during this period of the year. Another critical time exists during late winter as oxygen can be depleted from the entire water column in certain lakes under conditions of prolonged snow cover.

Dissolved Oxygen

This dissolved gas is one of the most significant chemical substances in natural waters. It regulates the activity of the living aquatic community and serves as an indicator of lake conditions. Dissolved oxygen is measured using the Winkler method with the azide modification. Fixed samples are titrated with PAO (phenol arsene oxide) and results are expressed in mg/L (ppm) of oxygen, which can range normally from 0 to about 14 mg/L. Water samples for this and all other chemical determinations are collected using a device called a Kemmerer water sampler, which can be lowered to any desired depth and like the Ekman grab sampler, tripped using a messenger (weight) on a calibrated line. The messenger causes the cylinder to seal and the desired water sample is then removed after the Kemmerer is brought to the surface. Most oxygen in water is the result of the photosynthetic activities of plants, the algae and aquatic macrophytes. Some enters water through diffusion from air. Animals use this oxygen while giving off carbon dioxide during respiration. The interrelationships between these two communities determine the amount of productivity that occurs and the degree of eutrophication (lake aging) that exists.

A series of dissolved oxygen determinations can tell us a great deal about a lake, especially in summer. In many lakes in this area of Michigan, a summer stratification or stagnation period occurs (See previous thermal stratification discussion). This layering causes isolation of three water masses because of temperature-density relationships already discussed. In the spring turnover period dissolved oxygen concentrations are at saturation values from top to bottom. However, in these lakes by July or August some or all of the dissolved oxygen in the bottom layer is lost (used up by bacteria) to the decomposition process occurring in the bottom sediments. The richer the lake, the more sediment produced and the more oxygen used up. Since there is no way for oxygen to get down to these layers (there is not enough light for algae to photosynthesize), the hypolimnion becomes devoid of oxygen in rich lakes. In non-fertile (Oligotrophic) lakes there is very little decomposition, and therefore little or no dissolved oxygen depletion. Lack of oxygen in the lower waters (hypolimnion) prevents fish from living here and also changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic).

Stratification does not occur in all lakes. Shallow lakes are often well mixed throughout the year because of wind action. Some lakes or reservoirs have large flow-through so stratification never gets established.

Stratified lakes will mix in the fall because of cooler weather, and the dissolved oxygen content in the entire water column will be replenished. During winter the oxygen may again be depleted near the bottom by decomposition processes. As noted previously, winterkill of fish results when this condition is caused by early snows and a long period of ice cover when little sunlight can penetrate into the lake water. Thus no oxygen can be produced, and if the lake is severely eutrophic, so much decomposition occurs that all the dissolved oxygen in the lake is depleted.

In spring, with the melting of ice, oxygen is again injected into the hypolimnion during this mixing or "turnover" period. Summer again repeats the process of stratification and bottom depletion of dissolved oxygen.

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 24-hour cycle. During the day in summer, plants photosynthesize and produce oxygen, while at night they join the animals in respiring (creating CO2) and using up oxygen. This creates a diel cycle of high dissolved oxygen levels during the day and low levels at night. These dissolved oxygen sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

pH

The pH of most lakes in this area ranges from about 6 to 9. The pH value (measure of the acid or alkaline nature of water) is governed by the concentration of H (hydrogen) ions which are affected by the carbonate-bicarbonate buffer system, and the dissociation of carbonic acid (H2CO3) into H + ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO2 from the carbonate-bicarbonate system. The pH will rise as a result. During evening hours, the pH will drop due to respiratory demands (production of carbon dioxide, which is acidic). This cycle is similar to the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO2 during the day in photosynthesis there is a drop in CO2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO2), thus causing a rise in CO2 concentration and a concomitant decrease in pH toward a more acidic condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution, which would cause deviations from expected values. We measure pH the field with color comparators and in the laboratory with a Beckman pH meter.

Alkalinity

The amount of acid (hydrogen ion) that needs to be added to a water sample to get a sample to a pH of 4.5 (the endpoint of a methyl-orange indicator) is a measure of the buffering capacity of the water and can be quantitatively determined as mg/L or ppm as calcium carbonate (CaCO3). This measurement is termed total alkalinity and serves as an indicator of basic productivity and as an estimate of the total carbon source available to plants. Alkalinity is a measure of hydroxides (OH-), carbonates (CO3=) and bicarbonates present. Plants utilize carbon dioxide from the water until that is exhausted and then begin to extract CO2 from the carbonate-bicarbonate buffer system through chemical shifts. As discussed before, this decrease in CO2 concentrations causes great pH increases during the day and a pH drop during the night. There are two kinds of alkalinity measured, both based on the indicators, which are used to detect the end-point of the titration. The first is called phenolthalein alkalinity (phth) and is that amount of alkalinity obtained when the sample is titrated to a pH of 8.3. This measurement is often 0, but can be found during the conditions previously discussed; that is, during summer days and intense photosynthesis. Total alkalinity was noted above and includes phenolthalein alkalinity.

Hardness

Like alkalinity, hardness is also a measure of an ion, though these are divalent cations, positive double charged ions like calcium (Ca++) and magnesium (Mg/L++). Again, the units of hardness are mg/L as CaCO3. A sample of water is buffered and then an indicator is added. Titration to the indicator endpoint using EDTA completes the analysis. As with all our analyses, for more detail, consult Standard Methods. Alkalinity and hardness are complementary, so that comparing the two readings can give information about what ions are present in the system and confirm trends seen in other data. Alkalinity and hardness are complementary because every calcium ion must have a bicarbonate ion or other such divalent negative ion and vice versa; each carbonate or hydroxide ion must have a divalent or monovalent anion associated with it. For example, we might find high chlorides from street run-off in a particular sample. Since chlorides are probably applied as calcium chloride (CaCl2), we would confirm our suspicions when hardness (a measure of Ca++ ions) was considerably higher than alkalinity. If alkalinity were higher than hardness it would indicate that some positive anion like potassium (K+) was present in the lake, which was associated with the bicarbonate and carbonate ions but was not measured by hardness. Generally speaking, high alkalinity and hardness values are associated with a greater degree of eutrophication; lakes are classified as soft, medium, or hard-water lakes based on these values.

Chlorides

Chlorides are unique in that they are not affected by physical or biological processes and accumulate in a lake, giving a history of past inputs of this substance. Chlorides (Cl-) are transported into lakes from septic tank effluents and urban run-off from road salting and other sources. Chlorides are detected by titration using mercuric nitrate and an indicator. Results are expressed as mg/L as chloride. The effluent from septic tanks is high in chlorides. Dwellings around a lake having septic tanks contribute to the chloride content of the lake. Depending upon flow-through, chlorides may accumulate in concentrations considerably higher than in natural ground water. Likewise, urban run-off can transport chlorides from road salting operations and also bring in nutrients. The chloride "tag" is a simple way to detect possible nutrient additions and septic tank contamination. Ground water in this area averages 10-20 mg/L chlorides. Values above this are indicative of possible pollution.

Phosphorus

This element, as noted, is an important plant nutrient, which in most aquatic situations is the limiting factor in plant growth. Thus if this nutrient can be controlled, many of the undesirable side effects of eutrophication (dense macrophyte growth and algae blooms) can be avoided. The addition of small amounts of phosphorus (P) can trigger these massive plant growths. Usually the other necessary elements (carbon, nitrogen, light, trace elements, etc.) are present in quantities sufficient to allow these excessive growths. Phosphorus usually is limiting (occasionally carbon or nitrogen may be limiting). Two forms of phosphorus are usually measured. Total phosphorus is the total amount of P in the sample expressed as mg/L or ppm as P, and soluble P or Ortho P is that phosphorus which is dissolved in the water and "available" to plants for uptake and growth. Both are valuable parameters useful in judging eutrophication problems.

Nitrogen

There are various forms of the plant nutrient nitrogen, which are measured in the laboratory using complicated methods. The most reduced form of nitrogen, ammonia (NH3), is usually formed in the sediments in the absence of dissolved oxygen and from the breakdown of proteins (organic matter). Thus high concentrations are sometimes found on or near the bottom under stratified anoxic conditions. Ammonia is reported as mg/L as N and is toxic in high concentrations to fish and other sensitive invertebrates, particularly under high pHs. With turnover in the spring most ammonia is converted to nitrates (NO3=) when exposed to the oxidizing effects of oxygen. Nitrite (NO2-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured.

Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. Nitrates, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about succession of algae species, which usually proceeds from diatoms, to green algae to blue-green algae. Blue-green algae (an undesirable species) can fix their own nitrogen (some members) and thus out-compete more desirable forms, when phosphorus becomes scarce in late summer.

BIOLOGICAL PARAMETERS

Bacteria

This group of organisms is extremely important in the biology of lakes in that they are responsible for all the decomposition that occurs in a lake as well as many chemical transformations, such as the manufacture of hydrogen sulfide by sulfur bacteria, the transformation of nitrate to ammonia by denitrifying bacteria, etc. Another important group is the coliform bacteria which when present can indicate that sewage has somehow entered the body of water. The methods used (Standard Methods) indicate the degree of contamination of the water with wastes from human or animal sources. Since this is a public health aspect, we do not interpret nor routinely run coliform, unless there is a special reason to do so.

Macrophytes

The aquatic plants (emergent and submersed), which are common in most aquatic environments, are the other type of primary producer in the aquatic ecosystem. They only grow in the euphotic zone, which is usually the inshore littoral zone up to 6 ft., but in some lakes with good water clarity and with the introduced Eurasian water-milfoil (*Myriophyllum spicatum*), growths have been observed in much deeper water. Plants are very important as habitat for insects, zooplankton, and fish, as well as their ability to produce oxygen. Plants have a seasonal growth pattern wherein over wintering roots or seeds germinate in the spring. Most growth occurs during early summer. Again plants respond to high levels of nutrients by growing in huge beds. They can extract required nutrients both from the water and the sediment. Phosphorus is a critical nutrient for them. The aquatic plants and algae are closely related, so that any control of one must be examined in light of what the other forms will do in response to the newly released nutrients and lack of competition. For example, killing all macrophytes may result in massive algae blooms, which are even more difficult to control.

Zooplankton

This group of organisms is common in most bodies of water, particularly in lakes and ponds. They are very small creatures, usually less than 1/8 inch long, and usually live in the water column where they eat detritus and algae. Some prey on other forms. This group is seldom seen in ponds or lakes by the casual observer of wildlife but is a very important link in the food web leading from the algae to fish. They are usually partially transparent organisms, which have limited ability to move against currents and wave action, but are sometimes considered part of the 'plankton' because they have such little control over their movements, being dependent on wind-induced or other currents for transport.

Zooplankters are important indicators for biologists for three reasons. First, the kind and number present can be used to predict what type of lake they live in as well as information about its stage of eutrophication. Second, they are very important food sources for fish (especially newly hatched and young of the year fish), and third, they can be used to detect the effects of pollution or chemical insult if certain forms expected to be present are not. These data can be added to other such data on a lake and the total picture can then lead to the correct conclusions about what has occurred in a body of water.

Zooplankton is collected by towing a No. 10 plankton net through the water and the resulting sample is preserved with 10% formaldehyde and then examined microscopically in the laboratory. Qualitative estimates of abundance are usually given.

Benthos

The group of organisms in the bottom sediments or associated with the bottom is termed benthos. These organisms are invertebrates (lacking a backbone) and are composed of such animals as aquatic insect larvae (e.g., chironomids) and adults, amphipods (fairy shrimp), oligochaetes (aquatic worms), snails, and clams. The importance of this group for fish food and as intermediates in the food chain should be emphasized. Because of the tremendous variety of animals in each group and their respective tolerances for different environmental conditions, this group is a very important indicator of environmental quality. We examine samples from deep water stations for the presence of organisms, as certain types live in low to no dissolved oxygen conditions, whereas other kinds can only exist when their high dissolved oxygen needs are satisfied.

These benthic organisms are collected using a special sampler called an Ekman dredge or Ekman grab sampler. It is lowered to the bottom in the open position, a messenger sent down the line and tripped. This results in about an l square foot section of bottom being sampled. The sample is washed through a series of screens to remove the fine mud and detritus, leaving only the larger organisms and plant material behind. The sample is then picked in the field or lab and the organisms found identified.

Fish

The top carnivores in most aquatic ecosystems, excluding man, are the fish. They are integrators of a vast number and variety of ever-changing conditions in a body of water. They, unlike the zooplankton and benthos, which can reflect short-term changes, are indicative of the long-range, cumulative influences of the lake or stream on their behavior and growth. The kind of fish, salmon or sunfish, can tell us much about how oligotrophic (low productivity) or eutrophic (high productivity) a lake is. We collect fish with seines, gill nets and from lucky fishermen on the lake. Most fish are weighed, measured, sexed, and their stomach contents removed and identified. Fish are aged using scales, and breeding condition is observed and recorded. The catches from our nets and age information on the fish will tell us how your length-at-age data compare with state averages and whether or not fish growth is good. Another problem, "stunting", can be detected using these sources of information.

Stomach contents of fish document whether or not good sources of food are present and help confirm age and growth conclusions. Imbalances in predator-prey relationships are a closely related problem, which we can usually ascertain by examining the data and through discussions with local fishermen. From studying the water chemistry data and supportive biological data, we can make recommendations, such as habitat improvement, stocking of more predators, and chemical renovation. We can also predict for example, the effects of destroying macrophytes through chemical control. All elements of the ecosystem are intimately interrelated and must be examined to predict or solve problems in a lake.

LAKE GEORGE

INTRODUCTION

Lake George is a 134-acre, elongated lake with four major basins, where maximum depth is around 22-24 ft. Being shallow and having an active community that has many recreational motorized water craft that traverse this narrow lake has resulted in the lake being well mixed, as opposed to Shingle lake, which has a much deeper and wider lake where stratification does occur and is maintained. The watershed is 2,502 acres, which is very large, and the area is mostly residential homes ringing the lake and lots of forested area. All houses are on septic tanks. It is considered mildly eutrophic, which means it contains a fair amount of nutrients (fertilizer) which generates aquatic macrophytes and algae. Sediments are peat, sand, gravel and organic muck. The fish population is a warm-water community composed of panfish (bluegills, pumpkinseeds, black crappies, and rock bass) and top predators of largemouth bass and northern pike. There are other species present too as well: yellow perch, bullheads, golden and emerald shiners, white suckers, and Iowa and Johnny darters (based on a MDNR study and the map – APPENDIX 2). This study was done on Lake George during May 1993 by MDNR. Their conclusions were that they caught very few northern pike, that largemouth bass were doing well, that bullheads were large but overabundant, and that bluegills and pumpkinseeds were growing poorly. Black crappies appeared to be more numerous and were slow growing as well. There is a public access on the lake.

STUDY AREA

Lake George is long, shallow, narrow lake of 134 acres ringed with a littoral zone with abundant aquatic plant growth (Fig. 1). It has good habitat diversity. Since the watershed is so large (2,500 acres) there is great potential for runoff to enter the lake. Most of the land in the watershed we saw was residential with abundant forested areas, which should provide good ability to absorb nutrients, road salt, pesticides, and other contaminants generated by residents in the watershed. However, care must be given to assessing any areas where runoff could be a problem now and any future developments for their potential impacts on the lake through runoff. The slopes of the lake are steep and hence will facilitate nutrients and contaminants entering the lake through surface runoff and through groundwater inflow.

We established two types of stations in the lake: those to sample water quality (station A and B) on the map (Fig. 1) and those to sample fish (see places where the seine, trap nets, and gill nets were deployed). The water quality sites were chosen to represent the deepest places in the lake and to measure the degree of stratification and the water quality. The sites we picked for the trap nets, gill nets, and for seining were chosen to represent a diversity of habitats. We used three different kinds of gear in order to sample all the various types of fishes in the lakes (see Picture 2). Trap nets are excellent for sampling bullheads, sunfish, suckers, and sometimes other species as well. The gill net is very effective at sampling fish that move around and since there are different mesh sizes in the net, various sizes of fish (and species) are vulnerable to the net. The seining is good for catching fish that are near shore and associated with aquatic plants. The seines usually collect juvenile fishes which can give us a sense of how well various species are reproducing and whether or not there is a good supply of prey species available for predators (e.g., minnows). More detail in provided in the introductory material (under Methods) above.

Picture 2. Small trap net set on the west end of Shingle Lake, 11 June 2009.

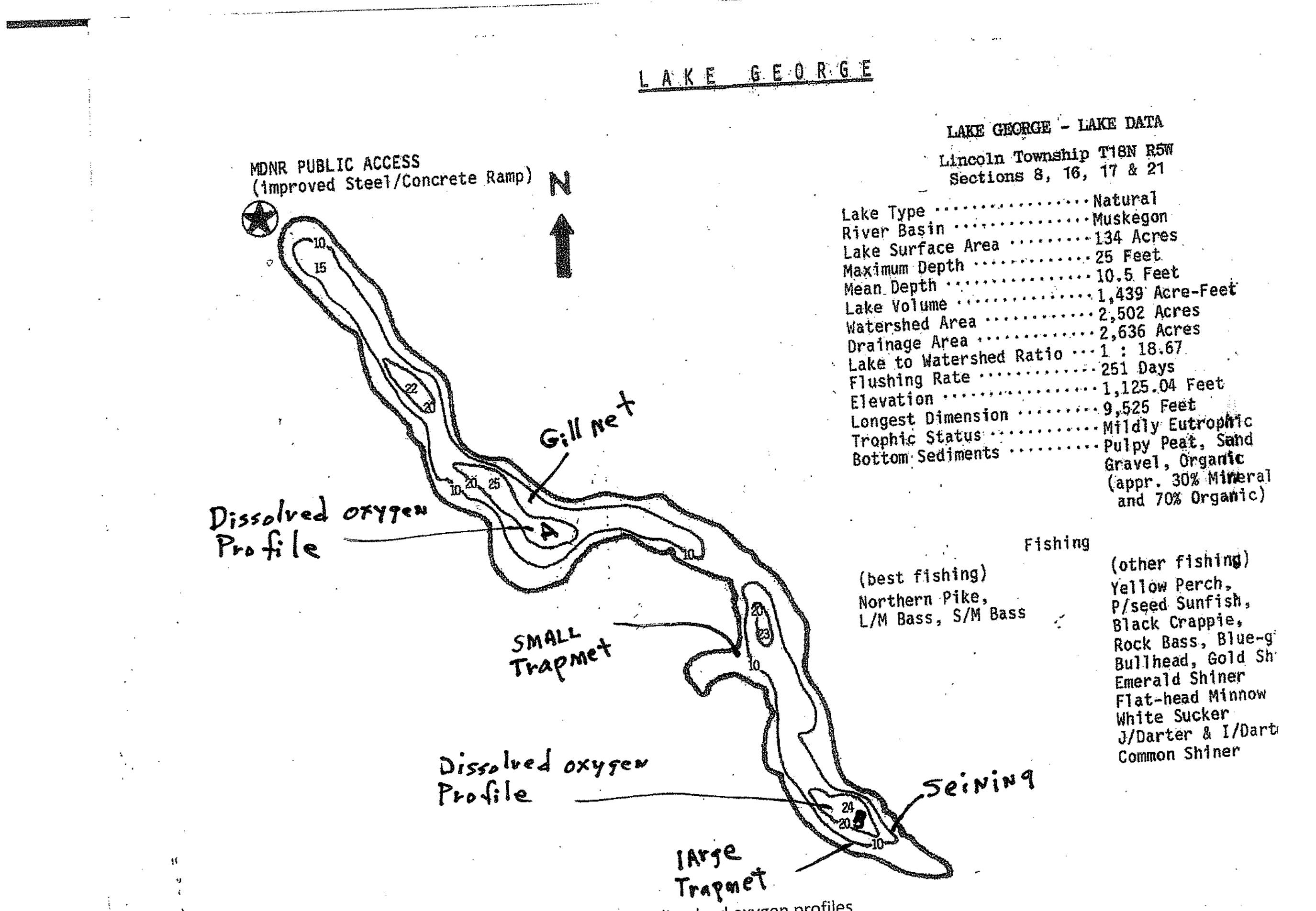


Figure 1. Map of Lake George showing stations A and B (deep spots) where dissolved oxygen profiles were obtained, sites where the gill nets, trap nets (small and large) and seining occurred, and the public access site on the north end.

RESULTS

Water quality

In order to get some information on the chemical state of Lake George, we analyzed three water samples from the deep hole (station A, where the dissolved oxygen profile was taken) at three depths (surface, mid depth, and bottom) on 29 August 2009 for: soluble reactive phosphorus, nitrate, chlorides, and ammonia. We also took a measure of water clarity to determine if there were turbidity issues with algal blooms or sediment inputs. These parameters provide some information on the nutrient status of the lake and the chlorides of historical pollution, either by road salt or septic tank contamination (see Methods for more extensive explanation of these parameters).

Chlorides in Lake George were uniformly 20 mg/L, low by most standards, and lower by 10 mg/L when compared with Shingle Lake values (Table 1). Chlorides are useful indicators of septic tank pollution and road salt runoff and since they are changed neither by chemical or physical mechanisms (only evaporation will change concentrations) they are cumulative in the lake and can show us if there is extensive runoff. Chlorides (regular salt) are not toxic at the concentrations we usually find in inland lakes. This is a good sign for the lake, but not an excuse to delay getting on sewers if the opportunity ever arises, since more extensive research would have to be done to measure nutrients coming in from the septic tank effluent.

Table 1. Water quality parameters for Lake George, 29 August 2009 at Station A (Fig. 1). Chlorides, nitrates, ammonia, soluble reactive phosphorus, and hydrogen sulfide are in mg/L or ppm. Conductivity is in microSiemens/cm and water clarity was measured with a secchi disk in feet. The first value came from the surface, followed by the second value at 10 ft, and the last values near bottom (ca. 20 ft.).

CHLORIDES	NITRATES	AMMONIA	SOLUBLE REACTIVE PHOSPHORUS	HYDROGEN SULFIDE	CONDUCTIVITY (uSiemens)	SECCHI DISK (FT.)
20	<0.001	<0.01	<0.005	ND	189	12.8
20	<0.001	<0.01	<0.005		192	
20	<0.001	<0.01	<0.005		197	

The nutrients in Lake George were also uniform from surface to bottom, like the chlorides and conductivity (measure of the ions in the water – see Methods), and nutrients were very low as well. We can make two conclusions from these data: First, because the parameters are uniform from surface to bottom, it indicates extensive mixing of the water column, probably due to the pervasive boat traffic in the lake, which can destroy stratification (see methods for discussion of this phenomenon) and lead to uniform chemical parameters from top to surface. Second, we can conclude that probably algae and the aquatic plants have taken up most of the nutrients in the lake leading to low values of nutrients in the entire water column. (Usually we like to collect these samples in spring after spring turnover to get a better estimate of their concentrations before algae begin to flourish). In support of this finding was that hydrogen sulfide was not present on the bottom. Hydrogen sulfide is only produced during times of stratification when there is no dissolved oxygen on the bottom of the lake. This too is a good sign. In addition, another positive feature of this finding is that phosphorus is NOT re generated from the sediments if there is oxygen on the bottom, reducing the amount present in the lake from re generation from the sediments, which is then re distributed in the fall overturn for use by plants. A similar event occurs during winter if the bottom waters go anoxic (no dissolved oxygen).

Lastly, the secchi disk reading was 12.8 feet, which is not a great reading, nor is it a problem reading. It does indicate that either turbidity from boat traffic was high or that there was an algal bloom ongoing when we sampled.

Dissolved oxygen

In order to determine how the fish habitat is affected during summer by stratification and the degree of formation of low dissolved oxygen on the bottom (which has nutrient regeneration implications – see above and Methods), we performed a dissolved oxygen/temperature profile with a YSI dissolved oxygen meter with a 100-ft cord in Lake George on 29 August 2008 and on 11 June 2009 when the nets were deployed. On 11 June there was not much stratification, although dissolved oxygen was low on the bottom of the lake (2 mg/L) (Table 2, Fig. 2). This was not severe enough to re generate phosphorus, but will prevent fish from foraging in that area for very long. During August, we found as expected warmer waters and reduced oxygen on the bottom (4.6 mg/L at station A and zero at station B- Table 2, Fig. 3, 4). It appears that during mid summer the conditions on the bottom in some places can reach zero dissolved oxygen (dead zone), which will result in regeneration of nutrients from the bottom sediment and will prevent fish from foraging in that location.

These data are also critical in evaluating the habitat suitability for cool-water fishes, such as northern pike and walleye (should anyone be interested in stocking these fish). For example, walleyes require cold and well oxygenated water. The summer stratification period represents a bottleneck for this species, since as can be seen from the data below, water temperatures become very high in summer and the only place where there is cold water is in the hypolimnion (bottom strata of water), where often we see dissolved oxygen depletions. In the case of Lake George, any walleyes that would be stocked would be severely stressed by the high water temperatures and the lowest water temperatures available have no or low dissolved oxygen present. Some fish might survive, but most would probably die or be severely stressed by the temperature-dissolved oxygen relationships observed in Lake George.

Table 2. Dissolved oxygen (mg/L) and water temperature (degrees C) profile for Lake George, 11 June and 29 August 2009.

LAKE GEORGE 11 JUN 09 STATION A

DEPTH (FT.)	**TEMP(C)**	**DO (MG/L)**
0	18.6	9.8
3	18.6	10.1
7	18.6	10.1
10	18.4	9.6
13	18.2	9.2
16	18	8.4
20	18	4.2
22	17.8	2

LAKE GEORGE 29 AUG 08 STATION A

DEPTH (FT.)	**TEMP(C)**	**DO (MG/L)**
0	26	8.5
3	25.6	8.5
7	25.1	8.5
10	24.8	8.5
13	24.3	8.4
16	24	8.8
20	23.7	4.6

LAKE GEORGE 29 AUG 08 STATION B

DEPTH (FT.)	**TEMP(C)**	**DO (MG/L)**
0	25.6	8.3
3	25.1	8.3
7	25	8.3
10	24.3	8.4
13	23.9	8.3
16	23.6	7.2
20	23.2	4.6
23	23	0

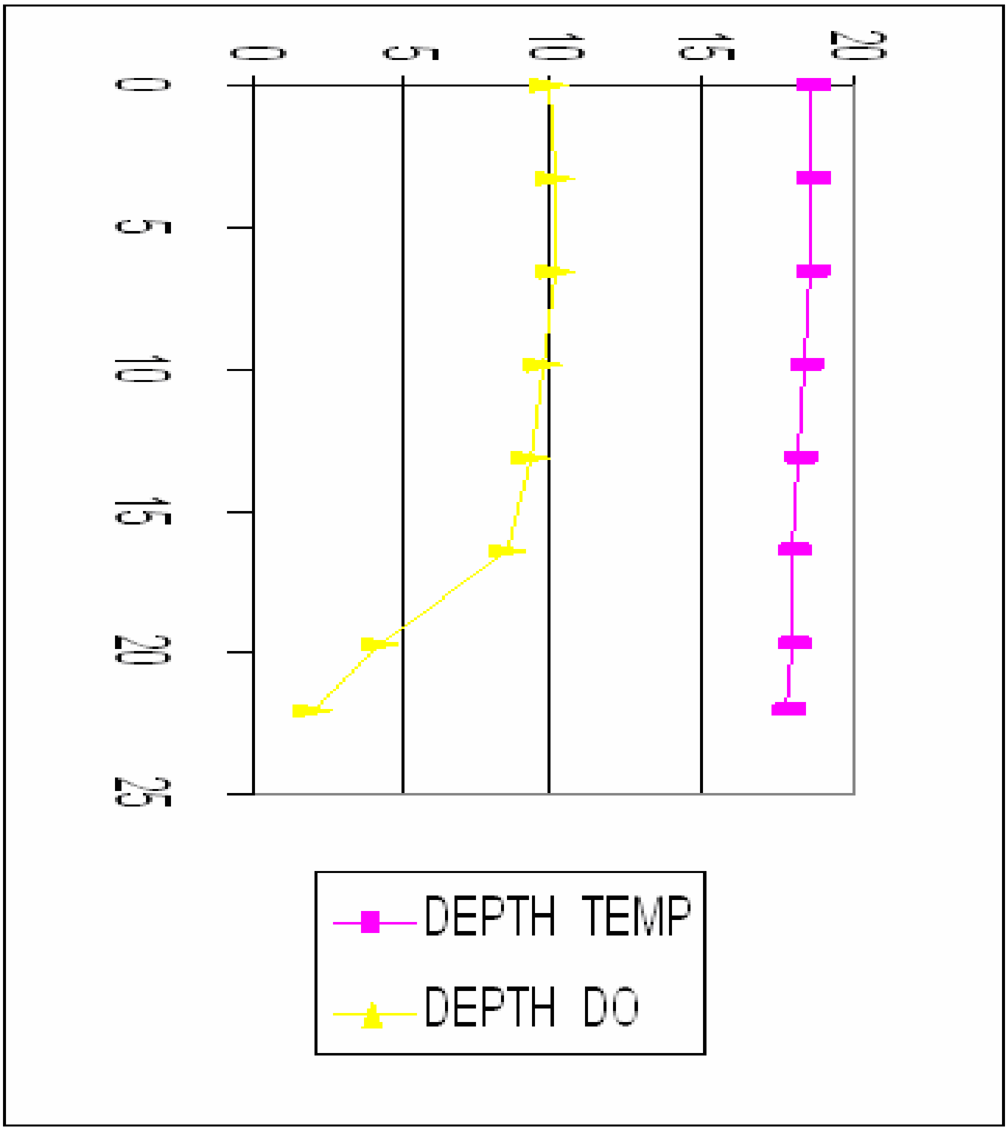


Figure 2. Graph of dissolved oxygen (DO - triangle) and water temperature (TEMP - squares) for Lake George, 11 June 2009. The Y axis (vertical axis) is depth in feet.

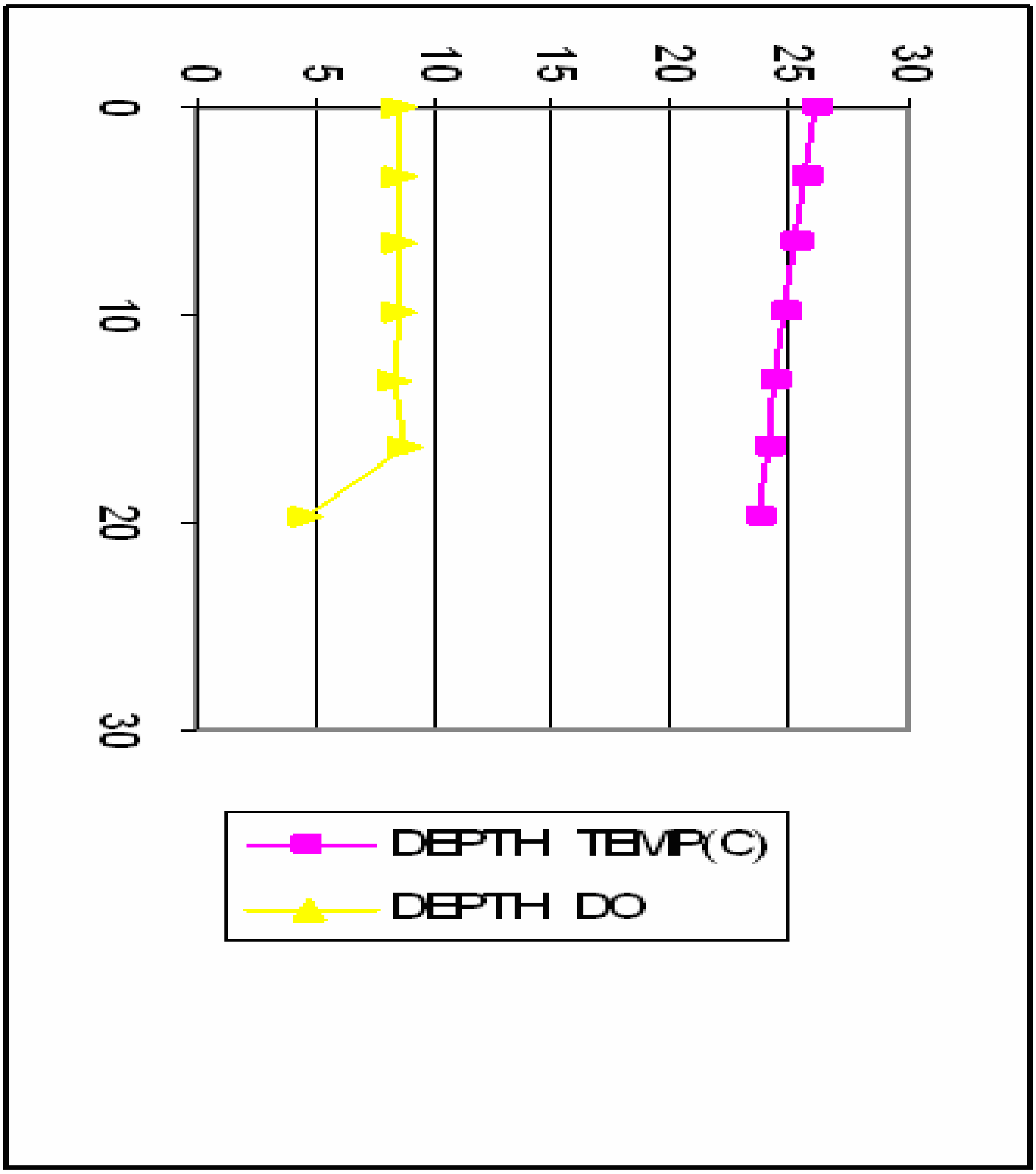


Figure 3. Graph of dissolved oxygen (triangle) and water temperature (squares) for Lake George, 29 August 2009 at station A.

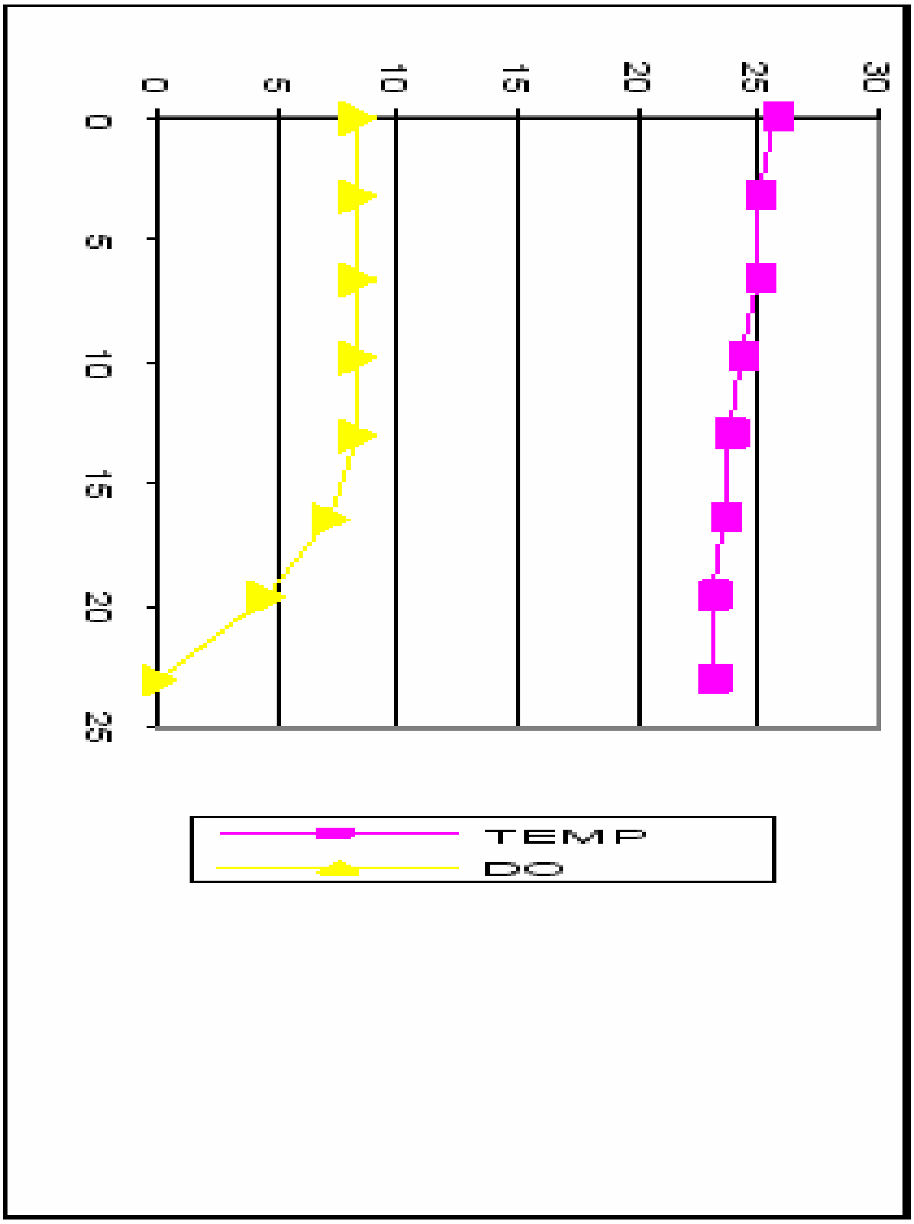


Figure 4. Graph of dissolved oxygen (triangle) and water temperature (squares) for Lake George, 29 August 2009 at station B. The Y axis (vertical axis) is depth in feet.

Fish

<u>Species composition:</u>

We used three different gear types (trap nets- two kinds, gill nets, and seines) to collect fishes from Lake George on 11 Jun 2009. The small trap net was deployed on a point in the middle of the lake in a small embayment on the SW corner at 1930 to 0820. The large trap net was set off the south shore line at 1950 to 0840, and the experimental gill net was set in the northern part of the lake north of the deep hole in about 12 ft of water from 2010 to 0900. This was near the spot were the dissolved oxygen profile was measured. We also seined with a 50-ft bag seine around 2200 on the north shore on the SE end of the lake.

We collected 10 species of fishes (Table 3, Picture 3) in these gear and there was one species collected by MDNR in 1993, the black bullhead (APPENDIX 2), that we did not collect. In addition, the map (Fig. 1) lists an additional seven species (golden shiner, emerald shiner, bluntnose minnow, white sucker, johnny darter and Iowa dater). This would put the total number of species collected by all entities at 18. The large trap net collected seven pumpkinseed, one largemouth bass, three bluegill, while the gill net collected five northern pike, three yellow perch, 1 black crappie, and bluegills. In the seine, we captured yellow bullheads, bluegill, largemouth bass, pumpkinseed, rock bass, and blackchin shiners. The small trap net contained rock bass, pumpkinseeds, and bluegills. Obviously with additional effort we could probably catch additional species, assuming they are still present in the lake. This species complex is indicative of a warm-water fish community and is fairly typical of eutrophic lakes across Michigan.

Table 3. Summary of data on fishes captured in Lake George, 11-12 June 2009. Shown is the gear type used to catch each fish (S = seine, G = experimental gill net, and T = trap net, a small one and a large one); species (BC = BLACK CRAPPIE, BG = BLUEGILL, NP = NORTHERN PIKE, LB = LARGEMOUTH BASS, BN = BROWN BULLHEAD, PS = PUMPKINSEED, GN = GREEN SUNFISH, HY = HYBRID SUNFISH, YP = YELLOW PERCH, BS = BLACKCHIN SHINER, AND RB = ROCK BASS); length (in inches); weight (in ounces); sex (M = male, F = female, II = immature, and the number after M and F refers to development of the gonads, from 1 = poorly developed, 2 = moderately developed, 3 = ripe, 4 = ripe running, and 4 = spent); age of fish in years; and diet (MT = empty stomach, XX = unknown fish) .

GEAR	SPECIES	LENGTH (INCH)	WEIGHT (OZ)	SEX	AGE	DIET
S	BS	2.1				
S	BS	2				
G	BC	5.5	0.9	II	2-3	CHIRONOMIDS
T	BG	4.6	0.6	F3	2--3	ZOOPLANKTON

T	BG	4.5		0.7	II	3	CHIRONOMIDS, SNAILS
T	BG	3		0.2	II	2	ZOOPLANKTON
T	BG	2.9		0.2	II	1--2	ZOOPLANKTON
T	BG	2.7		0.2	II	1	ZOOPLANKTON
G	BG	2.6		0.1	M1	1+	INSECTS
G	BG	1.6		0.03	II	0	
S	BG	1.6		0.02		0	
S	BG	1.9		0.02		0	
S	GN	1.9		0.1	II	0--1	INSECTS
S	GN	1.8		0.03	**II**		NO SCALES
S	HY	5.7		1.5			NO SCALES
T	LB	7		1.9	F1	2--3	5 DRAGONFLIES
S	LB	8.7		3.9	M1	3	2 BG(1.7, 2.4 IN)
S	LB	6.9		2.2	F1	1	BG 1.2 IN
S	LB	6.7		1.8	CC	3	MT
S	LB	6.8		2.0	CC	3--4	BG 2.2 IN
G	NP	20.7		25.5	M1	5--6	XX FISH BG?
G	NP	16.5		12.2	F1	4--5	MT
G	NP	16.6		13.4	M1	4--5	BG 3.5 IN
G	NP	15.5		8.9	F1	2	MT
G	NP	20	ND			4--5	
S	NP	14.5	ND			3	
S	NP	16.5	ND			2--3	
T	PS	6.8		3.3	F3	6	EARTH WORMS
T	PS	6.7		3.4	F3	5--6	SNAILS
T	PS	6.7		3.4	M1	5	SNAILS
T	PS	6.3		2.1	F1	4--5	SNAILS, CLAMS
T	PS	5.5		1.6	M1	3--4	SNAILS
T	PS	6		2.3	F3	5--6	MT
S	PS	4.7		1.1	M1	3--4	SNAILS
T	PS	5.3		1.5	F3	4	MT
S	PS	5.3		2.2	F3	4	MT
S	PS	4.4		0.9	F3	3	MT
T	PS	2.6		0.2	II	1	MT
S	PS	6.6		3.1	M3	3--4	MT
S	PS	6.3		2.8	M3	3--4	ALGAE,SNAILS
S	PS	6.3		2.6	M3	3--4	SNAILS
S	PS	5.6		2.0	M2	3+	SNAILS, INSECTS
T	RB	8		5.3	F3	6	CRAYFISH
S	RB	5.7		1.9	F3	3--4	MT
S	RB	7.6		5.1	M2	5--6	CRAYFISH
S	RB	7		3.7	M2	5	MT
S	RB	6.6		3.2	M2	5	MT
S	RB	3.6		0.5	II	1--2	DRAGONFLIES
S	RB	2.2		0.1	F1	0	INSECTS
S	RB	2.1		0.1	F1	0	DRAGONFLIES
S	YB	2	ND				
G	YP	11.8		9.6	F5	7--8	MT
G	YP	6.8		1.7	F1	3	MT
G	YP	6.6		1.9	F1	3	MT

S	YP	4.5	0.4	F1	1	MT
S	YP	4.5	0.4	F1	1	MT

Picture 3. Some of the fishes (northern pike, bluegill, pumpkinseed, and yellow perch) collected during studies on Lake George and Shingle Lake, 11 June 2009.

<u>Diet:</u>

We examined the diets of fishes in case some would be stunted or growing fast so that we might be able to determine if growth changes were related to diet. The black crappie we collected was eating chironomids (a common insect with an aquatic larval form in the fly (Diptera) family) (Table 3). Bluegills were eating typical food: zooplankton, insects (chironomids), and some were eating snails. Largemouth bass were consuming bluegills mostly and some dragonflies were eaten by the 7-in long fish. The northern pike prefer yellow perch and that is probably one reason why yellow perch appear to be in low abundance in the lake. The pike we collected were eating exclusively bluegills, while some had empty stomachs. The pumpkinseed sunfish we collected were eating large numbers of snails, which is typical of this species. In some cases, this species is stocked in lake with extensive swimmers itch problems, since the snails are intermediate hosts, and consumption of snails reduces the frequency of the infestations. This species was also eating some insects and apparently one was feeding on earth worms someone used for bait. Rock bass juveniles were eating insects, including dragonflies, while the larger individuals were eating crayfish, their preferred food item. All the yellow perch we collected had empty stomachs. These diet data are typical of a food web in a warm water fish community, with the smaller fishes feeding on aquatic insects and zooplankton, while the top predators are feeding on the most abundant prey items, in this case bluegills. We also collected blackchin shiners, which were fairly common in the seine hauls we conducted.

<u>Age:</u>

Age data are summarized for the seven Lake George fish species for which enough data were collected (Table 4, Figs. 5-9). Bluegill growth rates were slightly below state averages (Fig. 5), which is what MDNR reports indicated was true in Lake George during 1993 (APPENDIX 1). There certainly is fish predation on bluegills, as both the northern pike and the largemouth bass were eating bluegills, so there seems to be adequate predation pressure on them.

Table 4. Age data for fishes collected in Lake George, 11-12 June 2009. Also given is the total number of fish aged for each species. Under Michigan are the mean lengths for average fish of a given age in the state of Michigan (Latta 1953), while under Lk George are the mean lengths of aged fish collected during this study. Also see the Figures (5-10) where these data are shown in graphical form.

AGE GROUP		TOTAL LENGTH (IN)		SAMPLE SIZE
BLUEGILL		MICHIGAN	LK GEORGE	
	0	2.1	1.6	7
	1	2.9	2.7	
	2	4.3	4.0	
	3	5.5		
	4	6.5		
	5	7.3		
	6	7.8		
	7	8		
	8	8.5		
	9	8.5		
	10	9.2		
PUMPKINSEED		MICHIGAN	LK GEORGE	
	0	2		15
	1	2.9	2.6	
	2	4.1		
	3	4.9	4.6	
	4	5.7	5.8	
	5	6.2	6.2	

	6	6.8	6.7	
	7	7.3		
	8	7.8		
LARGEMOUTH BASS		MICHIGAN	LK GEORGE	
	0	3.3		5
	1	6.1	6.9	
	2	8.7	7.9	
	3	10	6.8	
	4	12.1		
	5	13.7		
	6	15.1		
	7	16.1		
	8	17.7		
	9	17.9		
BLACK CRAPPIE		MICHIGAN	LK GEORGE	SAMPLE SIZE
	0	ND		1
	1	ND		
	2	5.9	5.5	
	3	8		
	4	9		
	5	9.9		
	6	10.7		
	7	11.3		
	8	11.6		
NORTHERN PIKE		MICHIGAN	LK GEORGE	SAMPLE SIZE
	0	7.9		5
	1	15.5		
	2	19.4	15.5	
	3	22.2		
	4	23.9	17.7	
	5	25.4	20.7	
	6	27.7		
	7	32.5		
	8	37.1		
	9	34.8		
	10	44.4		
ROCK BASS		MICHIGAN	LK GEORGE	SAMPLE SIZE
	0	2.4	2.2	8
	1	3		
	2	4.3	3.6	
	3	5.4		
	4	6.4	5.7	
	5	7.2	6.8	

	6	8.1	8.3	
	7	8.8		
	8	9.4		
YELLOW PERCH		MICHIGAN	LK GEORGE	SAMPLE SIZE
	0	3.3		5
	1	4	4.5	
	2	5.7		
	3	6.8	6.7	
	4	7.8		
	5	8.7		
	6	9.7		
	7	10.5		
	8	11.3	11.8	
	9	11.7		

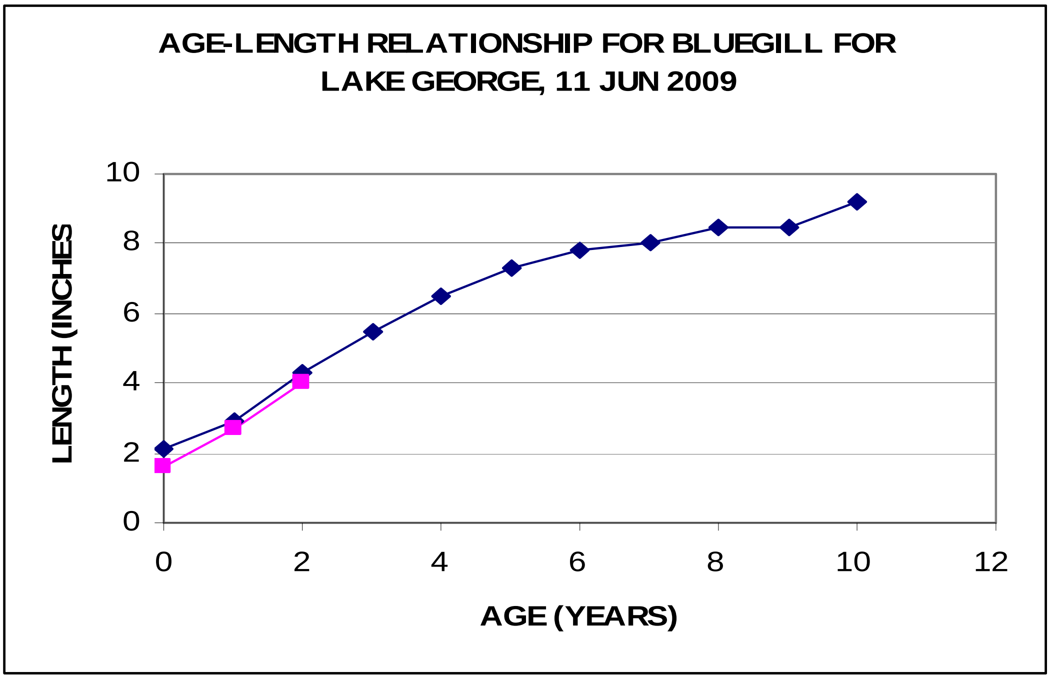


Figure 5. Age-length relationship for Lake George bluegills collected 11-12 June 2009. The squares are Lake George fish; the diamonds are State of Michigan average lengths for various fishes.

Pumpkinseeds were growing at the state averages (Fig. 6). We did not capture very many large fish, but those up to 2 years old were growing well. They seemed to be common in the seine hauls we made.

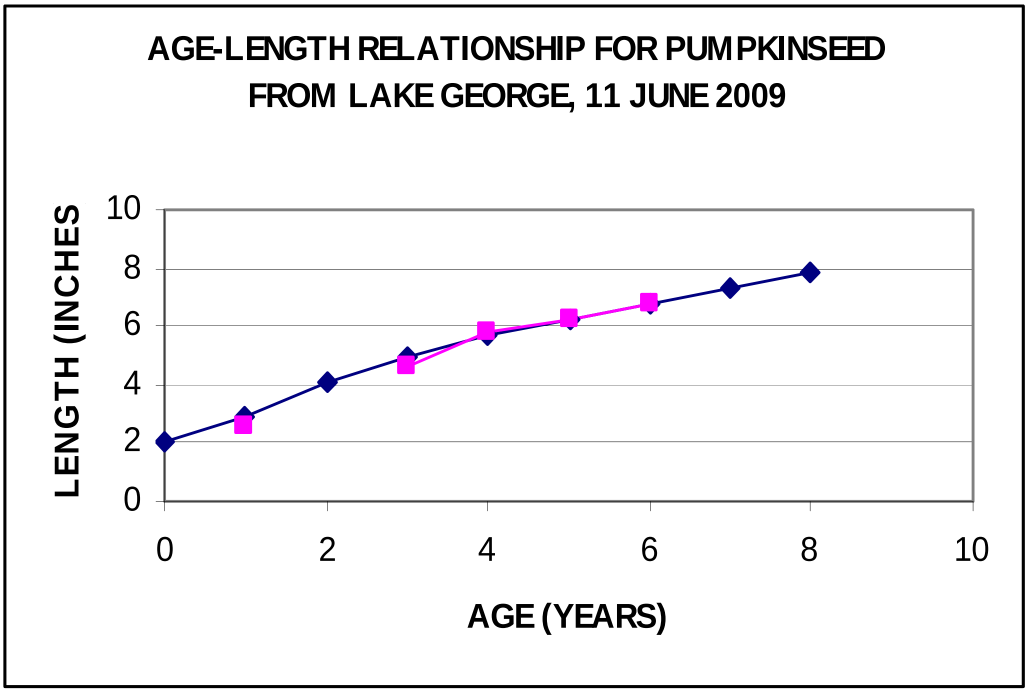


Figure 6. Age-length relationship for Lake George pumpkinseeds collected 11-12 June 2009. The squares are Lake George fish; the diamonds are State of Michigan average lengths for various fishes.

Largemouth bass are difficult to catch with the gear we used and we were fortunate to catch enough to evaluate their growth, at least at small sizes. They were growing at state averages through age 2, but declined at age 3 (Table 4, Fig. 9). Since our sample sizes are small (N = 5 – Table 4) and limited to smaller fishes, our conclusions are also limited. MDNR collected seven fish from 15-17 inches long (APPENDIX 2), so these fish of larger sizes are certainly present in the lake. Largemouth bass do well in the presence of sunfish and there are three species plus some hybrids (green sunfish, bluegills, and pumpkinseed) common in the lake. They are an important top predator along with northern pike and critical to maintaining a good balance between predators and prey in the lake. We would encourage catch and release fishing for the top predators largemouth bass and northern pike whenever possible to ensure good control of the panfish populations in Lake George.

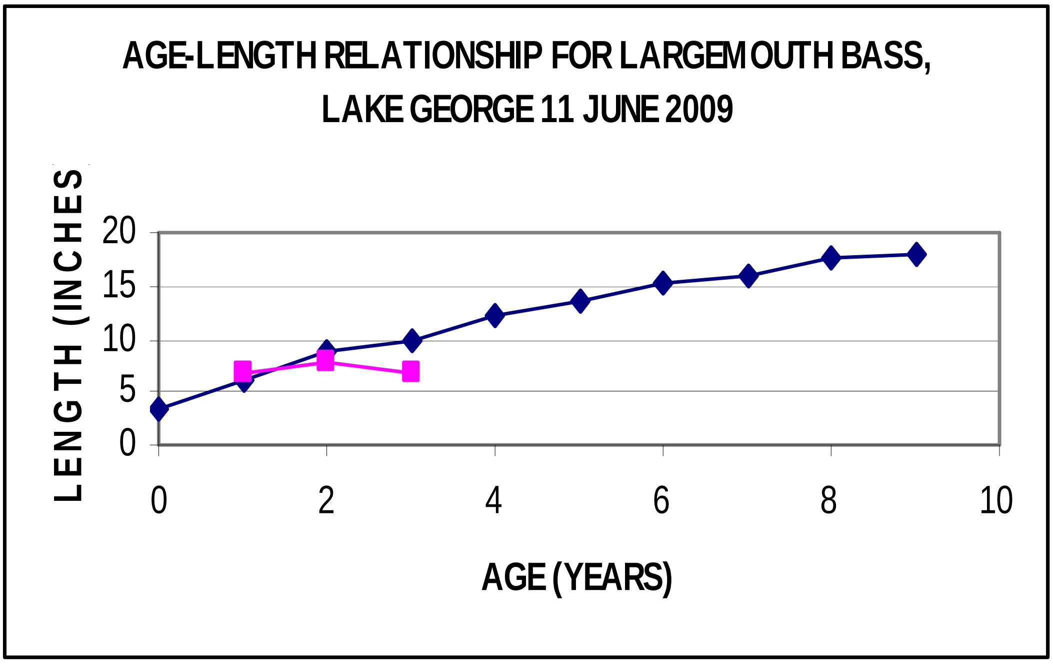


Figure 7. Age-length relationship for Lake George largemouth bass collected 11-12 June 2009. The squares are Lake George fish; the diamonds are State of Michigan average lengths for various fishes.

Northern pike were fairly abundant in our gill net collections (N = 5 – Table 4). They do appear to be growing below state averages (Fig. 8), but northern pike scales are very difficult to read, so there may be an error in reading. The reduced growth could be due to the warmer water temperatures in these lakes which can reduce growth. Northern pike prefer soft-rayed fishes and it has been shown they will decimate yellow perch as well from lakes. All the fish we found in their stomachs however, were bluegills.

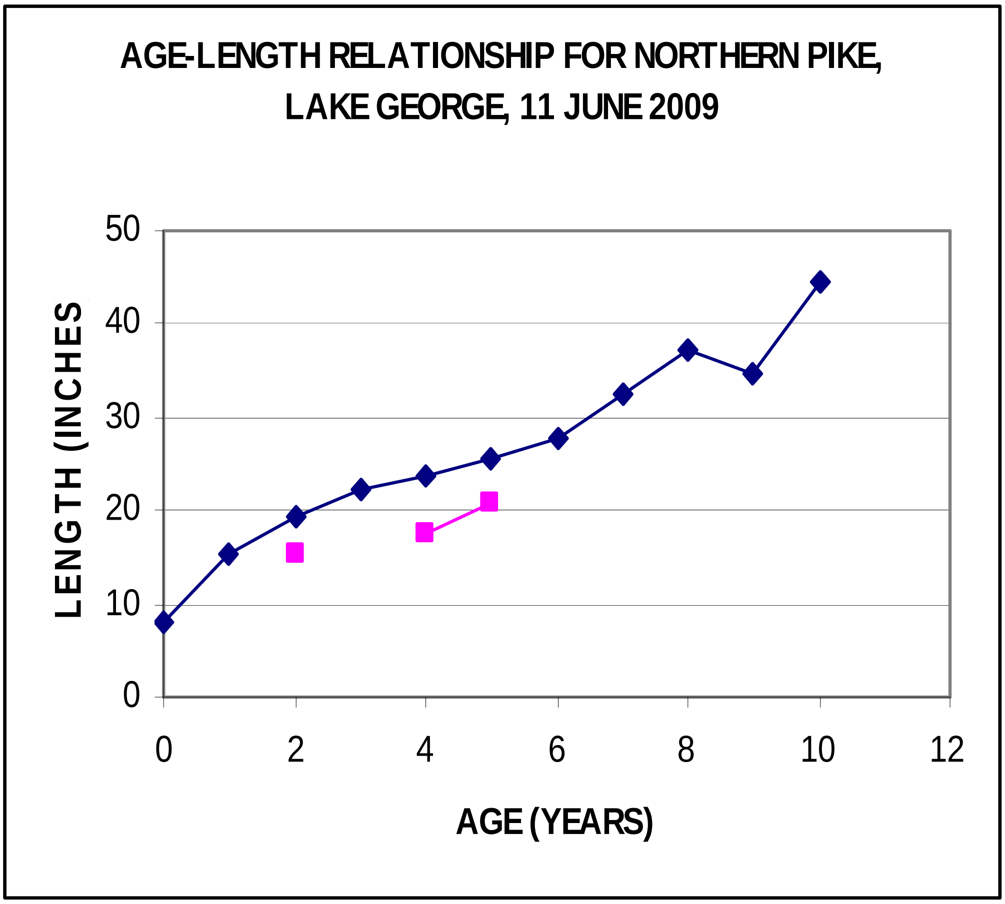


Figure 8. Age-length relationship for Lake George northern pike collected 11-12 June 2009. The squares are Lake George fish; the diamonds are State of Michigan average lengths for various fishes.

Rock bass were collected in a large range of sizes (Fig. 9, Table 4) and appear to be growing at state averages for this fish. Rock bass are not always present in a lake, so the addition of another species with a different niche is always good for biodiversity, providing another sport fish for recreation, and prey for the top predators. In addition, they specialize in eating crayfish (see below), a sometimes underutilized prey in lakes. The reverse side of this however, is that they probably compete with largemouth bass, which also prefers crayfish. Rock bass are also important fish predators when they get large enough, so they too serve as a control on the forage fish of the lake.

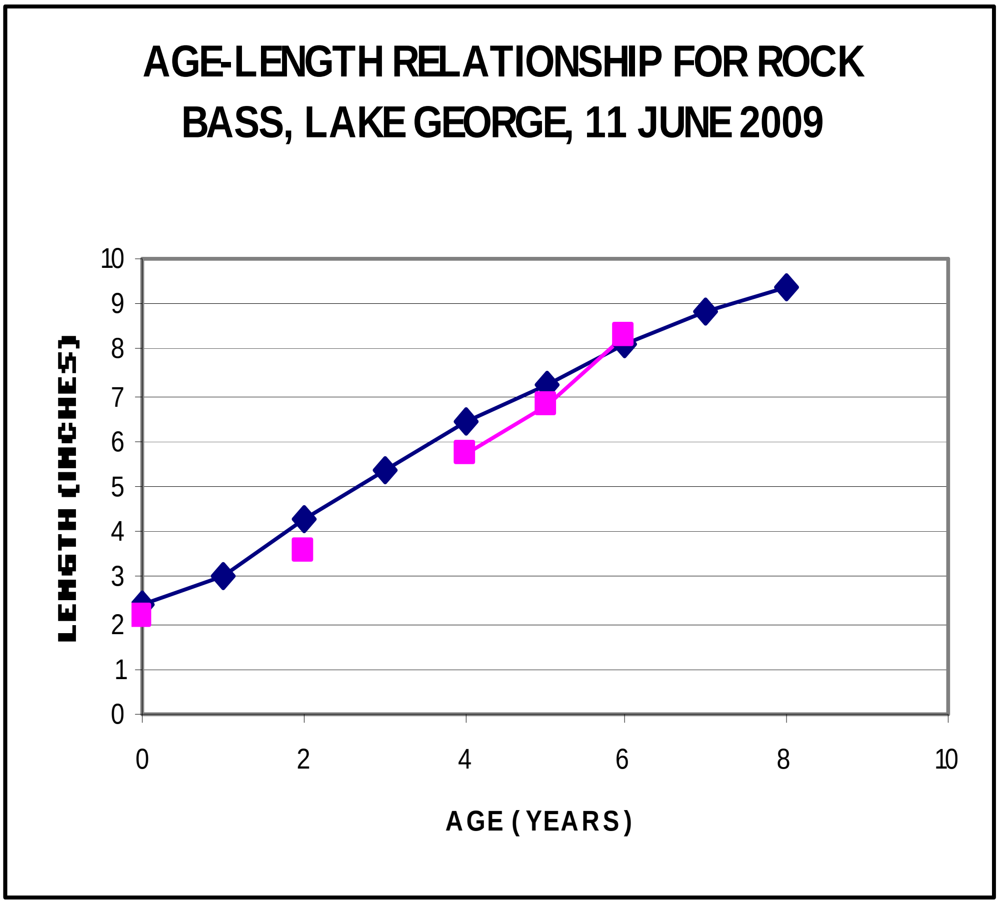


Figure 9. Age-length relationship for Lake George rock bass collected 11-12 June 2009. The squares are Lake George fish; the diamonds are State of Michigan average lengths for various fishes.

We collected a few yellow perch in Lake George (Table 4) and those we aged were all growing at state averages (Fig. 10). Whenever we see few yellow perch in a lake, it is indicative of severe predation by northern pike, which are fairly abundant in the lake. Despite no yellow perch in the stomachs of the northern pike we collected (they were eating bluegills), the literature is replete with reports of severely depleted yellow perch stocks wherever northern pike are abundant. It follows that any attempts to stock this species would only result in the feeding of the resident northern pike population.

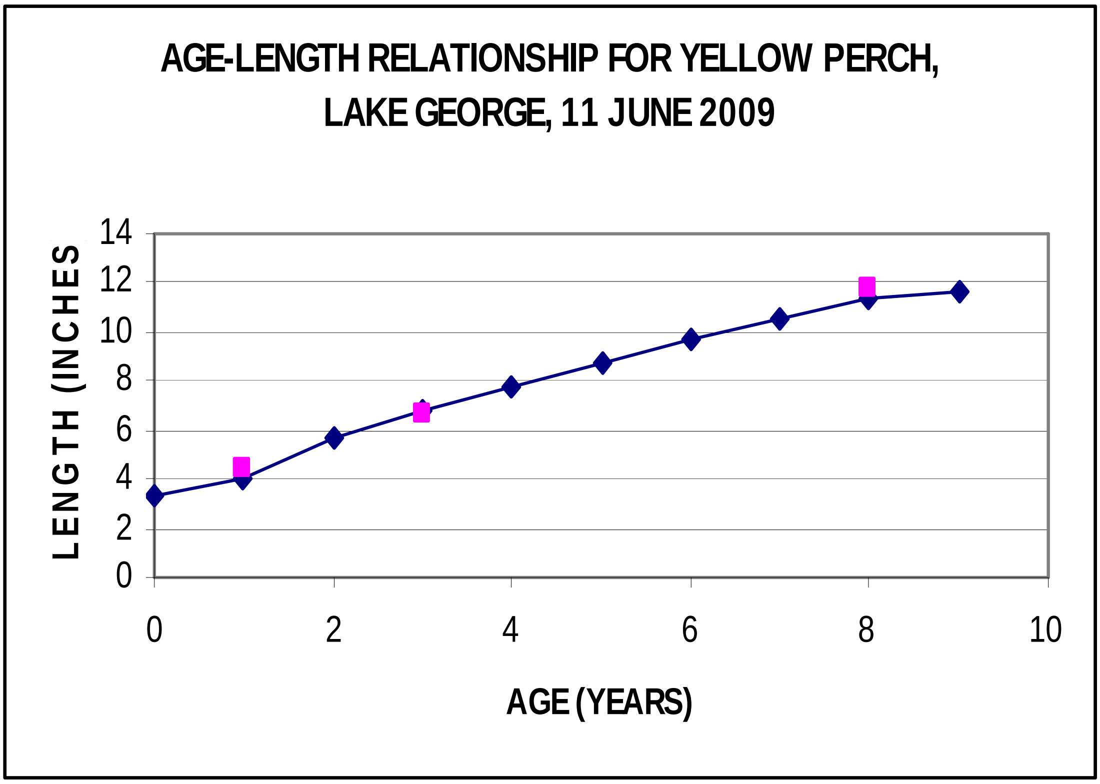


Figure 10. Age-length relationship for Lake George yellow perch collected 11-12 June 2009. The squares are Lake George fish; the diamonds are State of Michigan average lengths for various fishes.

DISCUSSION

Lake George is a long lake (134 acres) but is shallow, with maximum depths in four basins of around 25 ft. Chlorides were very low (20 ppm), which is somewhat lower by 10 ppm from what exists in Shingle Lake. Low chlorides auger well for Lake George, since it suggests that surface and ground water runoff inputs of chlorides (and by association other contaminants and nutrients) are minimal so far in the lake.

The dissolved oxygen levels in Lake George were similar from top to bottom, with a slight depression at the bottom where oxygen was around 4 ppm. This is apparently due to the shallowness of the lake which allows it to mix easily and probably all the boat traffic which disrupts stratification. As a result, the chemical data show that there is no accumulation of toxic substances on the bottom, at least during the 29 August 09 trip, a time of maximum stratification effects, which is a positive feature for the chemical environment. However, because the water gets so mixed, there is no cold refugium on the bottom for cool water fishes, such as northern pike and walleyes, which survive in the water temperatures we measured, but not very well and growth would certainly be reduced substantially for a species such as walleye, which requires cold water for optimal growth. As we noted earlier, stocked walleyes would get squeezed in the water column between the bottom where the dissolved oxygen is depleted but where there is cold enough water, and surface waters, which have enough dissolved oxygen but are too hot for survival and growth of this species. Northern pike are apparently growing slowly which could be errors in measuring ages or that the water temperature was warm enough to slow growth in the lake.

The fish population in Lake George is, like Shingle Lake, a typical warm-water fish community dominated by northern pike and largemouth bass. We collected 10 species in the lake including: black crappie, yellow bullheads, yellow perch, bluegill, pumpkinseed, rock bass, green sunfish, and blackchin shiners. Seven other species were recorded in the lake from past MDNR studies, showing Lake George has a diverse fish community. The fish populations seemed balanced, there was a good mixture of vegetation and a nice cove where spawning by largemouth bass and probably northern pike occurs. We did not catch as many northern pike in Lake George as we did in Shingle, which is probably due to the lack of a good spawning stream and the lack of depth, which leads to no cool water refuges for the northern pike during the summer. Growth was probably reduced because of the lack of a cold water refuge during the warm months of the summer. All species were growing at or slightly below state averages, except northern pike (which are difficult to age) and largemouth bass (age-3 fish were below average). The yellow perch population appeared to be low, probably because of predation by northern pike in the lake.

In considering some of the options for managing Lake George, there are several issues that need to be considered. The water quality of the lake appears to be fairly good, with no blatant pollution problems identified with the limited sampling we did. However, if the option for putting in a sewerage system arises, it should be supported to endure the continuing high water quality of the lake as more seasonal lake side dwellers become year-round residents and put more pressure on the resources, degradation of the lake can occur. The dissolved oxygen and warm temperatures which are well mixed, probably due to the recreational activity on the lake, limit fish growth for cool water species, such as northern pike, but on the other hand it limits the re generation of nutrients, especially phosphorus from the bottom waters. The aquatic plant growth from what we observed causally during sampling is fairly dense, with a diversity of species, including Eurasian milfoil. The milfoil has not apparently attained the dense abundances observed on Shingle Lake to date. We also did not hear of any severe blue-green algal blooms and to date there does not seem to be any zebra or quagga mussels introduced to the lake, which should be a priority to address. This can be done through the newsletter if you have one and signage at the public ramps to prevent transport of veligers from other infected waters, especially the Great Lakes to Lake George. Along these same lines, bait can be infected with viral hemorrhagic septicemia (VHS), an exotic virus that has killed many fishes, including muskies, in lakes like Lake St. Clair. There is a diverse warm-water fish community in Lake George. Some of the top predators, northern pike and largemouth bass, are not growing as fast as the state average, but samples sizes were small, so strong conclusions cannot be reached from the data we collected. It does suggest that catch and release fishing should be encouraged, first to promote balanced fish populations in the lake, and second, most of the large predators in most of Michigan's inland lake are polluted with mercury and should not be eaten in large numbers anyway (consult the MDNR fishing guide for recommendations). People should harvest and consume the panfish, rock bass, and yellow perch instead. Lastly, it should be obvious that stocking any fish into a balanced fish community is usually a waste of money and especially a species that is not adapted to a warm water lake, such as walleye. We would expect poor growth and survival of this species based on the dissolved oxygen - water temperature relationships we measured. In addition, there is a possibility of introducing VHS along with any fish stocked.

MANAGEMENT RECOMMENDATIONS

There are a few management recommendations we can make based on the information we gathered from this study. They include:

1.) Be vigilant about any type of development, habitat modification, or changes in the watershed that may increase the amount of nutrient and contaminant runoff into Lake George.
2.) Hook into sewers if the option presents itself. Many times septic tank effluent runoff into the ground water and then into a lake is the major source of nutrients that enter a lake.
3.) Monitor the aquatic plants in the lake, especially Eurasian milfoil, as this exotic plant can dominant native species, increase the habitat for young panfish, which can result in stunting, inhibit use of the lake since this plant grows all the way to the surface, and it can destroy spawning substrate by covering up optimal sites.
4.) Initiate a program to prevent entry of zebra and quagga mussels into the lake by informing residents that bring in boats, scuba gear, and/or bait from other lakes that may be contaminated with veligers.
5.) Consider banning bait (minnows, crayfish) from other lakes as they might contain VHS.
6.) No stocking of fishes are recommended at this time as the lake seems to have a balanced fish population. If at some time, it appears that northern pike are not reproducing adequately, this species, since it has limited habitat for spawning, could be considered as a candidate for stocking.
7.) Foster catch and release fishing for top predators, largemouth bass and northern pike to maintain pressure on the prey fish populations and because they are probably contaminated with mercury anyway.

SHINGLE LAKE

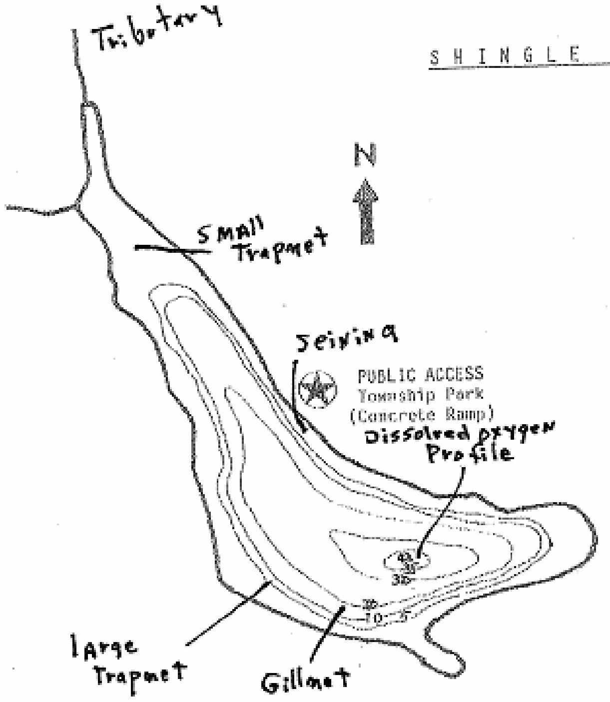
INTRODUCTION

Shingle Lake is a 33-acre lake with a single basin and a listed depth of around 42 ft – we were only able to find a 33-ft depth where we sampled. It has a creek running into it on the NW end, which undoubtedly serves as excellent spawning habitat for northern pike. It has extensive shallow areas with abundant aquatic macrophytes in the area of the tributary and there are large beds of plants (unfortunately most are Eurasian milfoil, an exotic plant) in other areas of the lake, especially around the 10-ft contour. There is a public access on the lake on the north side and it has homes ringing the lake, which are on septic tanks. It is rated as a mildly eutrophic lake (moderate amounts of nutrients) and sediments are marl (calcium carbonate deposits) and organic matter. The watershed area is 282 acres, which is fairly small. There has been an overabundance of exotic plants (Eurasian milfoil, *Potomogeton crispus*) in the lake in the past, which caused the use of herbicides to control these non-indigenous species. There are large beds of Eurasian milfoil and curly-leaf pondweed present. The fish community is a typical eutrophic, warm-water complex typified by: top predators northern pike and largemouth bass, sunfish species bluegill, pumpkinseed, rock bass, black crappie, and there are yellow perch. MDNR found that in 1979 bluegill growth was below state averages, and they rotenoned the lake (killed fish) to reduce numbers, which improved growth for about 6 years, then the bluegills returned to poor growth thereafter. The size structure for bluegill and pumpkinseeds was good. MDNR estimated there were 44 dwellings along the 1.5 mi of shoreline; this value increased to 71 in 1998 (from 30 to 48 per mile), well above the recommended density levels that would harm fish habitat. They recommended no more development be allowed on the lake to protect terrestrial and aquatic habitat. Dissolved oxygen measurements in 1954 and 1987 showed that there was a depletion below the thermocline (at 18-20 ft) in the lake, which we also found during 2009.

STUDY AREA

In order to determine how the fish habitat is affected during summer by stratification and the degree of formation of low dissolved oxygen on the bottom, we performed a dissolved oxygen/temperature profile with a YSI dissolved oxygen meter with a 100-ft cord in the lake on 29 August 2008 and on 11 June 2009 when the nets were deployed. Samples were collected at station A (Fig. 5) in about 33 ft of water. In addition, we collected and analyzed three water samples from the deep hole on 29 August 2009 at three depths (surface, mid depth – 15 ft, and bottom – 31 ft) for: soluble reactive phosphorus, nitrate, chlorides, conductivity, and ammonia and we also measured water clarity with a secchi disk. These parameters provide some information on the nutrient status of the lake and the chlorides of historical pollution, either by road salt or septic tank contamination.

We used three different gear types (trap nets- two kinds, gill nets, and seines) to collect fishes from Shingle Lake on 11 June 2009 at various sites on the lakes (see Fig. 5 for location of the sampling stations). The small trap net was deployed on the west end of the lake near the tributary stream in the vegetation from 1615 overnight till 1050 (Picture 2). The large trap net was set off the south shore line overnight from 1630 through 1115, and the experimental gill net was set slightly east of the trap net on the southern part of the lake overnight from 1750 - 1035. We also seined the beach area at the public access on Shingle Lake around 2300; we used a 50-ft bag seine for this haul.



S H I N G L E   L A K E

SHINGLE LAKE - LAKE DATA

Lincoln Township T18N R5W
Sections 7 & 8

Type of Lake .... Natural
River Basin .... Muskegon
Sub-River Basin .... Doc & Tam Creek
Lake Surface Area ...... 33 Acres
Maximum Depth .... 42 Feet
Mean Depth .... 13.7 Feet
Lake Volume .... 452 Acre Feet
Watershed Area .... 282 Acres
Drainage Area .... 315 Acres
Lake to Watershed Ratio . 1 : 8.55
Flushing Rate .... 335 Days
Elevation .... 1,123.8 Feet
Longest Dimension ...... 2,542 Feet
Trophic Status .... Mildly Eutrophic
Bottom Sediments .... Marl, Organic (appr. 45% Mineral and 55% Organic)

Fishing

(best fishing)	(other fishing)
Northern Pike, L/M Bass, S/M Bass, Blue-gill	Perch, P/seed Sunfish, Black Crappie, Rock Bass, Bullhead

Figure 5 . Map of Shingle Lake showing stations A (deep spot) where a dissolved oxygen profile was obtained, sites where the gill nets, trap nets (small and large) and seining occurred, the public access site on the north end, and the tributaries coming in on the west side.

RESULTS

Water quality

We measured water quality parameters during our fish sampling activities and during summer stratification, the time of maximum development of degraded conditions on the bottom of Shingle Lake. We wanted to characterize the overall water quality of the lake and asses conditions for fish habitat, an ecosystem approach to managing the lake. Chlorides, an indicator of historical input of materials (originates from road salting and septic tank leakage) and a chemical that is unchanged by biological or chemical activity were fairly low (ca. 30 mg/L – Table 4) compared to lakes we have seen in lower Michigan. Values over 200 mg/L are common there. Concentrations were 10 mg/L higher in Shingle Lake than in Lake George, indicating somewhat higher inputs to Shingle than to Lake George. This is interesting since Lake George has a much larger watershed than Shingle Lake, yet lower chloride levels. The nutrient data showed some unusual patterns. First, we saw an accumulation of ammonia on the bottom which suggests decomposition of the sediments produced high quantities of this material, but we usually see higher nitrates and phosphorus as well, but we did not observe this. Hydrogen sulfide was zero, suggesting some oxygen was present on the bottom and the dissolved oxygen profiles also suggested, although showing low dissolved oxygen concentrations, that there was some dissolved oxygen left on the bottom. The conductivity measurements (measure of electrical conductivity of the water or the amount of ions present) confirmed that there was stratification, with more ions in the bottom waters than above (Table 4). The secchi disk reading was somewhat better at 15.7 ft than what we measured at Lake George. It indicates a good degree of productivity for the lake.

Table 4. Water quality parameters for Shingle Lake, 29 August 2009. Chlorides, nitrates, ammonia, soluble reactive phosphorus, and hydrogen sulfide are in mg/L or ppm. Conductivity is in microSiemens/cm and water clarity was measured with a secchi disk in feet. The first value came from the surface, followed by the second value at 15 ft, and the last values near bottom (ca. 30 ft.).

CHLORIDES	NITRATES	AMMONIA	SOLUBLE REACTIVE PHOSPHORUS	HYDROGEN SULFIDE	CONDUCTIVITY uSiemens	SECCHI DISK (FT.)
29	<0.001	<0.01	<0.005	0.000	293	15.7
28	<0.001	<0.01	<0.005		290	
30	<0.001	0.224	<0.005		352	

Dissolved oxygen

We measure dissolved oxygen-temperature relationships as these are critical habitat parameters for evaluating the overall health of the ecosystem and the suitability of the aquatic habitat for fishes. The Shingle Lake profile showed the classic pattern of a warm, well oxygenated top layer (epilimnion), a transition zone of quickly decreasing water temperature (thermocline area), and a hypolimnion, which is essentially sealed off from the surface waters because of water density differences (cold water is heavier – see Methods for an explanation of stratification). The amount of dissolved oxygen left on the bottom is indicative of decomposition processes, which can vary from lake to lake. Shingle Lake had full stratification present on 11 June with very low dissolved oxygen below 20 feet (Table 5, Fig. 12). Most fish would be stressed in this area of the lake during stratification in June and this has implications for growth of northern pike which require cool water to grow well and survival of stocked fish which require high dissolved oxygen conditions and low water temperatures, such as walleyes. The August profile was worse (Table 5, Fig. 13), as there was reduced dissolved oxygen below 16 feet in Shingle Lake. This will essentially confine all fishes to that area of the lake above 16 ft. Some fish can make forays into low dissolved oxygen waters, but not for very long. This warm water situation during spring and summer will probably have implications for lowering the growth of northern pike (which we observed) and would severely stress any cold water fish, such as walleye, if it would be stocked in the lake.

Table 5. Dissolved oxygen (mg/L) and water temperature (degrees C) profile for Shingle Lake, 11 June and 29 August 2009 at station A.

SHINGLE LAKE 11 JUNE 2009 STATION A

DEPTH (FT.)	TEMP(C)	DO (MG/L)
0	19	8.7
3	19	8.8
7	18.8	8.8
10	18.4	8.5
13	18.1	8.3
16	17.7	7.8
20	15.4	6.8
23	13.7	2.1
26	12.2	0.5
30	11.4	0.3
33	11	0.2

SHINGLE LAKE 29 AUGUST 2009 STATION A

DEPTH (FT.)	TEMP(C)	STA A DO (MG/L)
0	25.2	8.8

3	25	7.7
7	24.6	8.2
10	24	8.3
13	23.6	7.6
16	22.9	5.4
20	19.4	0.9
23	16.8	0.6
26	15	0.5
30	13.8	0.4
33	13	0.4

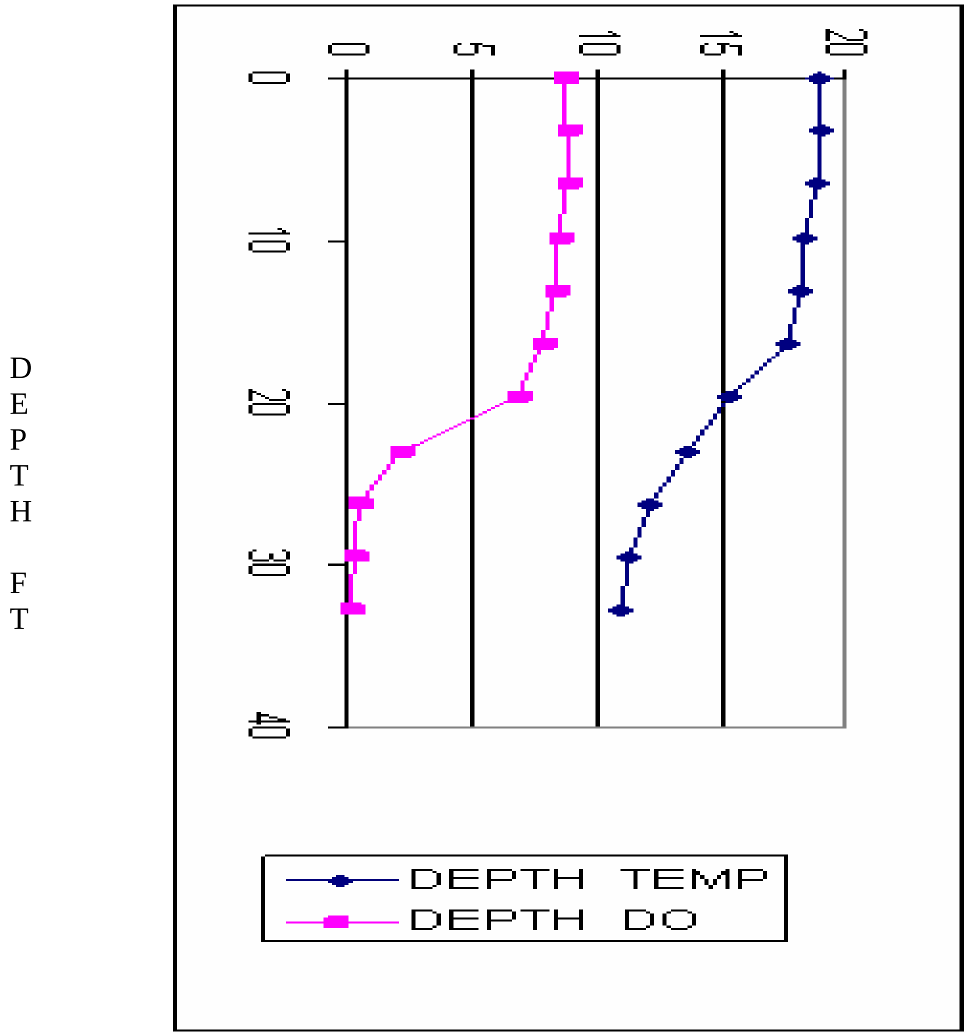


Figure 12. Graph of dissolved oxygen (triangle) and water temperature (squares) for Shingle Lake, 11 June 2009.

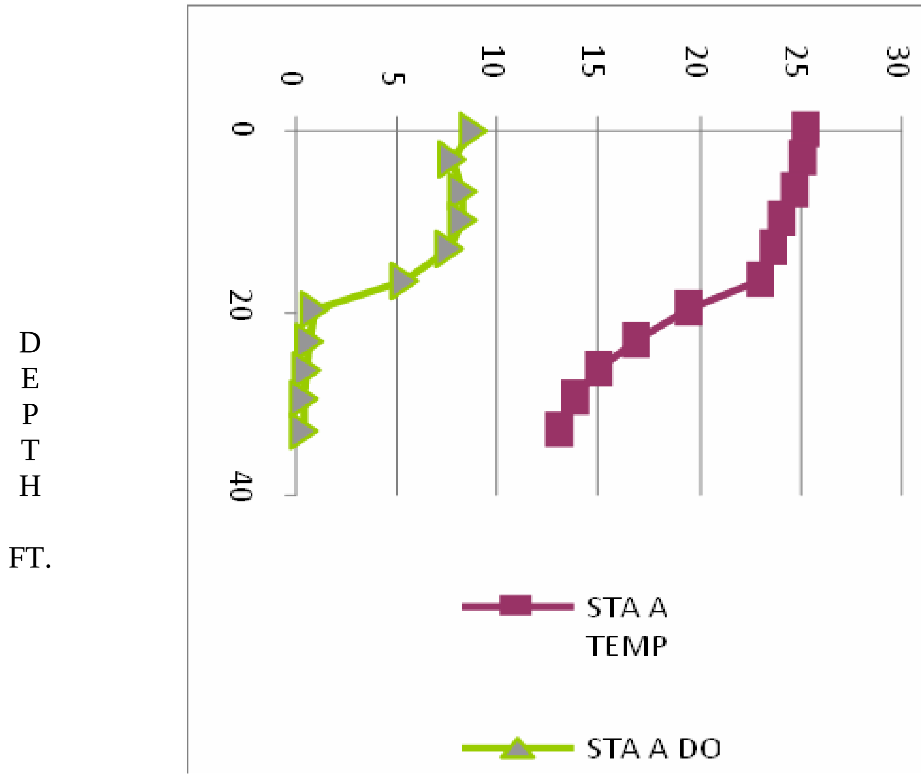


Figure 13. Graph of dissolved oxygen (triangle) and water temperature (squares) for Shingle Lake, 29 August 2009.

Fish

Species composition:

We caught bluegills and pumpkinseeds in the small trap net, and yellow perch, many northern pike, two largemouth bass, black crappie, and brown bullheads in the gill net (Table 6). The seine captured a small northern pike, largemouth bass, yellow perch, pumpkinseed, rock bass, and bluegill. This is a total of 9 species we collected and the map lists smallmouth bass as present, but we do not think they are currently present and if they were recorded in the lake, they must have been stocked in the past. MDNR recorded the presence of one other species, white sucker, during 1993 (APPENDIX 3). This appears to be a well balanced fish community with a diversity of different species.

Table 6. Summary of data on fishes captured in Shingle Lake, 11-12 June 2009. Shown is the gear type used to catch each fish (S = seine, G = experimental gill net, and T = trap net, a small one and a large one); species (BC = BLACK CRAPPIE, BG = BLUEGILL, NP = NORTHERN PIKE, LB = LARGEMOUTH BASS, BN = BROWN BULLHEAD, PS = PUMPKINSEED, GN = GREEN SUNFISH, YP = YELLOW PERCH, AND RB = ROCK BASS); length (in inches); weight (in ounces); sex (M = male, F = female, II = immature, and the number after M and F refers to development of the gonads, from 1 = poorly developed, 2 = moderately developed, 3 = ripe, 4 = ripe running, and 4 = spent); age of fish in years; and diet (MT = empty stomach, XX = unknown fish) .

GEAR	SPECIES	LENGTH (IN)	WEIGHT Oz	SEX	AGE	DIET
G	BC	8.4	3.9	F3	4--5	20 CHIRONOMIDS
S	BG	5.4	1.3	II	4--5	ZOOPLANKTON
S	BG	4.5	0.5	II	1--2	ZOOPLANKTON
S	BG	5.4	1.3	II	4+	ZOOPLANKTON, CHIRONOMIDS
S	BG	4.6	0.6	F3	2	ZOOPLANKTON
S	BG	2.8	0.1	II	0--1	MT
S	BG	4.6	0.7	II	2	ZOOPLANKTON
S	BG	5.9	1.6	F1	4+	MT
S	BG	4.8	0.9	F1	4--5	CHIRONOMIDS, DRAGONFLIES
T	BG	4.5	0.8	M2	2	CHIRONMIDS
T	BG	4.6	0.8	F3	2--3	CHIRONOMIDS AND DRAGONFLIES
S	BG	4.2	0.5	II	1--2	CHIRONOMIDS
S	BG	3.9	0.5	M3	1--2	DRAGONFLIES
S	BG	3.7	0.4	II	1	CHIRONOMIDS
S	BG	2.8	0.2	II	0--1	CHIRONOMIDS
S	BG	2.6	0.1	II	0--1	LARVAL FISH
S	BG	2.2	0.1	II	0	CHIRONOMIDS
S	BG	2.1	0.1	II	0--1--2	MT
S	BG	1.6	0.0	II		
S	BG	1.3	0.0	II		
S	BG	1.2	0.0	II		
G	BN	10.7	10.1	F3		2 CRAYFISH
S	GN	3.9	0.6	F3		DRAGONFLIES
S	GN	2.7	1.9	F2		ZOOPLANKTON
G	LB	14.5	21.8	F5	7	2 CRAYFISH
G	LB	13.5	17.5	F5	4--5	1 CRAYFISH
G	LB	10.5	8.7	M1	4	MT
S	LB	7.7	2.9	F1	2	MT
S	LB	7.7	2.9	F1	2	MT
S	LB	4.4	0.5	II	1	INSECTS
S	LB	8.3	3.8	II	3	XX FISH
S	LB	13	14.7	F2	5	2 CRAYFISH
S	LB	4.6	0.6	F1	1--2	XX FISH
S	LB	4.4	0.5	F1	1	MT
G	NP	26			3--4	
G	NP	24			3--4	RELEASED
S	NP	9			0?	NO SCALES TAKEN, RELEASED YOY

G	NP	14.5				3	
G	NP	16.5			2--3		
G	NP	20					
G	NP	12	5.1	M1		2	BG 2 IN; MANY BLACK GRUBS
G	NP	22			5--6		
G	NP	22			5--6		
T	PS	3.3	0.4	F3		2	MT
S	PS	8	5.9	M2	6--7		SNAILS
S	PS	5.5	1.9	M2		4	MT
S	PS	5.8	2.4	M2	4--5		SNAILS
S	PS	5.8	2.3	M2		5	MT
S	PS	5.9	2.6	F3+	3--4		MT
S	PS	4.6	1.2	F4		4	SNAILS-ABUNDANT
S	PS	4.7	1.3	F3	4+		SNAILS
S	PS	4	0.8	F3		2	SNAILS
S	PS	3.4	0.4	M1		2	SNAILS
S	PS	3	0.3	F3	1+		CHIRONOMIDS
S	RB	1.5	0.02	II		0	MT
S	RB	5.7	1.9	M1		4	DRAGONFLIES
S	RB	5.7	2.0	M2	5--6		2 DRAGONFLIES
S	RB	5	1.4	F3		4	1 DRAGONFLY;RB 1.6 IN
S	RB	4.8	1.2	F3	3--4		MT
S	RB	4.8	1.2	F3		3	MT
S	RB	4.2	0.7	F2	2--3		MT
S	RB	4.1	0.8	M1	3--4		2 DRAGONFLIES
G	YP	6.6	1.5	F1		4	ZOOPLANKTON
G	YP	6.6	1.4	F1		4	MT
S	YP	5.1	0.8	F1		1	XX FISH
S	YP	4.6	0.5	F1	1--2		INSECTS
S	YP	5.7	0.6	F1		2	CHIRONOMIDS
S	YP	3.8	0.3	M1	1--2		MT

Diet:

The black crappie we collected was eating chironomids, a member of the fly or Diptera family (Table 6). Chironomids are very abundant in most lakes and make up a considerable part of the diet of many small and some larger fishes (see Methods – Benthos for more detail on this group). The bluegills were eating chironomids and a larval fish at small sizes, switched to chironomids and dragonflies at intermediate sizes, and were eating mostly zooplankton (see Methods – zooplankton for more details on this group) and some chironomids at larger sizes. These fish are eating a good benthic food supply and seem to be growing well in Shingle Lake. The brown bullhead was eating crayfish, while green sunfish ate dragonflies and zooplankton. Small largemouth bass were eating insects and unknown fish, while the larger bass were eating crayfish and some unknown fish as well. Largemouth bass (along with rock bass) seem to prefer to eat crayfish, but they also prey on panfish, even though we did not document this in our study. However, the unidentified fish we saw might have been bluegills. Most of the northern pike had empty stomachs, but one 12-inch individual had eaten two bluegills and was infected with black grubs. These black spots on fish are caused by a larval trematode (*Climostomum neascus*) and are part of a complex life cycle involving birds (usually great blue herons or kingfishers that eat the fish, fish get infected by infected snails and so the cycle continues). They are not harmful to humans and these fish can be eaten with no effect on taste, although one might want to skin them and apply lots of pepper.

Pumpkinseeds are known for being molluskavores and many were eating snails in this study (Table 6). A few chironomids were also eaten by some of the smaller individuals. Rock bass usually eat crayfish, but the fish we examined were consuming only dragonflies; one was cannibalistic. Lastly, yellow perch were eating a wide variety of common food items, including zooplankton, chironomids and other insects, and fish (species unknown).

<u>Age:</u>

Bluegills were growing at or slightly below Michigan averages (Table 6, Fig. 14). The largest one we collected was 4 years old.

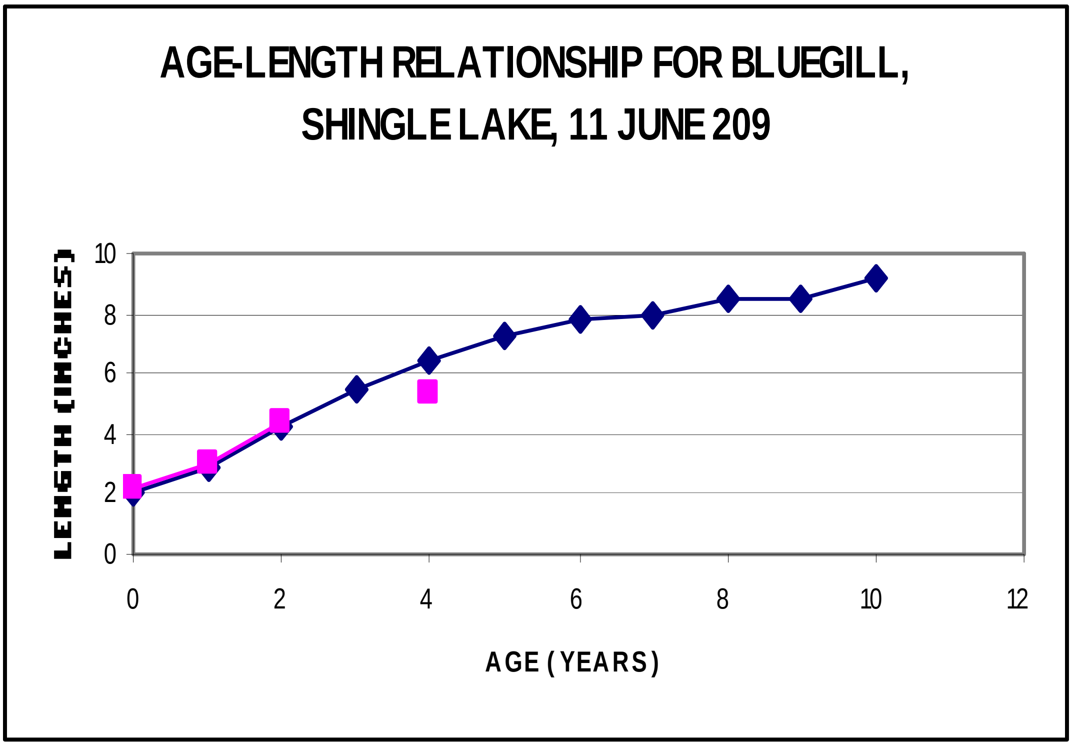


Figure 14. Age-length relationship for Shingle Lake bluegill collected 11-12 June 2009. The squares are Shingle Lake fish; the diamonds are State of Michigan average lengths for various fishes.

The growth relationships for pumpkinseeds were almost identical to the state averages for this species (Table 6, Fig. 15). We collected 7-year old fish and they were growing slightly larger than the state average. It appears that pumpkinseeds are doing well in Shingle Lake.

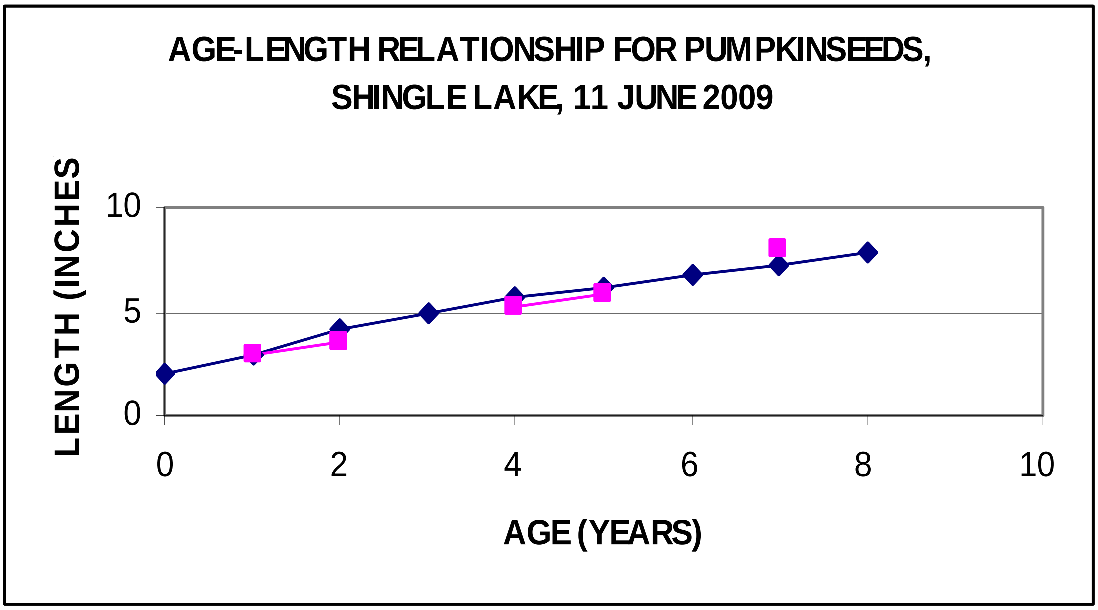


Figure 15. Age-length relationship for Shingle Lake pumpkinseed collected 11-12 June 2009. The squares are Shingle Lake fish; the diamonds are State of Michigan average lengths for various fishes.

Largemouth bass appeared to be growing just at or slightly below the state averages (Table 6, Fig. 16). We collected fish up to 7 years old.

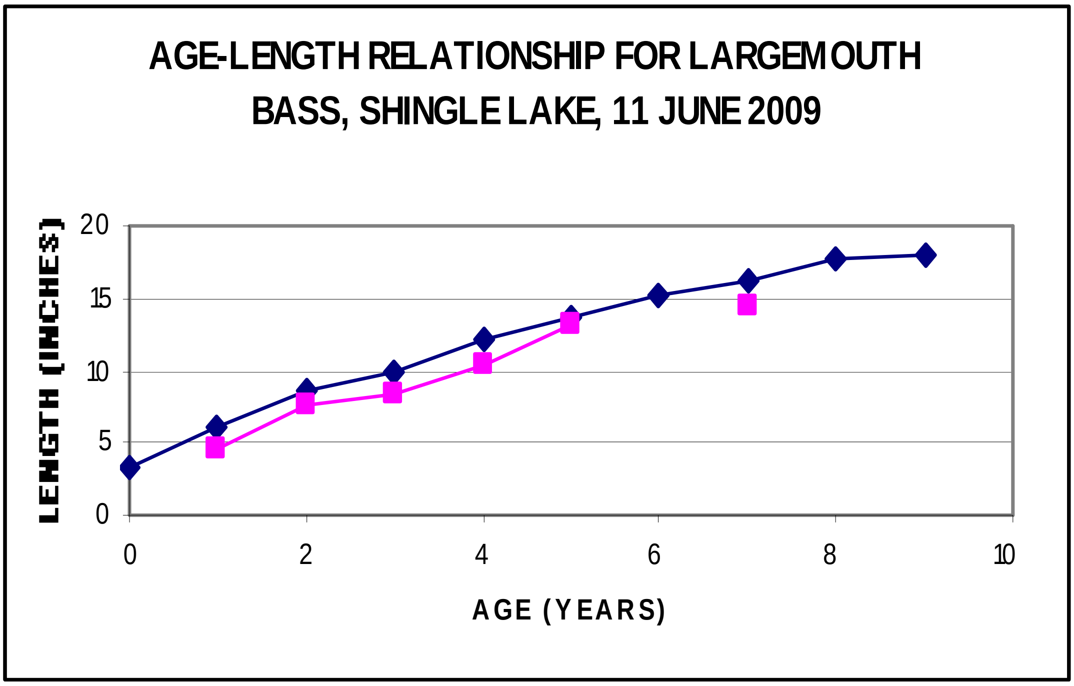


Figure 16. Age-length relationship for Shingle Lake largemouth bass collected 11-12 June 2009. The squares are Shingle Lake fish; the diamonds are State of Michigan average lengths for various fishes.

We collected a number of northern pike in Shingle Lake and also seined one at the public access area (a 9-in young of the year we think; it was released). We aged these fish and found they ranged up to 5 years old. Most age groups were at the state average, while the 3- and 5-year old fish were growing below state averages. As noted, northern pike are difficult to age, but the data seem consistent. One reason for the poor growth could be difficulty in catching prey, since Eurasian milfoil, which is prevalent in the lake, can be so dense it thwarts predators like largemouth bass and northern pike from successfully catching prey items.

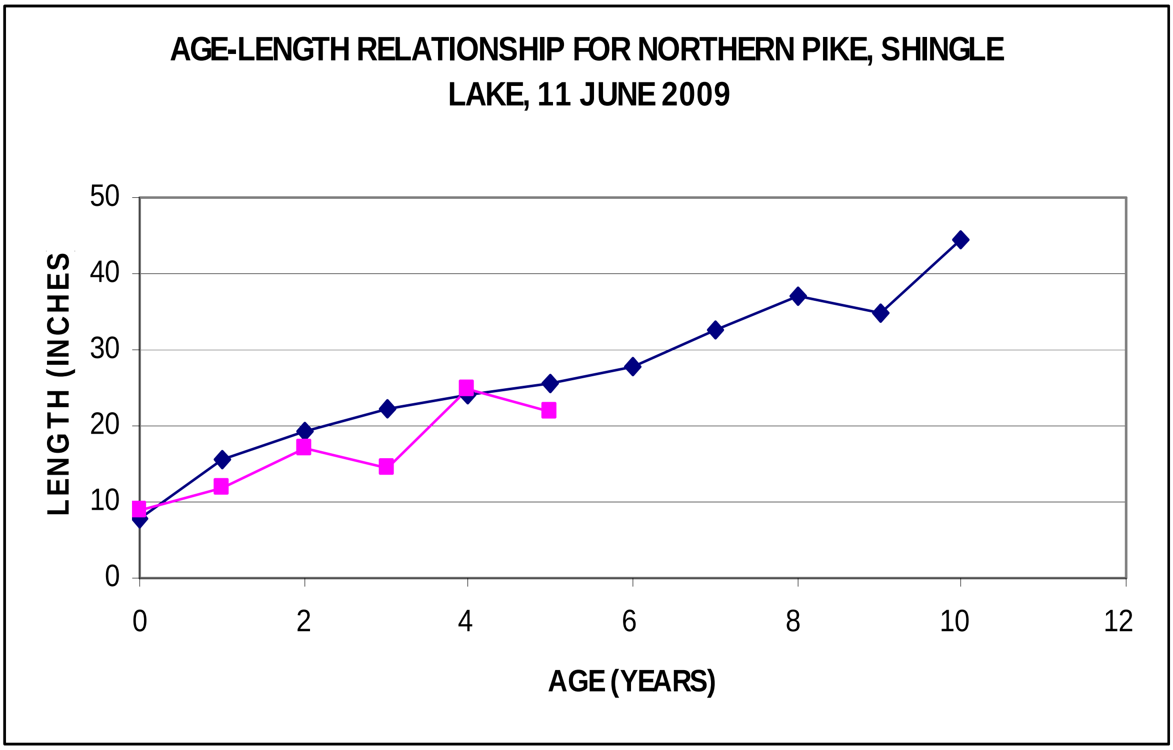


Figure 17. Age-length relationship for Shingle Lake northern pike collected 11-12 June 2009. The squares are Shingle Lake fish; the diamonds are State of Michigan average lengths for various fishes.

Growth of rock bass, although sample size is small, shows some age groups at state averages and some below those averages (Table 6, Fig. 18). We collected fish up to 4 years old.

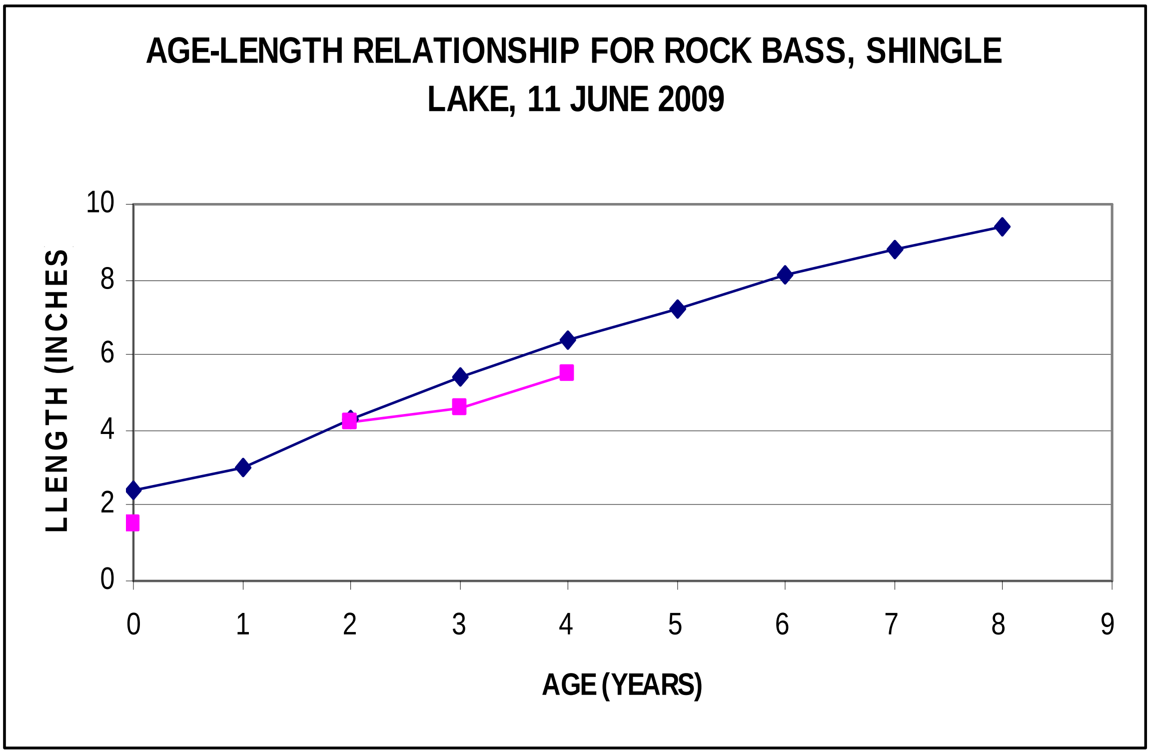


Figure 18. Age-length relationship for Shingle Lake rock bass collected 11-12 June 2009. The squares are Shingle Lake fish; the diamonds are State of Michigan average lengths for various fishes.

Yellow perch are valued sport fish and preferred prey (after soft-rayed fishes) of northern pike. The fish we captured were growing at state averages at early age groups, but then the one 4-year old fish we collected was growing below state averages (Table 6, Fig. 19).

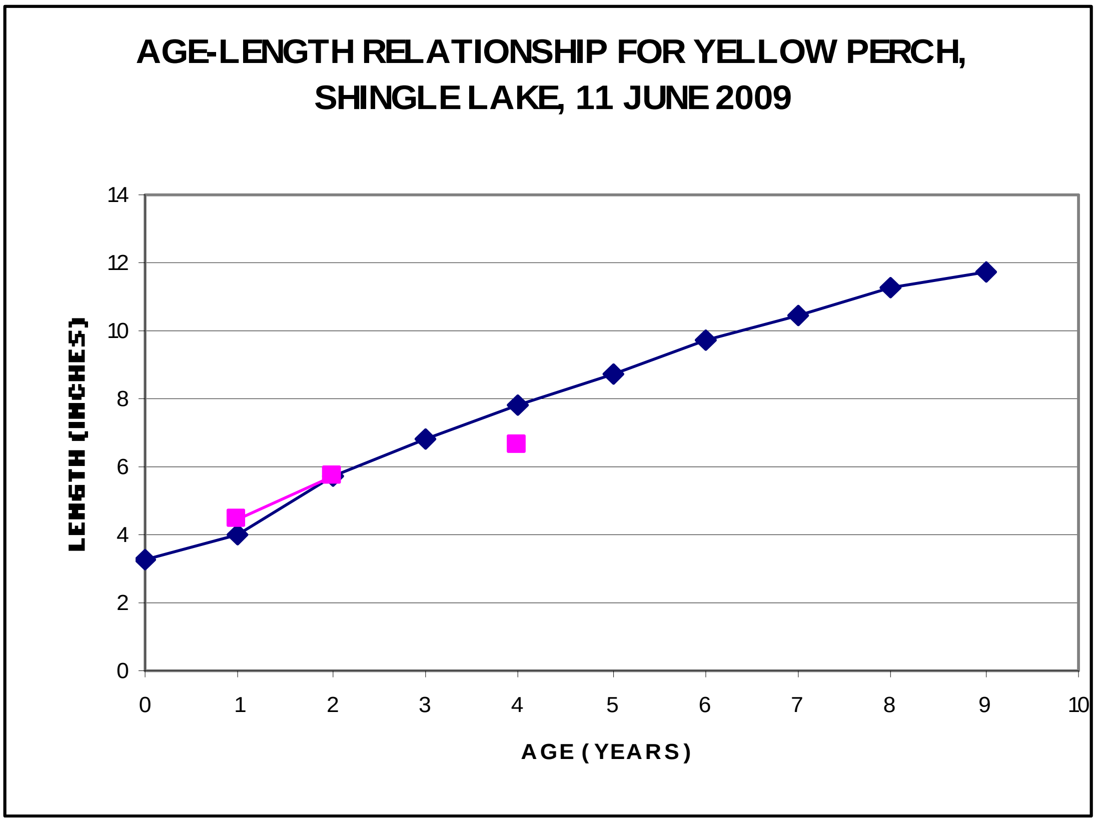


Figure 19. Age-length relationship for Shingle Lake yellow perch collected 11-12 June 2009. The squares are Shingle Lake fish; the diamonds are State of Michigan average lengths for various fishes.

DISCUSSION

For Shingle Lake, which is a 33-acre lake with a 42-ft maximum depth (we only found 33 ft of depth), we found that there was fairly low chloride levels (ca. 30 mg/L or ppm) indicating that the lake is probably not receiving large amounts of chlorides either from road salt or septic tanks (more extensive work would be needed to confirm this). This finding also suggests that other contaminants and nutrient entry into the lake are probably low as well. However, it should be noted that chloride levels in Lake George were 10 ppm lower than Shingle, which might suggest more inputs from these sources (road salt or septic tanks) than what is entering Lake George. Also the watershed of Shingle Lake is much smaller than Lake George, which is contrary to what one might expect. The incoming creek into Shingle Lake may also be bringing in chlorides (and other substances) from the water shed it drains. It should also be noted that septic tanks can contribute considerable amounts of nutrients into the lake, thus helping to fuel plant growth.

Shingle Lake also has had an infestation of Eurasian milfoil, an exotic plant that grows in very dense patches (which we saw when we set the nets). Milfoil and curly leaf pondweed have been a problem in the past and considerable amount of effort and money has gone into controlling it. (see APPENDIX 1 and 4 for further discussion of this problem). This plant can provide refuge for sunfish and cause the predators to be less successful in catching them, which can lead to stunted panfish and poor growth of predators. Fortunately, it appears we are not seeing stunted panfish in Shingle Lake at this time, despite this being a problem in the past.

The type of stratification and the dissolved oxygen-temperature relationship in Shingle Lake is very important to assist in evaluating options for any problems in the lake of a limnological or a fisheries nature. The amount of dissolved oxygen on the bottom is critical to cool water species such as northern pike for good growth and for providing advice in stocking walleyes. The lake was stratified (formed three layers) on 11 June (very little dissolved oxygen below 20 ft) and on 29 August (no dissolved oxygen below 18 ft). This has three ramifications: 1.) this low dissolved oxygen in the zone where the temperatures are coldest would prevent walleye or other cool water fishes from growing very well as they would be confined to a small layer of water with adequate dissolved oxygen and cold enough temperatures. 2.) the low dissolved oxygen promotes anoxia (no oxygen on the bottom) which results in buildup of many toxic chemicals, such as carbon dioxide, ammonia, nitrates, and hydrogen sulfide. However, we only measured a large quantity of ammonia on the bottom; nevertheless this area of the lake would be toxic to fish because of the ammonia and the low dissolved oxygen and fish would not be found there during summer stratification. 3.) because it stratifies, there is cold water where fishes like northern pike can flourish during summer if there is adequate dissolved oxygen which does occur part of the time.

The fish community in Shingle Lake is a typical warm-water, eutrophic fish community; we collected the following nine species: top predators northern pike and largemouth bass, while there were also black crappie, brown bullheads, yellow perch, bluegill, pumpkinseed, rock bass, and green sunfish. It appears that there is an excellent population of northern pike in the lake, probably because of the optimal spawning stream on the west end of the lake and because it is deeper providing cool water for this species during the summer stratification (this does not happen in Lake George). We also collected what we think was a young of the year northern pike, further evidence of successful spawning. This creek is a critical spawning and nursery area for Shingle Lake and all efforts should be made to: 1. prevent any poaching of northern pike during the spring spawning runs and 2. protect the stream from any detrimental effects of runoff, erosion, or other negative impacts. In addition, we strongly recommend like we did for Lake George, that top predators, largemouth bass and northern pike, be part of a catch and release program because it will provide good predator pressure on the panfish and allow them to grow well and because most of these fish are probably laden with mercury and should not be eaten anyway. The panfish should be the targets for consumption including yellow perch, pumpkinseed, bluegill, and rock bass. There are also moderate populations of largemouth bass and black crappies (which were reported to be spawning during our study on 11 June). Previous studies by MDNR stated that the bluegills were growing slowly. We did not find that they were growing poorly, although some age groups were growing below the state averages. We examined the diets of the fishes and found typical stomach contents: fishes in the predators (mostly bluegills) and crayfish in the largemouth bass and aquatic insects (midges and dragonflies) and zooplankton in the panfishes. The Shingle Lake food web appears to be functioning efficiently.

MANAGEMENT RECOMMENDATIONS

Shingle Lake has had severe problems with Eurasian Milfoil in the past and those continue in the present during this study. Some control of this species is warranted because of the adverse impact on fish – sunfish can hide in the dense plants and predators cannot get very good access to them, which can lead to stunting. They also adversely affect recreational traffic. MDNR has commented on this situation (see APPENDIX 1 AND 4) and their advice should be heeded. They believe that some control has been attained and that care needs to be exercised so that native plants are not totally eliminated from the lake.

The water quality of Shingle Lake appears to be very good and the chloride levels are low, indicating a low level of input from runoff and septic tanks. However, if the option arises to hook up to sewers, we highly recommend that, as future development and additional septic tank use at some point will compromise the lake water quality and lead to more dense plant growth and algal blooms. The lake is deep and stratifies in summer, which leads to the buildup of ammonia on the bottom; we did not see buildup of nitrates and phosphorus as expected, which is a good thing. If additional nutrients enter the system, this situation could reverse and we could see additional buildup of nitrates and phosphorus, which then gets re distributed in the fall and spring into the lake and can fuel algal and macrophyte growth.

The dissolved oxygen depletion on the bottom of Shingle Lake is of great concern. As noted above, water quality can be affected. At the present time, there is still a small amount of dissolved oxygen on the bottom which prevented more severe deterioration of the water near the sediments. But more importantly, there is a dead zone for fish that was below 20 ft on 11 June and below 16 ft on 29 August. This dead zone will prevent fish from entering any water below these depths for most of the summer during stratification. This has implications for cool water fishes – the northern pike will have reduced growth as a result of being forced into warm water when it prefers cooler water, but that water is now devoid of dissolved oxygen. Second this condition will prevent or severely stress any stocked fish, such as walleyes, which require cool temperatures and adequate dissolved oxygen. Hence, the recommendation for fish for Shingle Lake is to not stock any fishes since the lake appears to be well balanced at the current time. There is good reproduction of northern pike because of the tributary stream, which should be protected at all costs from impacts due to runoff, development, and erosion. In addition, a fish such as walleyes will be squashed between the surface where the temperatures are too warm and the bottom where the cold temperatures exist, but this area is now devoid of most dissolved oxygen. Lastly, we recommend a voluntary catch and release program to encourage fishers to return the top predators to the lake to promote good balance in the prey fish population and they should not be eating most large predators anyway because of mercury contamination problems.

We also recommend the initiation of a program to prevent entry of zebra and quagga mussels into the lake by informing residents that bring in boats, scuba gear, and/or bait from other lakes that may be contaminated with veligers. You should also consider banning bait (minnows, crayfish) from other lakes as they might contain veligers or VHS.

ACKNOWLEDGEMENTS

It was a pleasure to do this study because of the wonderful assistance, lodging, and nutrients provided by our on-lake hosts Maggie and Roger Mcarey. We also were provided a map for each lake and research vessels (thank you Mike Hart), for which we are grateful. Another Hart, James, assisted with the collection and processing of the fishes we collected. Kevin Wehrly provided access to MDNR data on fish collections for the lake and Richard Rediske, Grand Valley State University provided water chemistry data. I thank Jason Jude for help with figures, pictures, and graphs.

APPENDIX 1.

LETTER FROM MICHIGAN DEPARTMENT OF NATURAL RESOURCES TO J. BALE REGARDING SHINGLE LAKE MANAGEMENT, 30 MARCH 2004.

Jaimee Bale
Professional Lake Management
P. O. Box 132
Caledonia, MI 49316 March 30, 2004

Subject: Shingle Lake, Clare County, 2004 DEQ required management plan

Dear Jaimee,

I am writing this letter to provide you with information requested in your March 10, 2004 e-mail regarding Shingle Lake. Please consider these comments when developing the management plan required by the Department of Environmental Quality for conducting whole lake removal programs of aquatic vegetation in Shingle Lake.

The Michigan Department of Natural Resources (DNR) is responsible for managing fisheries and wildlife and protecting the public trusts in these resources in Michigan. There are many factors that the DNR must consider in fulfilling its obligations under the public trust doctrine. This is especially true for Michigan lakes. Human developments in and around lakes continue to increase and alterations to fish and wildlife habitat are also expanding. Both commercial; and residential land-uses are significant factors influencing lake management, including activities related to home and septic tank construction, dredging and filling of bottomland (including beach sanding), dock and marina construction, shipping on the Great Lakes and connecting waterways, artificial lake levels maintained by dams, and removal of vegetation within and around the lake. Michigan lakes are used by many recreational interests in addition to lakeshore property owners (riparians). Swimming, boating, sunbathing, relaxation, scuba diving, sightseeing, fishing, hunting, trapping, and wildlife viewing are some of the reasons people are attracted to lakes.

A goal of the DNR is to promote optimum recreational use of public trust resources for Michigan citizens. However, with such highly diverse interests and activities associated with Michigan lakes, this can be a difficult goal to reach. Lake alterations prescribed to improve one type of recreational use often reduce the system's ecological integrity and/or recreational opportunities for other users. Conservation of biodiversity and ecological integrity require planning and management when alterations are proposed to a lake system. A thorough knowledge of, and proper planning for lake resources management will help to insure that ecological integrity is conserved and that sustainable populations of fish and wildlife remain available for current and future generations of Michigan citizens.

Inland lakes are some of the most productive and biologically diverse ecosystems that exist. A vast array of aquatic organisms including plants, crayfish, fish, mollusks, and amphibians, as well as many reptiles, birds, and mammals, depend on lakes and their associated wetlands and uplands for survival. Surveys were conducted in Shingle Lake by Fisheries Division in 1954, 1979, 1982, 1983, 1985, and 1993. Shingle Lake contains a typical warmwater fish community. Species of fish collected in this lake include northern pike, largemouth bass, bluegill, pumpkinseed, rock bass, black crappie, yellow perch, white sucker, bullheads, bluntnose minnow, Johnny darter, and Iowa darter.

In 1979, bluegill growth was below state average in this lake. A partial rotenone treatment was conducted to reduce the number of bluegill in the lake and improve growth rates and size structure. Bluegill growth rate was improved in 1985, but returned to somewhat below average growth by 1993. The effects of fish population reductions using chemicals generally have only short-term affects. Growth rates in 1993 were just above state average for yellow perch and rock bass, and somewhat below state average for most other species. The size structure of the bluegill and pumpkinseed populations was good, indicating fishing pressure is not excessive in this lake.

There appears to be reasonable fisheries for panfish, bass, and northern pike in this lake. Average fisheries were present for native warmwater fish in this lake in 1993, and appear to be similar to conditions noted in the 1980s.

Largemouth bass are a common predator gamefish in Shingle Lake. They inhabit the upper levels of small, shallow lakes and shallow bays of larger lakes. They are rarely caught at depths over 20 feet. They are almost always found in association with soft substrate, stumps and extensive growths of a wide variety of both emergent and submergent vegetation. Water lilies, cattails, and various species of pond weeds are some of the favorite vegetation types. Most warmwater fish, including sunfish, muskellunge, northern pike, yellow perch, bullheads and many minnow species are found in the same types of habitat. (Scott and Crossman, 1973). Aquatic plants play a key role in different life stages of many fish species. This includes serving as substrates for eggs and providing habitat for some species that require plants for their existence (Becker 1983; Scott and Crossman 1973; Trautman 1981). Submerged aquatic plants also provide living areas for invertebrates that are a principal food source for many fish (Engel 1985; Keast 1984; Wiley et al. 1984).

Reptiles and amphibians need well vegetated shallow water habitats with natural shorelines. Turtles live in shallow water with moderate to dense vegetation and usually a muddy substrate.

Most species like to bask in the sun on emergent logs or grassy banks. Food includes aquatic plants, small fish, snails, aquatic insects, and carrion. All aquatic turtles require sunny nesting sites near water with a sandy or loamy soil (Harding and Holman 1990). Frogs inhabit marshes, meadows and the grassy edges of ponds and lakes (Harding and Holman 1992). Natural lake shore areas have more frogs than highly developed areas because natural vegetation and shorelines tend to provide not only living habitat and food sources but also have less wave action. Construction of seawalls, removal of naturally fallen trees, and removal of aquatic vegetation destroys the habitat and food sources of aquatic turtles and frogs and tends to restrict their presence to any undeveloped sections of the lake.

Most lakes in Michigan, including Shingle Lake, have been subjected to significant biological and ecological changes as a result of human influences. These changes can degrade lake quality, resulting in losses of fish and wildlife species, lost recreational opportunities for citizens, and, ultimately, a lower quality of life for residents. The following factors should be considered when developing management plans for any inland lake, including Shingle Lake.

Overall development

Alteration or development of Michigan lakes should not exceed 25%, water quality should be maintained within Michigan Surface Water Quality Standards, and no loss of navigable waters should occur. Development of 25% or less of the lake is recommended to provide reasonable riparian owner access and recreational use, while preserving ecological integrity, sustaining natural resources for future generations, and protecting the public trust. Development activities should be viewed from a whole lake perspective, as well as individual habitat components and individual properties. Examples of habitat components include shoreline slope and structure, vegetation (trees and shrubs) within the shoreline ecotone, emergent and submergent vegetation (distribution, composition, and architecture), submerged deadwood, lake level, bottom contours and composition, and surface water area. These objectives can be achieved on individual properties by maintaining naturally sloped shorelines, with a 35 foot vegetated buffer strip above the ordinary high water mark, and using 25% of the shoreline property for access and use of the lake. Boat docks and other structures should not interfere with navigation or natural movements of water or animals. A narrow boating lane can be cut through dense surface vegetation if needed, while preserving the ecological values and wave dampening features of this important habitat component.

Single-family residential home development is present on a substantial portion of the shoreline of Shingle Lake. Since so much of the shoreline of Shingle Lake is already developed, it is critical to protect the remaining undisturbed portions of the lake and to rehabilitate as much of the developed areas as possible.

Water quality

Lake water quality should be maintained above Michigan Surface Water Quality Standards for dissolved solids, hydrogen ion concentration, taste or odor producing substances, toxic substances, nutrients, microorganisms (bacteria), dissolved oxygen, and temperature. Other inorganic and organic components should be maintained at natural levels.

Water quality degradation in most inland lakes results from development in the uplands and along the immediate shoreline of the lake. Protection of water quality in lakes will require reducing artificial drainage from roadways, agriculture, urban areas, as well as residences within the watershed and along the shoreline of the lake. Natural shoreline buffers need to be established and maintained between residential lawns and the shoreline of lakes, and riparian lawn fertilization should be discontinued or modified where it affects water quality. Wastewater systems should be developed where septic systems are contributing nutrients to the lake.

Dissolved oxygen readings were collected in Shingle Lake in 1954 and 1987. During both years, dissolved oxygen readings were very low below the thermocline (18-20 feet). Alkalinity was 120-240 in 1954. Secchi disk readings in July 1954 were 10 - 11 feet, and in June 1987 were 10.7 – 11.8 feet. Secchi disk readings and low dissolved oxygen levels measured in 1954 and 1987 indicate this lake has moderate productivity, or is mesotrophic.

Shoreline development

Alteration of natural shorelines should consider potential effects on habitat and biological communities, as well as the natural aesthetic aspects of lakes. Naturally sloped and vegetated shorelines should be preserved as much as possible. Shoreline vegetation should be maintained to provide natural rates of deadwood to fall into the lake, and to provide adequate habitat to maintain plant and animal communities. Natural buffer-strips should be maintained a minimum distance of 35 feet above the ordinary high water mark of a lake.

Inland lakes should be managed to contain appropriate levels of deadwood in the littoral zone. Natural levels of 2” and larger logs in north temperate lakes range from 470 to 1,545/mi. Tree densities (2” and larger) within 33 feet of the shoreline in natural lakes range from 363 to 1,017/acre. As a result of logging activities and development of the shoreline over the past 150 years, the level of deadwood falling into Michigan lakes has been significantly below natural rates. Based on natural rates of tree drop in northern hardwood forests, natural deadwood accrues at a rate of approximately 1 log/year/mile of shoreline in Michigan lakes. Programs designed to restore natural levels of deadwood in Michigan lakes should consider the importance of this habitat component to shore dwelling animals as well as aquatic animals. Logs should be randomly distributed throughout the lake. Amphibians and reptiles should be provided logs for cover and basking at the shore-water interface. Logs should be placed in the littoral zone to provide fish and invertebrate habitat, but may require a bottom anchoring system to allow navigation by boats without causing a safety problem.

Degradation of littoral zone deadwood abundance, aquatic vegetation abundance, fish production, amphibian abundance, and fish and bird community composition have all been related to development of lake shorelines. Some of these changes were visible at dwelling densities of less than 2 per mile of shoreline. Changes in all of these resource components were visible at dwelling densities between 5 and 10 per mile of shoreline. Management planning should consider this aspect of shoreline development, including options for rehabilitation of affected habitat components.

Shingle Lake has a surface area of 35 acres and a shoreline length of approximately 1.5 miles. In 1954, the number of cottages on the lake was estimated at 44. The 1998 topographic map indicates approximately 71 structures present along the shoreline. These values indicate an increase from 29.9 to 48.3 dwellings per mile of shoreline between 1954 and 1998. Shoreline dwelling densities were well above levels shown to affect natural resources by 1955.

Dredging and filling

Placement of permanent structures or other types of fill below the ordinary high water mark should be avoided, including beach sanding (except for natural habitat restoration). Structures that removes navigable waters or impede navigation, including shoreline access, should not be allowed because they degrade public trust resources and often remove navigable waters from use by Michigan citizens. Seawalls should not be constructed and existing seawalls should be removed where possible.

Aquatic vegetation

Native plants should not be removed or reduced in our lakes. This includes native milfoils and coontail which are often secondary targets of treatment and treated as "nuisance" species, when in fact these species are very valuable sources of food and habitat for many species of fish, invertebrates, waterfowl and other wildlife (Schloesser 1986). Non-indigenous plants should be controlled, provided that the most selective methods that protect native plants are used. Plant communities should be protected and restored to provide lasting conservation of natural biological diversity, and to maintain natural levels of production. Native species, natural diversity and architectural types, and total surface coverage and biomass of native plants should not be changed or reduced. Shallow lakes that naturally have extensive native plant cover should be maintained in their natural condition. Programs and techniques that reduce native plant or animal diversity, distribution or abundance should not be allowed. Removal of native plants and animals promotes colonization by non-indigenous species. Generally, inland lakes in Michigan with moderate levels of submersed plant coverage (25% - 35% coverage of total lake surface) have the best overall fisheries. Diminished fish production is usually associated with plant coverage below these levels.

Aquatic vegetation surveys in Shingle Lake should incorporate emergent plants, as well as submergent and floating-leaved plants. Vegetation surveys in Shingle Lake in 1955 indicate abundant levels of submerged vegetation, moderate levels of floating-leaved vegetation, and sparse emergent vegetation were present. A partial list of aquatic vegetation from 1955 included the genera listed below.

Elodea – moderate
Myriophyllum – dense
Nymphaea– sparse
Pontedaria – sparse
Potamogetons – sparse to moderate
Scirpus – sparse
Typha – sparse
Vallisneria – sparse
Chara – dense
Lemna – sparse to moderate
Najas – sparse
Polygonum – sparse

Swimmer's itch

Chemical control of swimmers itch needs to be carefully considered, and based on reasonable significant levels of human health afflictions.

Dams and lake-level control

Man-made dams on lakes and tributaries should be removed or managed to insure natural downstream movement of deadwood, natural upstream and downstream fish movements, and appropriate habitat needs of plant and animal communities. Lake-levels should not be controlled by dams or augmentation wells, because of the need to preserve natural seasonal water fluctuations, abundance and diversity of vegetation, spawning and nursery areas for fish and wildlife, and to prevent shoreline erosion.

In conclusion, management of natural resources requires consideration of the affects of all alterations caused by development on and in a lake. Recreation and reasonable use of a lake by property owners is also a management goal of the Department of Natural Resources. The objectives of lake management programs are to optimize social benefits, insure sustainable resources for the future, and maintain ecosystem integrity. Recreation needs of boaters and riparian owners must be balanced with natural resource needs to conserve biological diversity and productivity.

Sincerely,

Richard P. O'Neal
Fisheries Biologist
Michigan Department of Natural Resources
Muskegon State Game Area
7550 E. Messenger Road
Twin Lake, MI 49457
231-788-6798

cc: Matt Preisser, MDEQ

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APPENDIX 2.

MICHIGAN DEPARTMENT OF NATURAL RESOUCES FISH SUMMARY FOR LAKE GEORGE, MAY 1993. SHOWN IS THE LIST OF SPECIES COLLECTED, THEIR LENGTHS IN COLUMN 2, THE NUMBER OF FISH OF EACH LENGTH CAPTURED, AND TOTAL WEIGHT IN COLUMN 3.

Black crappie	7	8	1.66	
Black crappie	8	14	3.62	
Black crappie	9	5	1.93	
Black crappie	10	4	2.27	
Black crappie	11	1	0.66	
Black crappie	12	2	1.9	

Black crappie	13	1	1.3	
Black bullhead	7	3	0.9	
Black bullhead	8	166	57.6	
Black bullhead	9	110	54.2	
Black bullhead	10	66	42.7	
Black bullhead	11	30	26.7	
Black bullhead	12	3	2.8	
Bluegill	2	1	0.01	
Bluegill	3	16	0.37	
Bluegill	4	16	0.71	
Bluegill	5	1	0.06	
Bluegill	6	2	0.38	
Bluegill	7	1	0.26	
Largemouth bass	2	3	0.03	
Largemouth bass	9	3	1.41	
Largemouth bass	10	2	1.7	
Largemouth bass	11	3	2.3	
Largemouth bass	12	4	4.3	

Largemouth bass	13	6	7.4	
Largemouth bass	14	8	11.1	
Largemouth bass	15	2	3.3	
Largemouth bass	16	1	2.2	
Largemouth bass	17	4	10.4	
Northern pike	19	1	1.7	
Northern pike	20	1	1.5	
Northern pike	22	1	2.3	
Northern pike	23	1	2.3	
Northern pike	26	1	3.3	
Pumpkinseed	3	15	0.4	
Pumpkinseed	4	19	0.96	
Pumpkinseed	5	5	0.55	
Pumpkinseed	6	4	0.85	
Pumpkinseed	7	3	0.94	
Pumpkinseed	8	1	0.44	
Rock bass	4	2	0.13	

Rock bass	5	11	1.45	
Rock bass	6	17	3.98	
Rock bass	7	25	8.95	
Rock bass	8	11	5.37	
Rock bass	9	3	1.91	
Rock bass	10	1	0.81	
Yellow Perch	6	2	0.16	
Yellow Perch	8	2	0.48	

APPENDIX 3.

MICHIGAN DEPARTMENT OF NATURAL RESOUCES FISH SUMMARY FOR SHINGLE LAKE. DATE UNAVAILABLE. SHOWN IS THE LIST OF SPECIES COLLECTED, THEIR LENGTHS IN COLUMN 2, THE NUMBER OF FISH OF EACH LENGTH CAPTURED, AND TOTAL WEIGHT IN COLUMN 3.

Black crappie	6	1	0.16
Black crappie	8	9	2.98
Black crappie	9	3	1.17
Black crappie	12	1	1.01
Bluegill	4	1	0.09
Bluegill	5	16	1.57
Bluegill	6	28	4.94
Bluegill	7	18	5.06
Bluegill	8	6	2.4
Bullhead Catfishes (Family)	8	5	1.4
Bullhead Catfishes (Family)	9	18	9.5
Bullhead Catfishes (Family)	10	22	15.8
Bullhead Catfishes (Family)	11	16	13.9
Bullhead Catfishes (Family)	12	2	1.8
White sucker	20	2	8.4
Largemouth bass	10	2	1.1
Largemouth bass	11	1	0.7

Largemouth bass	12	5	4.9
Largemouth bass	13	1	1.2
Largemouth bass	14	1	1.6
Largemouth bass	16	1	3
Northern pike	13	3	1.09
Northern pike	14	1	0.59
Northern pike	16	3	2.9
Northern pike	17	2	2
Pumpkinseed	4	1	0.09
Pumpkinseed	5	1	0.11
Pumpkinseed	6	11	2.55
Pumpkinseed	7	4	1.34
Pumpkinseed	8	2	0.92
Rock bass	5	3	0.39
Rock bass	6	5	1.16
Rock bass	7	4	1.4
Rock bass	8	3	1.31
Rock bass	9	4	2.78

Rock bass	10	1	0.7
Yellow Perch	10	1	0.66
Yellow Perch	11	1	0.65

APPENDIX 4.

LETTER. FROM THE MICHIGAN DEPARTMENT OF NATURAL RESOURCES TO THE MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY ADDRESSING THE AQUATIC PLANT SITUATION IN SHINGLE LAKE DURING 2004.

Eric Bacon
Michigan Department of Environmental Quality
Inland Lakes and Remedial Action Unit
Water Division
P. O. Box 30438
Lansing, MI 48909-7938 April 8, 2004

Subject: Shingle Lake, Clare County

Dear Eric,

I am writing to provide comments regarding the application to remove vegetation in Shingle Lake, Clare County, for 2004. The permit requests the use of fluridone, Renovate, 2,4-D, Reward, Aquathol-K, Hydrothol, biological control and mechanical harvesting for control of Eurasian water-milfoil and curly-leaf pondweed; and Reward, Aquathol-K, Hydrothol, copper products, and mechanical control to kill native submergent and emergent vegetation; and algaecides and biological control to kill algae.

The required management plan states in part IV that Eurasian water-milfoil has grown dense throughout the lake and is out-competing natives. The management goals indicate they want to create/protect fish & wildlife habitat, and to improve native plant diversity.

Permits for aquatic vegetation control in this lake were issued in 1994, 1996, 1999, and 2001 through 2003. The table below summarizes the results of these surveys. The same consultant conducted all of these surveys, with the exception of the 9/2003 survey which was conducted by DEQ. There is significant disparity between the consultants 8/2003 survey and the DEQ 9/2003 survey. It is especially interesting to note that the consultant's survey showed none of the fluridone sensitive native species (*Elodea, Ceratophyllum, Najas*) present in the lake, yet they were found in the DEQ survey. This leaves the results of earlier surveys questionable. For 2003, I am assuming the DEQ survey is accurate.

	Number of species/genera			% distribution		Cumulative cover			
Survey date	Submerged	Floating & Emergent	Total	EWM	Curly-leaf	EWM	Curly-leaf	Total Submerged native	Total Emergent native
6/1999	10	5	15	100	40	32.0	6.0	66.4	26.3
9/2000	9	5	14	65	47	31.8	10.0	55.7	14.7
8/2001	13	6	19	13	9	0.7	0.7	36.2	12.4
8/2003	6	2	8	100	0	20.1	0	15.7	17
9/2003	14	9	23	94	6	10.8	0.1	131.1	28.7

Attachment-L (amendment) states that "chemical treatments have concentrated on Eurasian water-milfoil and nuisance algae on a limited basis until 2003 when Eurasian water-milfoil bloomed". Apparently this is the reason for the whole lake fluridone application. Information from the surveys indicates this is not the case. Eurasian water-milfoil had a 100% distribution and 32 % cumulative cover in 1999. Distribution and cover were reduced significantly by 2001. Distribution appeared to increase again by 2003, but cover is only at 1/3 of 1999 levels. Apparently the existing treatment program was effective at controlling Eurasian water-milfoil, as well as curly-leaf pondweed. The reason for the increased distribution of milfoil in 2003 needs to be evaluated. It appears the total cumulative cover of submerged native vegetation declined and then increased substantially. Total cumulative cover of floating leaf and emergent vegetation declined and then returned to normal levels in 2003. The existing treatment program appears to be working effectively for control of the exotics and retention of native vegetation.

The DEQ-ANC Administrative Rules requires that both a wide distribution and nuisance condition of Eurasian water-milfoil be present in a lake prior to issuing a whole-lake fluridone application. These conditions are not met in Shingle Lake. Cumulative cover of 10% does not represent a nuisance condition. In addition, three species of fluridone sensitive native species are also present in the lake. Dense stands of native milfoil also were present in the lake in the 1950s, but appear to be at very low levels or not present anymore. The present vegetation control program appears to achieving the objective of controlling non-indigenous plants, and protecting most native vegetation, including fluridone sensitive species.

The permit application also requests to kill native vegetation with a wide arsenal of treatment methods. This is inconsistent with stated objectives of the management plan, as well as appropriate management programs for non-indigenous species. The removal of native plants promotes the spread of non-indigenous species. I recommend full protection of native plants in this lake, with the possible exception of mechanical harvesting to provide boat lanes to open water where needed.

The DEQ-ANC Administrative Rules requires an appropriate management plan be developed for whole-lake vegetation treatments. This permit application does not include an acceptable management plan. None of the resource protection issues the DNR considers important for whole-lake management are addressed in this plan. The only proposal put forth is to use nearly every chemical, as well as biological control agents and mechanical harvesting to remove indigenous and non-indigenous plants. This document does not even state which chemicals will be used be used for any specific application, or where they will be used. There appears to be no plans submitted for this lake other than the historically standard request to use chemicals and other methods to remove plants. A true management plan may justify the request to use fluridone in this lake, but the present information does not. I recommend denial of this permit application.

Sincerely,

Richard P. O'Neal
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