Picture 1. Lake Shannon Fish and Limnological study: 1-2 September 2010

A LIMNOLOGICAL AND FISHERY SURVEY OF

LAKE SHANNON

WITH RECOMMENDATIONS AND A MANAGEMENT PLAN

Study performed: 2-3 September 2010

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INTRODUCTION

We were asked to perform a fishery and limnological investigation of Lake Shannon, located in Shiawassee County, near Owosso, MI (Picture 1) and develop short-term and long-term management plans for the lake with emphasis on fish management. We classified Lake Shannon as eutrophic, moderately high in nutrients, based on hypoxia (low dissolved oxygen) in the hypolimnion (bottom part of the lake), an ongoing blue-green algae bloom during September, an abundance of macrophytes (including Eurasian milfoil infestation requiring annual treatment), and a warm-water fish community, including a large number of common carp.

HISTORY

. Lake Shannon is a shallow, elongated lake formed by damming a river and is surrounded by many residential houses. The dam is on the north side. The lake has some islands, a few small, shallow bays and a typical warm water fishery composed of largemouth bass, panfish, and the exotic Asian common carp. There are also smallmouth bass and walleyes, which are unusual for this warm of a lake. Channel catfish were also stocked into the system and there are some large specimens present in the lake. There is an active group that water skies in the main basin. An extensive program of aquatic plant control for Eurasian milfoil is conducted on the lake and the lake is drawn down overwinter to control macrophytes and sediments.

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 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

Depth

Depth is measured in several areas with a sonic depth finder or a marked sounding line. We ran transects across all three lakes and recorded the depths since there seemed to be some confusion about the depths of the lakes. These soundings were then superimposed on a map of each lake and a contour map was constructed to provide some information on the current depths of the lake. From what was reported to us about the depth of the lakes in the past, the lakes have filled in a considerable amount since they were formed.

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 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.

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 (see Fig. 1 for documentation of this process over the seasons).

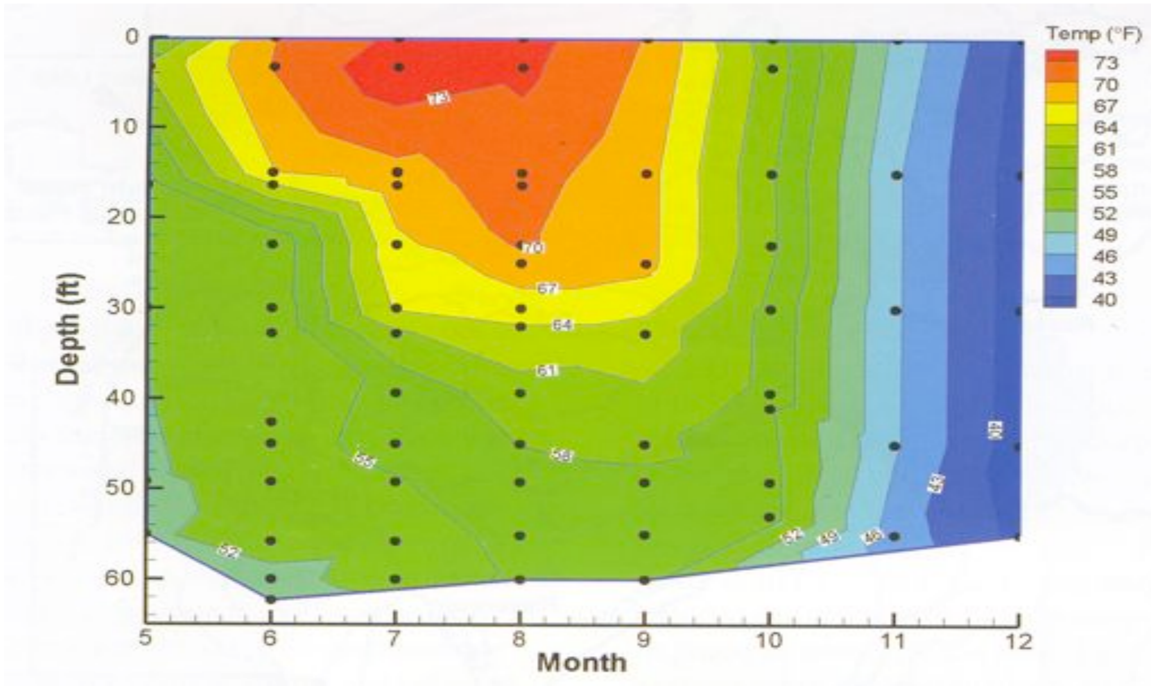


Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red yellow and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during summer months. Adapted from NALMS.

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 (blue part on right of Fig. 1), 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, 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.

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 an YSI, dissolved oxygen-temperature meter or 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 (see Fig. 2 for demonstration of this process).

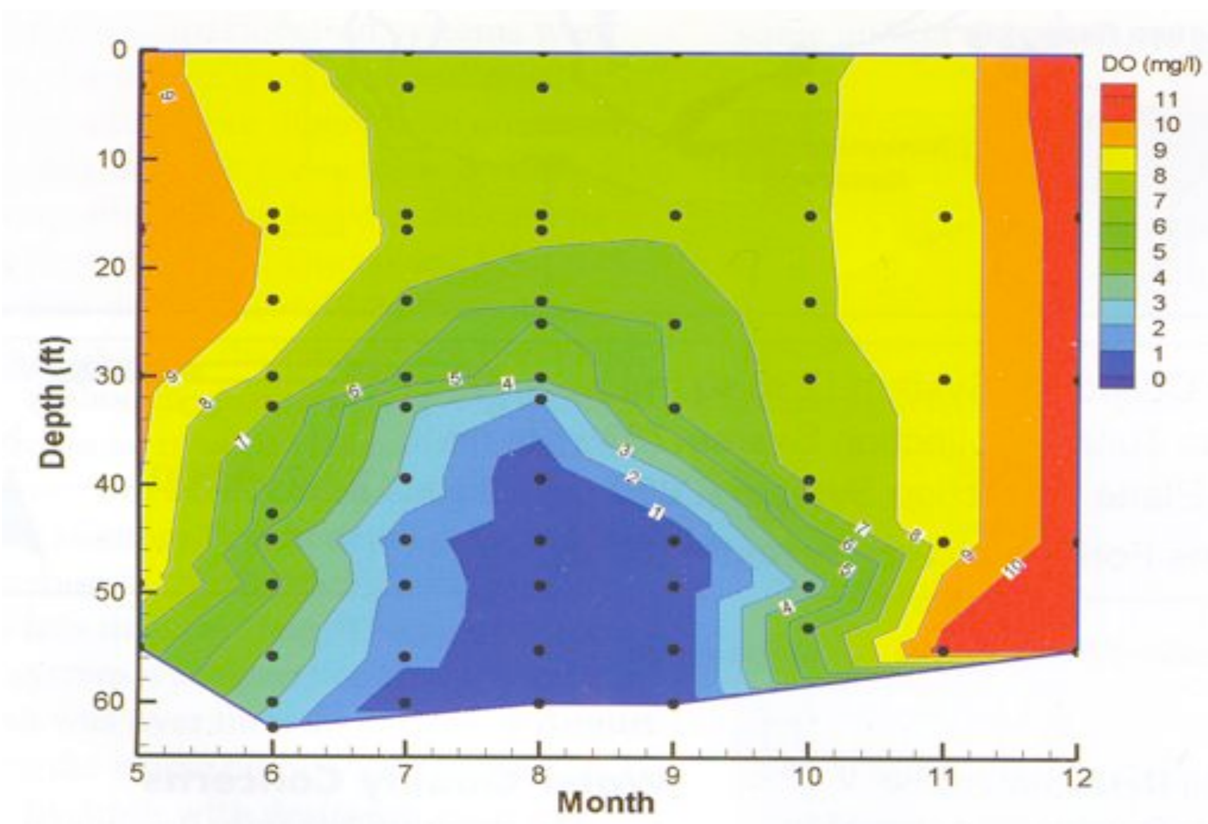


Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts

anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when the dissolved oxygen is the same from top to bottom. Adapted from NALMS.

In the spring turnover period dissolved oxygen concentrations are at saturation values from top to bottom (see red area which is the same in the spring – Fig. 2). 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 (blue area in Fig. 2). The richer the lake, the more sediment produced and the more oxygen consumed. 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 CO_2), thus causing a rise in CO_2 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. pH is measured in 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 ($CaCO_3$). 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 ($CO_3^{=}$) and bicarbonates present. Plants utilize carbon dioxide from the water until that is exhausted and then begin to extract CO_2 from the carbonate-bicarbonate buffer system through chemical shifts. As discussed before, this decrease in CO_2 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 $CaCO_3$. 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 ($CaCl_2$), 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 (NH_3), 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 ($NO_3=$) when exposed to the oxidizing effects of oxygen. Nitrite (NO_2^-) 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.

Algae

The algae are a heterogeneous group of plants, which possess chlorophyll by which photosynthesis, the production of organic matter and oxygen using sunlight and carbon dioxide, occurs. They are the fundamental part of the food chain leading to fish in most aquatic environments.

There are a number of different phyla, including the undesirable blue-green algae, which contain many of the forms, which cause serious problems in highly eutrophic lakes. These algae can fix their own nitrogen (a few forms cannot) and they usually have gas-filled vacuoles which allow them to float on the surface of the water. There is usually a seasonal succession of species, which occurs depending on the dominant members of the algal population and the environmental changes, which occur.

This usual seasonal succession starts with diatoms (brown algae) in the spring and after the supply of silica, used to construct their outside shells (frustules), is exhausted, green algae take over. When nitrogen is depleted, blue-green algae are able to fix their own and become dominant in late summer.

The types of algae found in a lake serve as good indicators of the water quality of the lake. The algae are usually microscopic, free-floating single and multicellular organisms, which are responsible many times for the green or brownish color of water in which they are blooming. The filamentous forms, such as *Spirogyra* and *Cladophora* are usually associated with aquatic macrophytes, but often occur in huge mats by themselves. The last type, *Chara*, a green alga, looks like an aquatic macrophyte and grows on the bottom in the littoral zone, sometimes in massive beds. Recently, a new invasive, related to *Chara* and looking like a macrophytes, starry stonewort, has invaded a number of lakes in Michigan. If you notice a plant similar to *Chara* in your lake, be sure to report it, as it can be controlled in its earliest stages (Google it for a picture). It is important to understand the different plant forms and how they interact, since plants and algae compete for nutrients present and can shade one another out depending on which has the competitive advantage. This knowledge is important in controlling them and formulating sensible management plans. Samples are collected using a No. 20 plankton net (153-micron mesh), preserved with 10% formaldehyde and examined microscopically in the laboratory.

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* - See Appendix 2), 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, 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.

Zooplankton is 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 (153-micron-mesh) 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 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 Shannon-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.

RESULTS

WATERSHED

Lake Shannon is located in Livingston County and is in the Saginaw River watershed. The local watershed is mostly developed all around the lake with some lawns running right to the lake shore with no riparian buffer greenbelt zone in most. The impacts generated by these disturbances to the land are further exacerbated with lawn fertilization, which acts to degrade the watershed and contribute more nutrients (fertilizers) to the lake. Septic tanks can also contribute more nutrients into the lake. Septic tanks are NOT designed to remove nutrients from the effluent, only solids. What remains seeps into the ground water, and depending on soil conditions, a small or a large percentage of the nutrients, mostly phosphorus and some nitrates, enter the lake with the ground water flow that is continually entering the lake from the watershed. If the soils are sandy, the nutrients enter the lake quickly; if they are loamy they may adsorb some of the nutrients before they enter the lake. There is also a problem with large numbers of Canadian geese, which can bring in a considerable amount of nutrients and leave them in the lake. However, one of the most important inputs of nutrients into the lake may be from agricultural runoff into the lake through runoff and creeks that enter the lake. We did not measure discharge nor the concentration of nutrients in incoming water, so we have no idea what this contribution might be. But we believe it is probably substantial.

Intensive development and agriculture in a watershed can contribute substantially to increasing the nutrient and sediment loading to Lake Shannon and along with the storm water inputs, can cause these lakes to become highly enriched fostering large growths of aquatic plants and algae, which were common to abundant in the lake system. Symptoms of this enrichment include degraded water quality, including anoxia in the dissolved oxygen profiles, and elevated concentrations of nutrients in bottom waters. Lake Shannon probably also has a rich, thick organic sediment (we did not sample it) which has been building up naturally from the input of leaves, tree limbs, and other organic material from the wooded and agricultural watershed. Humans can accelerate the process through the building of impervious surfaces, which accelerates runoff from the inhabited areas, from fertilizers that are put on lawns, from agricultural runoff; and from septic tanks.

The overall water quality appears to be degraded, based on the September samples; however, September is not the best time to ascertain nutrient status. During September, there was an algal bloom and the lake was infested with Eurasian milfoil. Hence, most of the phosphorus and nitrates are taken up quickly by these plants. However, the very presence of the algal bloom, the very low dissolved oxygen concentrations on the bottom in the deep basin, input of nutrients from the tributaries and septic tanks all point to over fertilization of Lake Shannon. Samples need to be collected in the spring right after overturn to get a better picture of the nutrient status of the lake.

The local riparian zone is very important also. As noted above, lawn fertilization, disturbance of the lake surface for new developments, creation of impervious surfaces (tennis courts, driveways etc.), can cause additional nutrients to be exported to the lake, and further speed the enrichment process (see Appendix 1 for lawn care and other recommendations). Things that can be done to inhibit entry of undesirable and deleterious substances into the lake are planting greenbelts (thick plants that can absorb nutrients and retard direct runoff into the lake) along the lake edge, reducing erosion where ever it occurs, reducing the use of fertilizers for lawns (use no fertilizer, or at least phosphorus-free fertilizer), pumping septic tanks every 2 years, cutting down on road salting operations, not feeding the geese or ducks, no leaf burning near the lake, prevention of leaves and other organic matter from entering the lake, and care in household use of such substances as fertilizers, detergents to wash cars and boats, pesticides, cleaners like ammonia, and vehicle fluids, such as oil, gas, and antifreeze (see Appendix 1).

STATION LOCATION

We established two types of stations on Lake Shannon for sampling various parameters in this study (Fig. 3, 4; Table 1). A water chemistry sampling station was set up in the deepest part of the lake (stations A – 15 ft), while fishes were collected using seines at station S1, S2, and S3, a gill net at station G1 and G2, and trap nets at stations TN1, TN2, TN3.

Table 1. Location and description of sampling stations where water quality and fishes were collected in Lake Shannon, Livingston County, Fenton, Michigan, 1 September 2010. See Fig. 1 for locations.

Station Letter	Description/Location
A	Water quality: In the northwestern part of Lake Shannon near the spillway, depth = 15 ft
S1	Seining station south of Lobster Island, middle section
S2	Seining station in middle section on west side
S3	Seining station in middle section on west side in small bay
G1	Gill netting in middle section on west shore
G2	Gill netting in middle section in narrows on south end
T1	Large trap net set in west end by small island
T2	Large trap net set in middle section
T3	Small trap net set in middle section west of Lobster Island

Figure 1. Google map of Lake Shannon showing the major basins, several bays, and incoming creeks. The lake has a dam on the north side of the major basin.

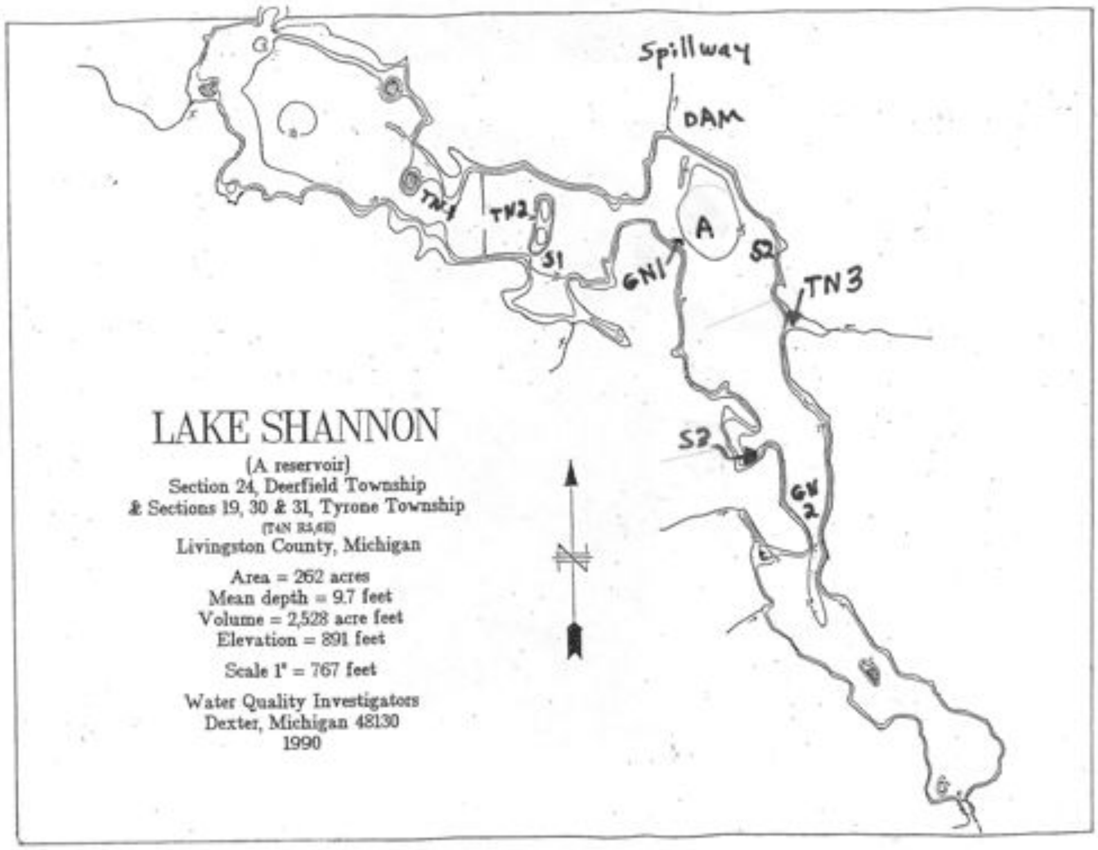


Figure 2. Map of Lake Shannon, Shiawassee Co. showing water quality sampling stations (A- see Table 1 for description) and fish sampling sites for seining (S), gill netting (G), and trap netting (TN). Fish and water were sampled on 1-2 September 2011.

PHYSICAL PARAMETERS

Depth

Lake Shannon has one shallow basin with depths at station A being around 15 ft deep near the dam face. Sediments buildup on the bottom of the basin and act as a reservoir of nutrients (nitrates and phosphorus – which are released at a faster rate during anoxic- no dissolved oxygen- conditions in late summer and winter than they would if the dissolved oxygen levels remained above zero). If sediments are thick and highly organic, like they probably are in Lake Shannon, these conditions during stratification in summer can degrade the dissolved oxygen from bottom waters at a much faster rate, reduce the water quality and hence make conditions for aquatic life much more difficult. The morphology of Lake Shannon is two major large areas of relatively deep water connected by a narrow isthmus with two smaller, shallow, macrophyte-dominated bays on the south and eastern ends of the lake. It also has a small island in the southern part of the main basin. Because it is shallow and nutrient-rich from lawn fertilization, agricultural runoff through the tributaries/ditches and septic tank seepage, luxuriant plant growth and algal blooms result.

Acreage

Lake Shannon is 262 acres based on map provided (Fig. 4). It is relatively shallow with most of it being 10 ft or less deep; the deep basin by the dam was only 15 feet deep. Winterkill is a possibility for this lake, because of these conditions, but discussions with residents, indicated that there has been few fish dieoffs. These conditions also make it a very productive lake.

Sediment

Sediment at seining station S3 (Fig. 4), in a small bay on the west side of the main basin, was thick with black organic muck with leaves and finely divided, organic material, the residue from years of rotting plant material. Our other seining sites (S1, 2) were mostly sandy with some organic material.

Light Penetration

The Secchi disc (measure of water transparency) reading at station A in Lake Shannon on 1 September 2010 was 1.4 m (4.6 ft) which is very low and may be due to a blue-green algae bloom or turbidity induced by the sport boat traffic. This measurement definitely makes this lake a eutrophic lake (highly enriched with low water transparency). Secchi disc data can provide an inexpensive, first-line indicator of water quality changes and can be carried on by the lake association. We would strongly recommend the collection of Secchi disc readings weekly to provide a record of change for the lake. These readings can also be linked with aquatic plant treatments to monitor how algae react to the ongoing aquatic plant management program. Usually if aquatic plants are killed, the rotting vegetation releases nutrients and an algal bloom often ensues. On the other hand, these blooms may also be related to runoff from the surrounding watershed. Such a data set could also shed light on the importance of rain events in promoting algal blooms during summer.

Temperature

Water temperature is intimately associated with the dissolved oxygen profiles in a lake. Lake Shannon was somewhat atypical of most lakes, since the expected strong stratification pattern we usually see during the summer was different (Table 2, Fig. 3). On 1 September 2010, water temperatures were almost 80 F at the surface (very warm) and almost 75 F on the bottom at 15-ft deep station A, a difference between surface and bottom of only 5 F. We believe this is due to the constant disturbance and mixing of the water due to boat traffic on the lake. A lake goes through a series of changes (see introductory material- Temperature) in water temperature, from spring overturn, to summer stratification, to fall overturn, to winter conditions. During both summer and winter, rapid decomposition of sediments and detritus occurs in bottom waters and can cause degraded chemical conditions on the bottom (found in Lake Shannon – will be discussed). Because the lake is essentially sealed off from the surface in summer during stratification, no dissolved oxygen can penetrate to the bottom and anoxia (no dissolved oxygen conditions- a dead zone) results. This condition has implications for aquatic organisms (fish will not go there) and chemical parameters (phosphorus is released from the sediments to contribute nutrients during the fall overturn). However, we did not see this typical pattern in the lake. Instead we found that water temperature was warmer on the bottom than what would be expected, while the dissolved oxygen was zero on the bottom (expected), but would probably be much lower and lower higher in the water column, were it not for the constant boat traffic. Boat traffic is de-stratifying the lake (breaking down the thermal barriers that usually exist in a lake during summer, resulting in re-suspension of bottom waters and warmer temperatures on the bottom). This condition is not optimal because it: 1.) mixes the bottom water with surface water. The bottom water contains fertilizers (nitrates, ammonia, and phosphorus from decomposition of bottom sediments) which promote aquatic plant growth and algal blooms, which were rampant when we sampled the lake in September, and 2.) still results in dissolved oxygen depletion from the bottom sediments, since they are apparently rich in organic matter (conditions would be much worse without the de-stratification, but you might not have such a severe algal bloom either). Not only are nitrates and ammonia released in large quantities (ammonia is toxic to fish as well as the low dissolved oxygen), but phosphorus is also released in large quantities under stratification conditions, which does not happen when the sediments have well oxygenated water above them. Hence fish are prevented from going below 13 ft (no dissolved oxygen there) and phosphorus is usually released from the sediments fueling algal blooms and plants. However, the odd thing about the nutrient data we collected, was that all nutrients, nitrates, ammonia, and phosphorus were very low, confirming that the water column was well mixed. Usually these three chemicals act in concert and are all high on the bottom during stratification on the bottom.

Table 2. Dissolved oxygen (mg/L) and water temperature (C, F) profile for Lake Shannon, Livingston County, 2010 at station A (see Fig. 3, Table 1).

DEPTH (FEET)	TEMP. C	TEMP F	DISSOLVED OXYGEN (MG/L)
0	26.6	79.9	10.3
3	26.4	79.5	10.2
7	26.3	79.3	10.2
10	24.8	76.6	6.8
13	23.9	75.0	0.4
15	23.8	74.8	0.3

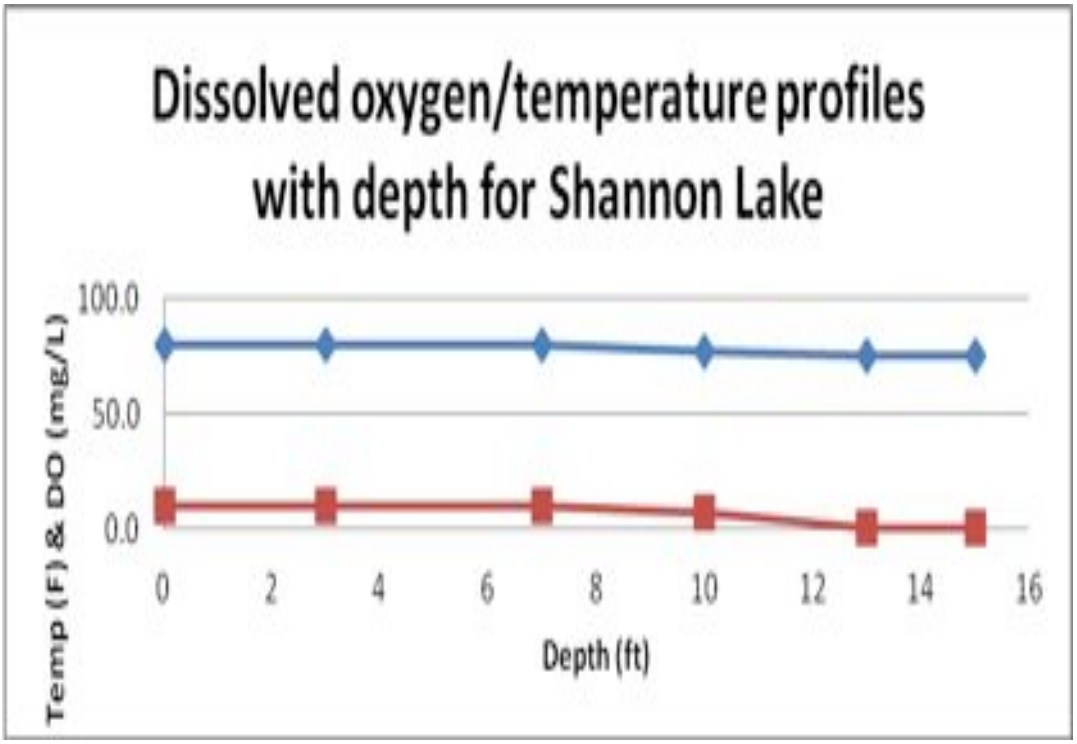


Figure 5. Dissolved oxygen (bottom red line – squares) and water temperature profile (top blue line – triangles) for Lake Shannon station A, 1 September 2010.

CHEMICAL PARAMETERS

Dissolved Oxygen

At station A on Lake Shannon, dissolved oxygen values on 1 September 2010 were 10.4 mg/L at the surface then declined to 0.3-0.4 mg/L at 13 ft to 15 ft where the lake was almost anoxic (no oxygen) (Table 2, Fig. 5). These profiles indicate that the lake is very productive with extensive decompositional processes ongoing in bottom waters. Despite the boat traffic, which tends to disrupt the stratification process, there was still enough decomposition ongoing on the bottom to remove almost all the dissolved oxygen from the bottom, but we saw equal concentrations of nutrients from surface to bottom. This has severe implications for the fish, since they will be prevented from staying in bottom waters during summer when these waters are hypoxic (low dissolved oxygen). Warm-water fish usually need a minimum of 3 mg/L to live, while walleyes, which are coolwater fish need 5 mg/L, so a considerable amount of the bottom waters are too devoid of dissolved oxygen to support fish life during this time below 13 ft.

As noted, anoxia on the bottom of a lake has some dire consequences for the ecology of the lake, since it not only affects fish and benthos survival, but phosphorus is also released from the sediments under anoxic conditions (but not when the sediments are oxygenated). When a lake shifts over to this mode, there can be some dramatic changes. This regeneration and recycling of phosphorus from the sediments under these conditions results in this important plant nutrient (P) being suspended throughout the water column in the spring turnover period (see introduction for an explanation of this). These nutrients are then available to fuel algal blooms and aquatic plants contributing to the cultural eutrophication of a lake. It appears from the dissolved oxygen data, which show hypoxia in Shannon Lake, that P was not being recycled from the bottom sediments in large quantities. More data are required to make concrete recommendations.

pH

The pH was 7.03 at the surface, 7.02 at 10 ft, and 7.01 on the bottom (15 ft), again showing the lake was mixed from surface to bottom.

Chlorides

Chloride concentrations from Lake Shannon were 60-63 mg/L at the surface, mid depth, and bottom (Table 3). They were around 14 mg/L in 1976 when we studied this lake (Freshwater Physicians 1977), so have increased substantially. Chloride ions are conservative ions, which means they are not altered by biological or chemical activity; they can only change with evaporation or input of water of differing concentrations of chlorides. Therefore they accumulate in a lake and give a good impression of the past history of inputs of that ion, as well as co-occurring substances from runoff, such as nutrients, toxic substances, and sediment. In addition, chlorides are usually well mixed with similar concentrations in the water column. We usually see a consistent concentration of chlorides from surface to bottom in a lake, unless there is an input to one of the stratified layers of the lake that would increase or decrease concentrations in that layer. For example we have seen increased levels of turbidity and chlorides associated with input of a small stream into a lake during the summer. Because of density and temperature differences, this water input accumulated at the middle or thermocline layer, causing a peak of increased turbidity and chlorides at that depth with lower concentrations at the surface and bottom layers. The levels of chlorides in Lake Shannon are moderate compared to the lakes we usually study in a more urban setting. Some lakes have up to 200 mg/L chlorides, a reflection of runoff of salt from winter salting operations and from septic tank effluent running into the lake from groundwater interception of the septic tank effluent. The moderate levels in Lake Shannon are an indication of the rural, wild setting the lake is in and apparently moderate levels of salting and septic tank inputs. In this case, chlorides may not be a good measure of input from the watershed, especially since concentrations may not reflect what we expect would be high concentrations of P and nitrates from a predominantly agricultural watershed. More data on input of nutrients would be needed to document how important this source is in providing nutrients to Lake Shannon.

Table 3. Water chemistry data for Lake Shannon, including data on nutrients (SRP – soluble reactive phosphorus, nitrates – NO3, ammonia – NH3), and chlorides - Cl. Data were collected from station A (see Fig. 1) during 1 September 2010.

Depth (ft.)	Cl mg/L	NO_3 mg/L	NH_3 mg/L	SRP mg/L
SURFACE	60	<0.01	<0.01	<0.005
8	63	<0.01	<0.01	<0.005
15	62	<0.01	<0.01	<0.005

Phosphorus

We are interested in phosphorus (P) because P is generally the limiting nutrient for plant growth and the level of concentrations can indicate the trophic state or amount of enrichment in the lake. Soluble reactive phosphorus (SRP) measures only that P which is dissolved in the water, which is the form that is readily available for algal and plant growth. Total P would be all the P in the water, dissolved and that tied up in algae or other detritus. During 1 September 2010, SRP at station A was <0.005 mg/L at the surface, mid depth and bottom (Table 3). This pattern is reflective of the mixing of the entire water column. Decomposition processes are ongoing on the bottom, which usually increases phosphorus concentrations (anoxia contributes to this), while uptake of P at the surface by plants depresses concentrations there. However, as indicated this pattern was not seen for the lake, which is unusual. Nitrate and ammonia concentrations were similar to P concentrations. Values of SRP are relatively low, since concentrations around 0.03 mg/L are required to be reached to prompt an algal bloom. Since there was a heavy blue-green algal bloom ongoing when we did the study, it suggests most of the P was taken up by aquatic plants and other algae in the lake, favoring algae that can fix their own nitrogen.

Nitrates

Nitrate is very important since it is a critical plant nutrient as well as P; however, blue-green algae can generate their own nitrogen, favoring them when nitrate concentrations are depleted. In September, nitrates were the same at all depths (<0.01 mg/L), which was somewhat surprising (see P discussion above) as we would expect to see more generated on the bottom during anoxia (Table 3). Nitrates must be rapidly taken up in Lake Shannon by the algae and plants present and mixing made concentrations the same from top to bottom.

Ammonia

Ammonia is also a plant nutrient, but it can be toxic to fish in high concentrations. It is formed by the decomposition of bottom sediments. Concentrations of ammonia in Lake Shannon on 1 September 2010 were the same at all depths at station A (Table 3).

Conductivity

Conductivity is a measure of the ability of water to conduct current and is proportional to the dissolved solutes present. Conductivity followed a general pattern of similar concentrations from surface (646 uS) to the bottom (slightly elevated at 680 uS). This supports our contention that the boat activity and aerators have mixed the lake, since many of the parameters we measured were similar from surface to bottom. The normal pattern we usually see is elevated conductivity on the bottom, which Shannon Lake appears to follow. Levels in Shannon Lake are moderate for lakes on which we have worked.

BIOLOGICAL PARAMETERS

Phytoplankton

The algae undergo a seasonal sequence of species changes from diatoms, to green algae, to blue-green algae (for more detail see methods- algae). Blue-green algae are rarely seen in oligotrophic (low in nutrients; low in productivity) lakes. Depending on how eutrophic (productive, enriched) the lake is, blue-green algae may never attain dominance, or they may just occur in the latter part of summer (the infamous "dog days"). When they occur and how early they occur are indicators of the trophic status (degree of enrichment) of a lake. Usually their appearance is related to the ratios of nitrogen and phosphorus in the lake. We did not collect algae during our study, but noted that the water was very green indicating that a probable blue-green algal bloom was ongoing. This is a bad sign of increased fertilization of the lake during summer.

Zooplankton

Zooplankton are small invertebrates present in most lakes and ponds. They are critical connectors between plants (they eat algae) and fish, since they are important as food for larval fish and other small fishes in the lake and are indicators of the amount of predation that fish exert on these organisms. Zooplankton we collected (Table 4) was comprised of several species, indicating that there is a diverse group of these organisms in Shannon Lake. The dominant species were: *Diaptomus minutus*., which are smaller copepods that are fast and can usually escape predation by fish. *Daphnia retrocurva* is a larger species and they and other daphnids are usually depleted under fish communities with an abundance of planktivores (fish that eat zooplankton), which are common in your lake (bluegills for example). We also found some *Leptodora*, which are large predaceous zooplankters, which we would expect would be reduced because of predation by fish such as bluegills and golden shiners. As noted, *Daphnia* are important since they are great fish food (large individuals) and they are more efficient at removing algae than the other groups in the sample we collected. Hence, one expects algae blooms to flourish because of the lack of control from the *Daphnia*.

Table 4. A listing of the abundance (composition based on counting a random sample of organisms) of zooplankton species found at Lake Shannon, 1 September 2010 at station A (see Fig. 4 for station locations). P = present, F=few, M=many, R=rare, A=abundant (ABUND.), V. = very.

Taxonomic group	Abundance
***Tropocyclops* – F**	**COMMON**
Ceriodaphnia	**RARE**
***Mesocyclops edax* immature**	**COMON**
***Mesocyclops edax* – M**	**FEW**
***Mesocyclops edax* – F**	**FEW**
Alona spp.	**RARE**
Daphnia retrocurva	**COMMON**
***Diaptomus* immature**	**ABUNDANT**
***Diaptomus minutus* – M**	**V. ABUNDANT**
***Diaptomus minutus* – F**	**V. ABUNDANT**
Diaphanosoma birgei	**COMMON**
Leptodora kindii	**RARE**

Aquatic Macrophytes

Because of the infestation of Lake Shannon with Eurasian Milfoil (*Myriophyllum spicatum*), the lake association carries on an extensive plant control program. The plant populations of Lake Shannon are diverse, but unfortunately Eurasian milfoil is pervasive in the lake, especially in shallow near shore areas, such as bays and tributaries. Our general feeling about the aquatic plants in Lake Shannon is that Eurasian milfoil is serious problem, justifying the intense efforts by the association to control it. Without control, there could be stunting of the panfish population and the quality of recreational activity will be diminished. Residents can help with the effort by mechanically harvesting or removing plants from their activity areas (swimming, boat access, etc.). Some information and suggestions are provided in Appendix 2. We did note that apparently application of herbicides was ongoing during our study in September. Since most herbicides only work when the plant is growing (Eurasian milfoil), application of herbicides for this plant is not efficacious after the growing season is over in late July-August.

Fish

We collected fish using a 50-ft seine (Picture 2) at three stations (at stations S1, S2, and S3), and by setting gill nets (Picture 3) at station G1 and G2 and three trap nets (stations TN1, TN2, TN3) (see Table 1, Fig. 4) on 1 September 2010 at stations throughout the lake. We never want to kill too many fish as they are so important to fish community balance in a lake (we released one channel catfish and several largemouth bass). The first seine haul at station S1 was done around 3 pm on the shoreline near Lobster Island; we did two tows parallel to shore. One was 40 yards and the other was 45 yards. The second seine collection site (S2) was on the east side of the lake, south of the dam on a sandy beach area. The last station (S3) was located on the west shore in the small bay and was done around 4 pm.

Picture 3. The 50-ft seine deployed at two sites on Lake Shannon, 2 September 2010.

Picture 3. Gill net deployed in Shannon Lake, 2 September 2010.

We set two gill nets: one was set by the seawall on in the main basin along the north shore from 1220 to 1515 on 1 September 2010; then it was reset overnight from 1555 to 1000 the next day (see Fig. 4) The second gill net was set from 1340 to 1540 at the narrows; then reset overnight from 1340 to 1015 the next day.

We also set three trap nets overnight. The first was set at 1240 in the lee of Kerry Island (Fig. 4); it was pulled the next day at 1030. The second was set 1310 on the north side of Blarny Island. The third trap net (a small one) was set at 1400 in a small bay (Fig. 4) on the northeast side of the main lake. Additional fish were graciously provided by fisherman on the lake.

Picture 4. Trap net deployed along the west shore of the main basin.

Fish Community Diversity

Overall we collected 19 species including species collected by Freshwater Physicians, Inc in 1976 (Freshwater Physicians 1977): bowfin, black crappie, bluegill, largemouth and smallmouth bass, pumpkinseed, Johnny darter, yellow perch, black and yellow bullhead, common carp (35 inches), brook silversides, channel catfish, walleye, northern pike, spotfin shiner, bluntnose minnow, common shiner, and golden shiner (Picture 5) (Table 5). Top predators included: largemouth bass, walleye, channel catfish, and northern pike. Yellow perch and black crappies also are predators at larger sizes. Black and yellow bullheads were also collected which can be piscivores at times. Among the Centrarchidae (sunfish family) besides the largemouth bass noted, there were black crappies, bluegills, and pumpkinseeds. Presence of Johnny darters, small members of the perch family, golden shiners, bluntnose minnows, common shiners, spotfin shiners, and brook silversides, provide a great diversity of prey for predators and diversity the fish community. Golden shiners in particular are excellent forage species, since they are fecund, abundant, attain large sizes and hence provide forage for the bigger predators in the lake, and they are pelagic (inhabiting the water column, rather than benthic (near bottom). This is a great diversity of fishes and provides a variety of fishing opportunities and a well balanced fish community.

Table 5. List of fish species collected or observed at various places at Lake Shannon, 1 September 2010. Given is the common name and scientific name of each species.

*Data from August 1976 (Freshwater Physicians 1977. A Limnological and Biological study of Shannon Lake, Livingston County, Mich. – Summer, 1976. 5293 Daniel Dr., Brighton, MI).

Fish Code	**Taxon**	**Scientific Name**
BB*	BLACK BULLHEAD	*Ictalurus melas*
BC	BLACK CRAPPIE	*Pomoxis nigromaculata*
BG	BLUEGILL	*Lepomis macrochirus*
BM	BLUNTNOSE MINNOW	*Pimphalus notatus*
BF*	BOWFIN	*Amia calva*
SV	BROOK SILVERSIDES	*Labidesthes sicculus*
CC	CHANNEL CATFISH	*Ictalurus punctatus*
CP	COMMON CARP	*Cyprinus carpio*
CS*	COMMON SHINER	*Luxilus cornutus*
GL*	GOLDEN SHINER	*Notemigonus crysoleucas*
JD	JOHNNY DARTER	*Etheostoma nigrum*
LB	LARGEMOUTH BASS	*Micropterus salmoides*
NP	NORTHERN PIKE	*Esox lucius*
PS	PUMPKINSEED	*Lepomis gibbosus*
SB	SMALLMOUTH BASS	*Micropterus dolumieu*
SF	SPOTFIN SHINER	*Cyprinella spiloptera*
WL	WALLEYE	*Sander vitreus*
YB	YELLOW BULLHEAD	*Ictalurus natalis*
YP	YELLOW PERCH	*Perca flavescens*

Picture 5. Some of the fishes collected during this study, 2 September 2010, from Shannon Lake. Shown are: northern pike, bluegill, largemouth bass, and common carp.

Fish Diets

When the diets of these fish were examined (Table 5), we found that small black crappies were eating zooplankton as expected. The large individuals from 7/8-9.9 inches were consuming considerable numbers of young-of-the-year bluegills and some cannibalism was also noted. In addition, some zooplankton and benthos (aquatic insects – chironomids) were also eaten.

Picture 6. Black crappie with several young-of-the-year bluegills in its stomach. Fish was collected from Shannon Lake, 2 September 2011.

Table 5. Listing of the species collected, length, weight, sex, and diet information for fishes from Lake Shannon, Livingston County, MI 1 September 2010. LB=largemouth bass, SB = smallmouth bass, BC = black crappie, BG = bluegill, PS = pumpkinseed, BM = bluntnose minnow, JD = Johnny darter, YB = yellow bullhead, NP = northern pike, SV = brook silversides, WL = walleye, YP = yellow perch, CC = channel catfish, XX = unknown fish, NA = not available, ZOOP = zooplankton, M = male, F= female, 1= poorly developed gonads. MT = empty stomach. OK

Species	Length (Inches)	Weight (ounces)	Sex	Diet
CHANNEL CATFISH				
CC	28	RELEASED		
BLACK CRAPPIE				
BC	2.8	0.1	II	MT
BC	3.0	0.1	II	zoop
BC	3.0	0.1	II	zoop
BC	7.8	4	F1	zoop
BC	8.0	4.4	F1	BG-1.8,1.2 in
BC	8.2	4.7	M1	BG-1.2
BC	8.5	5.1	M1	zoop
BC	8.7	5.6	F1	zoop
BC	8.7	6	F2	zoop, chironomids

BC	8.7	5.8	M1	zoop
BC	8.8	5.4	F2	xx
BC	8.8	6.3	M1	xx, zoop
BC	8.8	5.3	M1	zoop
BC	9.0	6.8	F1	BG-1.5,1.7 BC-2.6,2.4
BC	9.1	6.4	F2	MT
BC	9.1	7.3	M1	zoop; parasite
BC	9.1	6.7	M1	zoop
BC	9.2	6.9	M1	zoop, xx
BC	9.3	7	M1	MT
BC	9.3	6.9	F1	MT
BC	9.9	8.5	F1	BC-1.8,2.6,48 BG-1.4,1.8,1.8
BC	3.0	0.1	II	zoop
BLUEGILL				
BG	1.1	0.1	II	zoop
BG	1.7	0.1	II	
BG	2.0	0.1	II	
BG	2.2	0.1	II	
BG	2.2	0.1	II	
BG	3.0	0.1	II	zoop
BG	3.2	0.1	F1	chironomids
BG	3.4	0.2	II	chironomids
BG	4.2	0.9	II	plants
BG	4.4	0.9	II	?chironomids
BG	4.6	0.9	II	chironomids
BG	5.0	1.2	F1	MT
BG	5.2	1.4	F1	plants
BG	5.5	1.8	F1	plants
BG	5.5	1.8	II	plants
BG	5.8	2	F1	MT
BG	6.3	2.8	F1	MT
BG	6.5	2.8	M1	plants
BG	6.5	2.9	x	MT
BG	6.7	3.1	M1	chironomids, plants
BG	6.8	3.1	F1	plants
BG	6.9	3.7	F1	MT
BG	7.0	3.7	F2	plants
BG	7.0	3.8	M1	plants
BG	7.2	4.2	F1	MT
BG	7.2	3.7	M1	MT
BG	7.2	3.9	M1	MT
BG	7.4	4.1	F1	chironomids
BG	7.4	4.2	F1	MT
BG	5.4	2.3	F1	MT
BLUNTNOSE MINNOW				
BM	1.9	0.1		
BM	1.9	0.1		
BM	1.9	0.1		
BM	2.0	0.1		
BM	2.0	0.1		
BM	2.2	0.1		
BM	2.4	0.1		
BM	3.1	0.1		

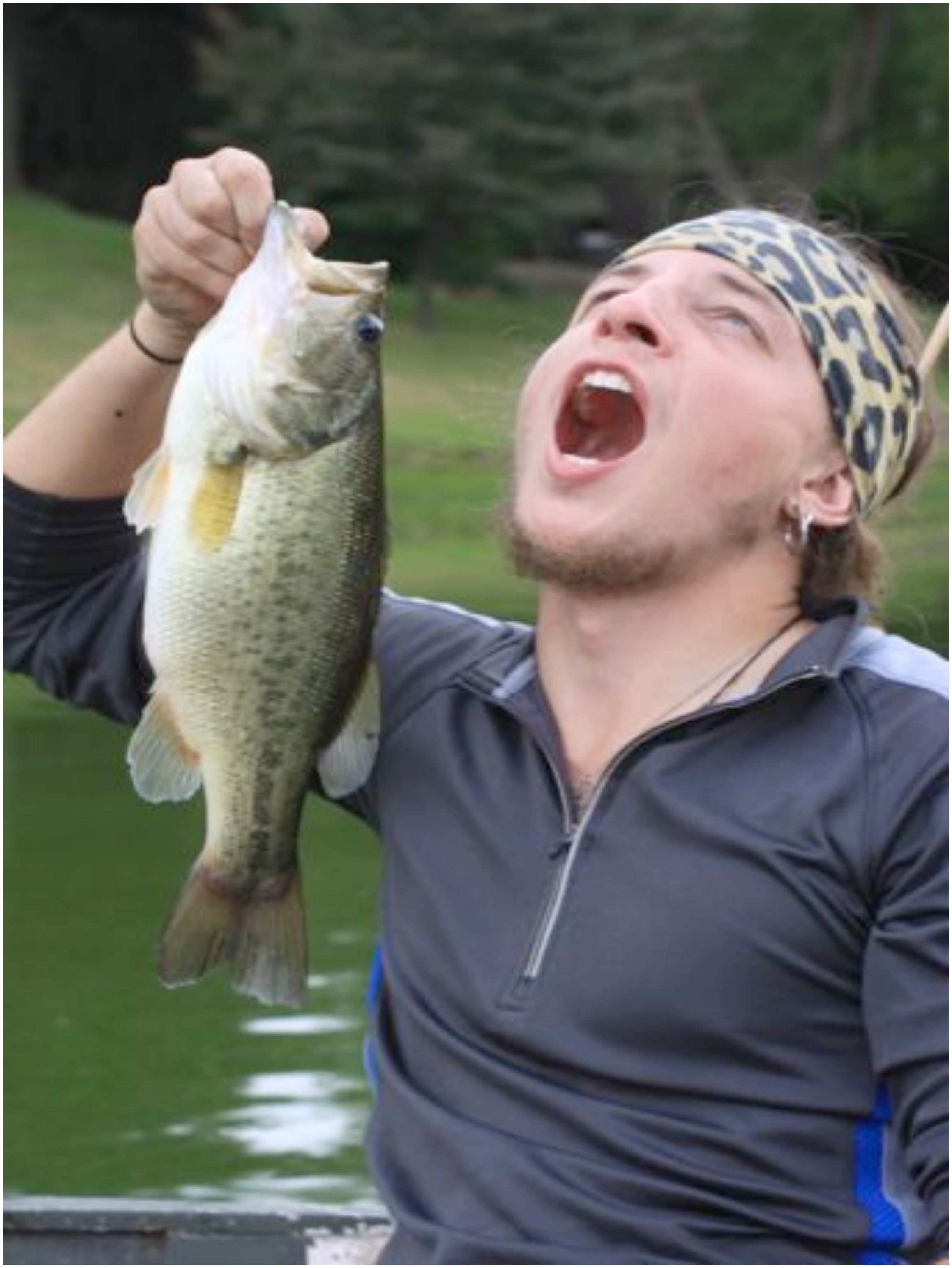
JOHNNY DARTER					
JD	2.1		0.1		
LARGEMOUTH BASS					
LB	2.6		0.1		
LB	2.8		0.1	II	larval BG
LB	2.8		0.1	II	MT
LB	3.7		0.2	II	BG-1.2 in
LB	4.1		0.7	II	BG-1.2 in
LB	4.2		0.6	II	BG-0.8 in
LB	4.3		0.4	II	BG-0.4 in
LB	4.5		1	F1	MT
LB	4.6		0.8	II	BG-1.4 in
LB	4.6		0.7	II	XX
LB	4.9		1.1	II	BG-0.8,0.8 in
LB	5.0		1	II	BG-0.5,0.8,1.2 in
LB	5.0		0.9	F1	XX Fish remains
LB	5.3		1.2	F1	BG-0.5
LB	5.4		1.3	II	larval BG-0.8 in
LB	5.5		1.3	F1	MT
LB	6.8		10.9	F1	?BG-1.8 in
LB	7.9		4	F1	XX Fish remains
LB	10.5		9.8	M1	BC-2.6,BG-0.8,1.2,1.7 in; ?BG-1.8 in
LB	16.3	5--6			HOOK LINE CAUGHT; RELEASED
LB	16.3	5--6			HOOK LINE CAUGHT; RELEASED
LB	17.5	6--7			HOOK LINE CAUGHT; RELEASED
LB	18.5	7--8+			HOOK LINE CAUGHT; RELEASED
LB	19.5				HOOK LINE CAUGHT; RELEASED
LB	19.5	8--9			HOOK LINE CAUGHT; RELEASED
LB	20.5	7--8			HOOK LINE CAUGHT; RELEASED
LB	20.5	7--8			HOOK LINE CAUGHT; RELEASED
LB	20.5	6--7			HOOK LINE CAUGHT; RELEASED
LB	22.3	8--9			HOOK LINE CAUGHT; RELEASED
NORTHERN PIKE					
NP	27.5		62.2	M1	MT
PUMPKINSEED					
PS	7.1		4.3	F1	MT
SMALLMOUTH BASS					
SB	3.5		0.2	F1	MT
SB	3.8		0.4	II	MT
SB	4.7		0.9	II	BG-larval
SF	3.0		0.2		
SF	3.1		0.2		
SF	3.3		0.2		
SF	3.5		0.2		
SF	3.8		0.2		
BROOK SILVERSIDES					
SV	2.6		0.1		
SV	2.9		0.1		
SV	2.9		0.1		
SV	3.0		0.1		
SV	3.1		0.1		
SV	3.2		0.1		
WALLEYE					

WL	10.3	5	F1	MT
WL	12.8	9.8	F1	MT
WL	14.0	13	F1	MT black grub
WL	14.5	14.4	F1	XX
WL	14.7	14.9	F1	BG-1.8,1.2,1.5 in
WL	14.9	16.5	F1	MT black grub
WL	24.0	71.5	F5	MT
YELLOW BULLHEAD				
YB	10.4	9.7	M1	MT
YB	10.9	13.8	F1	YP-4.3 in
YELLOW PERCH				
YP	2.9	0.1	II	zoop
YP	3.0	0.1	F1	MT
YP	3.0	0.1	II	MT
YP	3.3	0.2	F1	chironomids
YP	3.3	0.2	F1	zoop
YP	3.5	0.1	F1	MT
YP	4.2	0.3	II	chironomids
YP	5.3	0.9	M1	chironomids
YP	5.7	1	F1	MT
YP	5.9	1.1	F1	MT
YP	6.0	1.1	M1	chironomids
YP	6.1	1.4	M1	MT
YP	6.2	1.3	M1	BG-1.8 in
YP	6.4	1.4	F1	SV-2.6 in
YP	6.5	1.4	F1	chironomids
YP	7.1	2.1	M1	MT
YP	7.3	2.3	F1	BG-1.8 in
YP	7.7	2.7	F1	MT
YP	7.8	2.8	F1	MT
YP	8.6	4.2	F1	JD-2.0, BG-1.2,2.2 in

We also examined a large number of bluegills; the small ones were eating zooplankton and some chironomids, while the larger individuals consumed mostly aquatic insects (chironomids) and some were eating aquatic plants (Table 5). Eating plants is probably an attempt to get benthos and indicates food is scarce during this time for bluegills. Usually they eat zooplankton when they are small and switch to benthos when they grow to larger sizes. Some will eat fish if given the opportunity.

Picture 7. Bluegill and black crappie caught in Lake Shannon, 1 September 2010.

Largemouth bass (Picture 8) are known predators and those we examined from 3 to 10 inches were eating small bluegills (1-2 inches long) and some were eating black crappie young (Table 5). One was eating an unknown species, probably another bluegill. This is typical for largemouth bass and maintains the community relationships preventing stunting among the panfish. Diets of larger bass were not examined, since they were released. We would expect them to be also eating bluegills, black crappies, some minnows, and yellow perch (rarely). and several other unknown species, probably bluegills. It appears that the fish are eating species they are supposed to and also growing adequately (see next section).



Picture 8. Largemouth bass.

Small yellow perch we examined from 4 to 5 inches had eaten zooplankton and benthos (chironomids) (Table 5, Picture 9). The larger fish from 6 to 9 inches were also eating aquatic insects (chironomids), but also a variety of forage fishes, including: bluegills, Johnny darters, and brook silversides. Yellow perch are important prey of top predators, especially walleyes and northern pike, as well as important sport fish. Thus they tend to have a reduced population in a lake like Shannon with a plethora of predators.

Picture 9. Yellow perch with a young-of-the-year bluegill in its stomach. Fish was collected from Shannon Lake, 2 September 2011.

We obtained data on walleyes for two fish; the rest were released, had empty stomachs, or not data were given when we obtained scales for ageing. Those two fish had eaten bluegills and unknown fish (Table 5). In addition, black grubs (small black spots) were observed on two walleyes. Black grubs or black spot disease which we observed is commonly observed in rock bass and other sunfish, bass, pike, perch, minnows, and other fish species. It can be identified by the presence of small black spots, usually about the size of a pin head, in the skin, the fins, the musculature, and the mouth of the fish can be affected. The black spots are caused by pigment that the fish deposits around the larval stage of a parasitic, digenetic trematode, usually a *Neascus* or *Uvulifer* spp.

The lifecycle of the "black spot" parasite is complex. The adult parasite is found in a fish-eating bird, usually a kingfisher. The kingfisher eats a fish and the larval parasite is transferred from the infected fish to the bird during the feeding and digestion process. The larval stage develops into an adult parasite in the kingfisher. The adult parasite in the intestine of the bird then produces eggs that are eventually deposited in the water. There the eggs mature, hatch, and develop into the miracidium stage of the parasite. The active swimming miracidium penetrates into (infects) a snail in the lake. In the snail, the miracidium develops into the cercaria life stage. The cercaria (another actively swimming stage) leaves the snail and actively seeks and penetrates a host fish. The parasite then becomes encysted within the fish. In about 22 days, black spots form around the cyst.

This entire life cycle takes at least 112 days to complete. This cycle is also similar to "swimmers itch", a schistosome parasite that inadvertently penetrates humans, and helps understand why treating water with copper sulfate, which kills snails, will help reduce the incidence of this nuisance.

In general, presence of the "black spot" parasite does not affect growth or the longevity of the infected fish; however massive infections in young fish may cause fish mortality. The parasite is incapable of infecting humans and, as is the case with all fish parasites, it is destroyed by thorough cooking. When fish are heavily infected, some anglers prefer to remove the skin to improve the appearance of the cooked fish. The life history of this parasite can be disrupted by using copper sulfate to kill snails, but this has side effects, such as killing algae and one might have a buildup of toxic copper in the sediments if prolonged treatment is promulgated.

For further information see:

Parasites of North American Freshwater Fishes by G. L. Hoffman

We seined several smallmouth bass young-of-the-year which is an excellent sign of reproduction for this species, which usually does not do well in reservoir situations. One was eating larval bluegills.

One yellow bullhead was eating a 4.3-inch yellow perch, showing they too can become predators under some circumstances. The northern pike we collected had an empty stomach. One large (28 inch) channel catfish was collected in a gill net set at the narrows. This fish was trying to eat one of the crappies in the net; it was released. It indicates that the stocked channel catfish in the lake have grown to large sizes and they will provide a good, top-down predation pressure on the forage fishes and help to maintain a balanced population, which promotes good growth. These fish also provide another opportunity for sport fisherman.

Growth of Fishes

Growth of the fishes we collected was determined by ageing a sample of fish of various sizes using scales. Generally all the species we examined were growing near the average growth exhibited by Michigan fishes (Latta 1958, DNR pamphlet no. 56), with the exception of walleyes, which were growing slower than Michigan averages (Table 7).

Table 7. Growth of selected fishes collected from Lake Shannon, Shiawassee County, 2010. Fish were collected in seines, gill nets, and trap nets, scales removed, aged and compared with Michigan state averages (see Latta 1958). Shown is the age of the fish, the mean age reached by fish collected and compiled from MDNR sources, and the size-at-age determined from the fishes we collected during this study.

AGE GROUP	STATE OF MICHIGAN	SHANNON LAKE
	BLUEGILL	
0	2.1	3.2(1)
1	2.9	3.8(2)
2	4.3	
3	5.5	5.4(3)
4	6.5	6.6(3)
5	7.3	
6	7.8	
7	8	
8	8.5	
9	8.5	
10	9.2	
	PUMPKINSEED	
0	2	
1	2.9	
2	4.1	
3	4.9	
4	5.7	
5	6.2	7.1(1)
6	6.8	
7	7.3	
8	7.8	
	LARGEMOUTH BASS	
0	3.3	3.8(6)
1	6.1	5.9(3)
2	8.7	7.9(1)
3	10	10.5(1)
4	12.1	
5	13.7	
6	15.1	
7	16.1	
8	17.7	
9	17.9	19.5(1)
	BLACK CRAPPIE	
0	3.1	2.9(3)

1	4.3	
2	5.9	
3	8	
4	9	8.5(4)
5	9.9	9.3(4)
6	10.7	
7	11.3	
8	11.6	

YELLOW PERCH

0	3.3	3.3(6)
1	4	
2	5.7	
3	6.8	6.1(3)
4	7.8	7.5(4)
5	8.7	8.6(1)
6	9.7	
7	10.5	
8	11.3	

NORTHERN PIKE

0	7.9	
1	15.5	
2	19.4	
3	22.2	
4	23.9	
5	25.4	
6	27.7	27.5(1)
7	32.5	
8	37.1	
9	34.8	
10	44.4	

SMALLMOUTH BASS

0	3.4	4(3)
1	6.1	
2	9.2	
3	11.3	
4	13.3	
5	14.9	
6	15.7	
7	16.8	
8	17.5	
9	18.5	
10	19.2	

WALLEYE

0	7.1	
1	9.5	
2	13.3	
3	15.2	13.75(8)

4	17.2	14.25(2)
5	18.6	16.5(1)
6	19.2	
7	19.6	19.5(2)
8	21.6	
9	21.4	
10	25.2	

For bluegills, growth rates above state averages for YOY (young of the year) and 1-yr olds, while for the 4 and 5 year olds, fish were growing similar to those averages determined for the state using the Latta data (Figs. 6, Table 7).

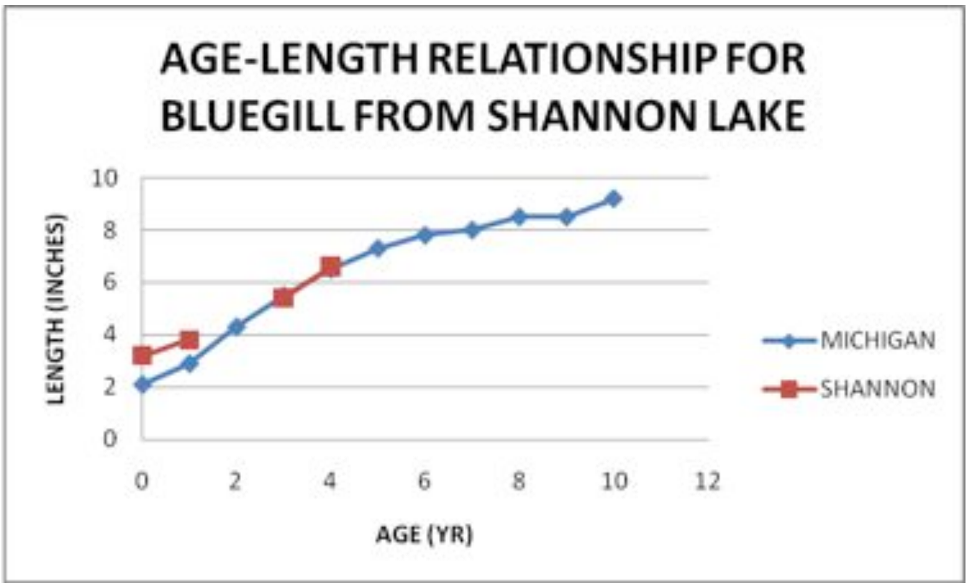


Figure 6. Growth of bluegill in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

For largemouth bass, growth rates were similar for all ages, up to the 9-year old fish (Fig. 7, Table 7). Considering we had a low sample size and the abundance of food in the lake for largemouth bass is excellent, we think the population is growing well and in great balance. Part of the reason for their abundance is that catch and release is practiced; we highly recommend this practice for most top predators as it maintains balance in the prey fish community.

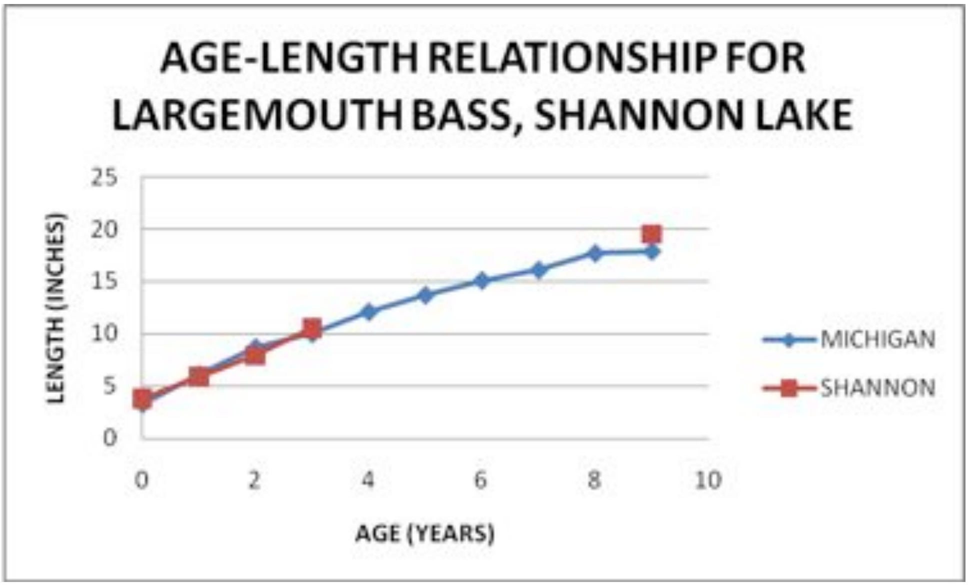


Figure 7. Growth of largemouth bass in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

Growth of black crappie generally was at or slightly below length-at-age data for state of Michigan averages (Picture 10, Fig. 8). We have reports of a large population of black crappies in the lake; sport fisherman catch them in large numbers during the summer and especially winter. We also collected large numbers of crappies in one of the trap nets set near the island; we released most of them. Thus this population appears to be growing adequately, is abundant, provides a great sport fishery, and will assist in maintaining good predator-prey relationships, especially in controlling sunfish young populations from stunting.

Picture 10. Numerous black crappies being re-deposited into Shannon Lake.

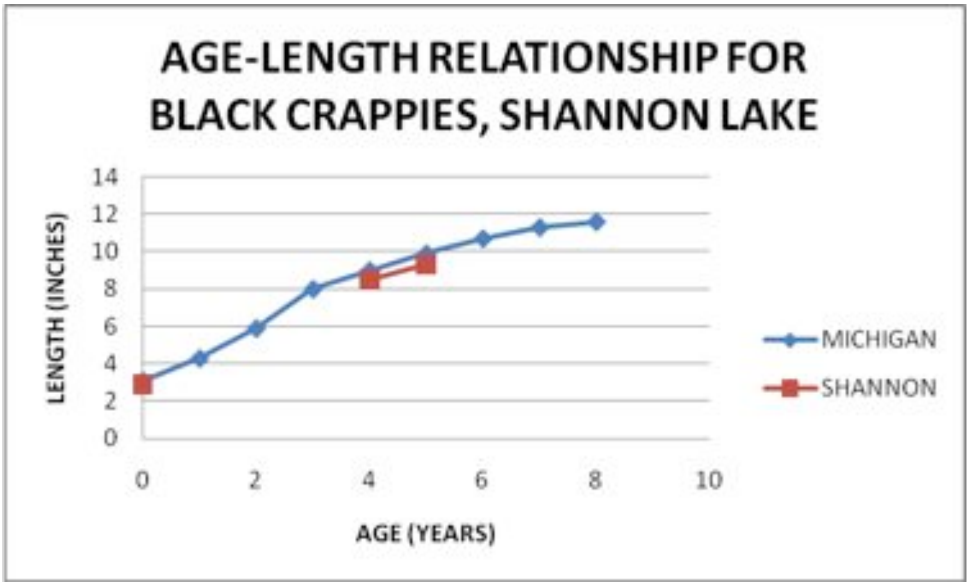


Figure 6. Growth of black crappie in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

Yellow perch growth was similar to that of black crappie, with Shannon Lake average sizes at age similar to, but slightly below state averages (Fig. 9). As noted, we believe yellow perch are targeted prey for several of the top predators in the lake as well as by sport fisherman, so we expect populations to be lower than some of the other species in the lake, which escape predation once they grow large enough (e.g., black crappies).

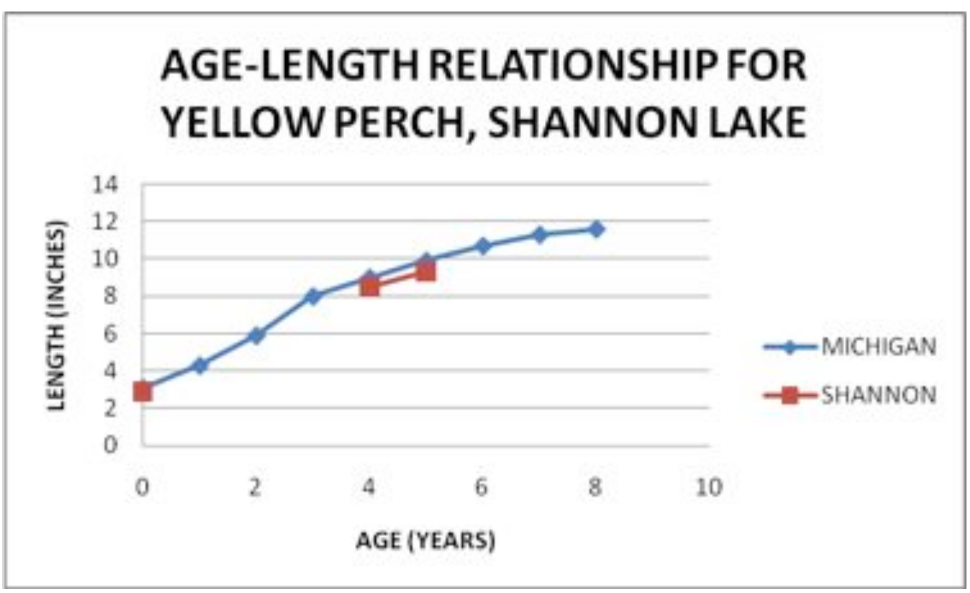


Figure 9. Growth of yellow perch in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

We only collected one pumpkinseed and it was growing slightly above state averages for 5-yr 0ld fish (Fig. 10)

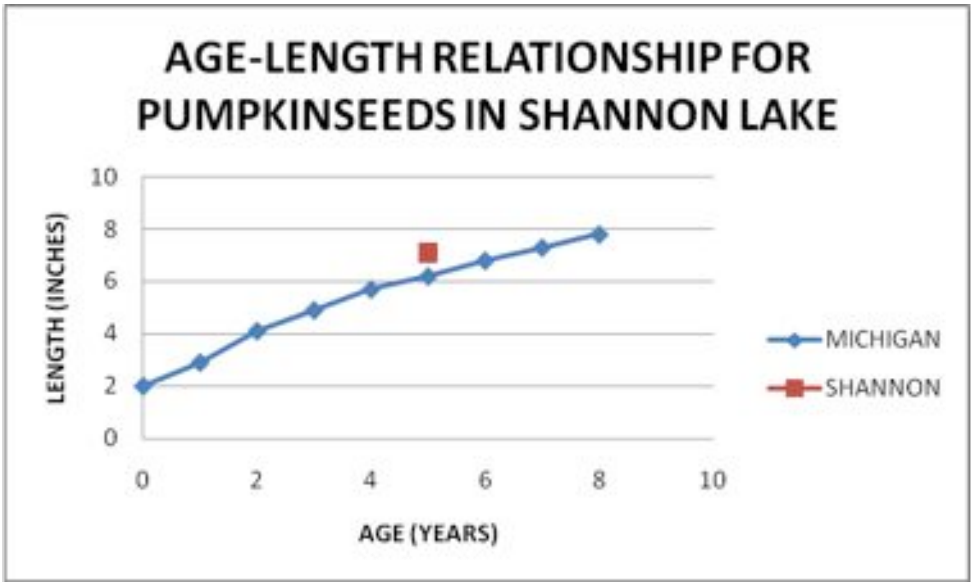


Figure 10. Growth of pumpkinseed in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

We collected only one northern pike, which is somewhat strange, but we believe that they are abundant in the lake, since they have optimal habitat for spawning; unfortunately, the warm water and low dissolved oxygen will have a detrimental effect on northern pike, since they like walleyes, are coolwater fish and require cool water to grow well. The one we did collect (6-yr old fish) was growing at state averages (Fig. 11).

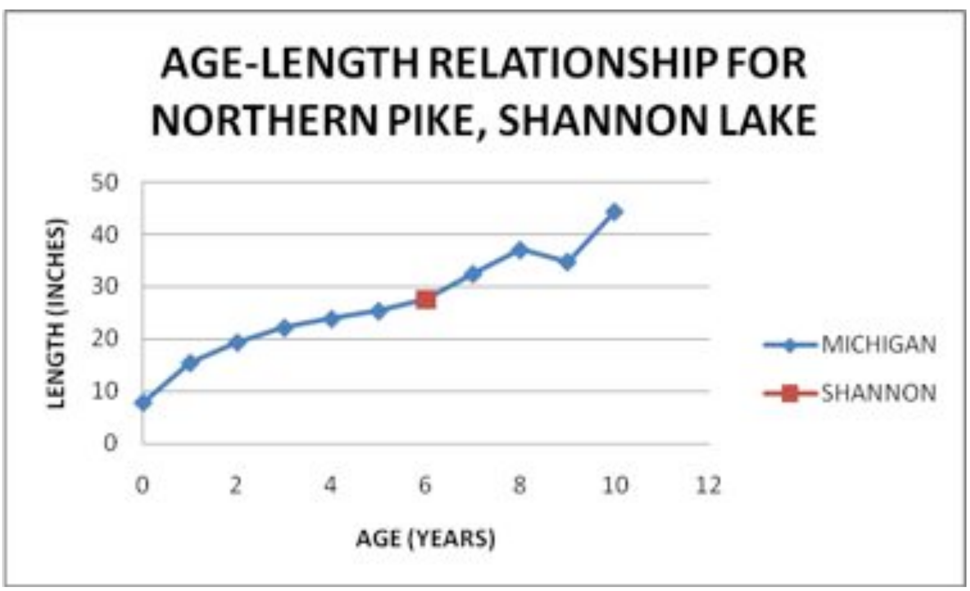


Figure 11. Growth of northern pike in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

We collected a number of YOY smallmouth bass, which were growing at state averages (Fig. 12). This species usually does better in cooler water situations, but appears to be flourishing if natural reproduction as we documented is ongoing. They are also being caught regularly by sport fisherman. Stocking additional fish probably will not help this population expand in the lake, unless adult numbers drop substantially.

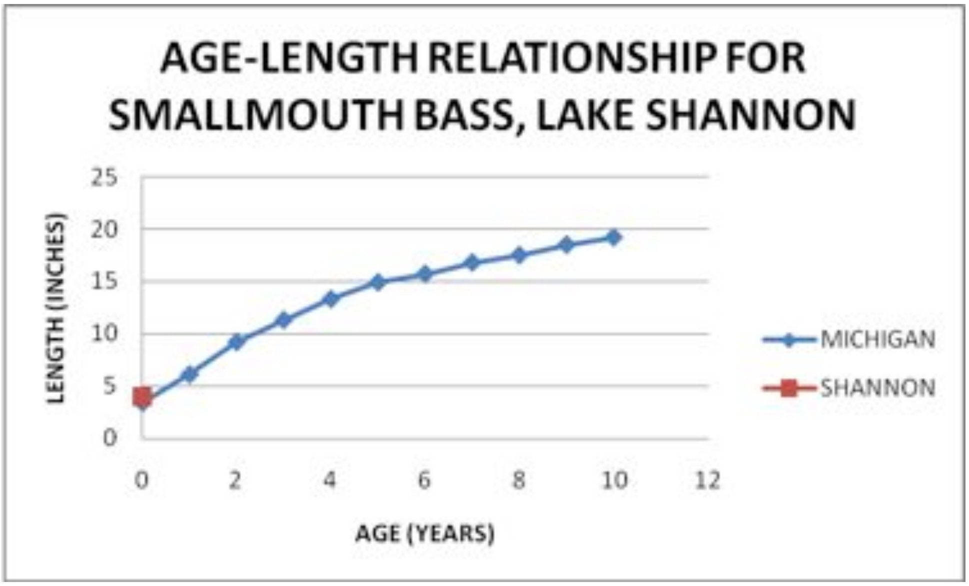


Figure 12. Growth of smallmouth bass in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

Walleyes were stocked into Shannon Lake and apparently are doing quite well, despite the poor water quality for their survival in the lake (Picture 10). As noted, water temperatures at the surface were near 80 F during our study and dissolved oxygen was near zero from 13 to 15 on the bottom where these fish like to reside. Hence we believe they are stressed fishes during this period of time (summer) and probably do not grow well, something we also suspect for northern pike. We aged about 13 fish and found as thought, that they are growing below state averages, with the exception of the 7-year old fish that are growing at state averages (Fig. 13). They appear to be rare to common in the lake, based on fishermen reports and our limited gill netting, which only collected them at one site: the narrows. They probably should not be stocked, but since they appear to be surviving under these severe conditions in summer, we have no problem if you wish to stock additional fish into the lake, as long as huge numbers of them are not stocked. We have seen situations where too many were stocked and they had a detrimental effect on prey fish in the lake. The MDNR does not recommend stocking walleyes into an existing fish community, especially a warm water fish community. We also do not believe any spawning will occur in the lake.

Picture 10. Walleyes from Shannon Lake, 2 September 2011. Fish were collected in gill nets.

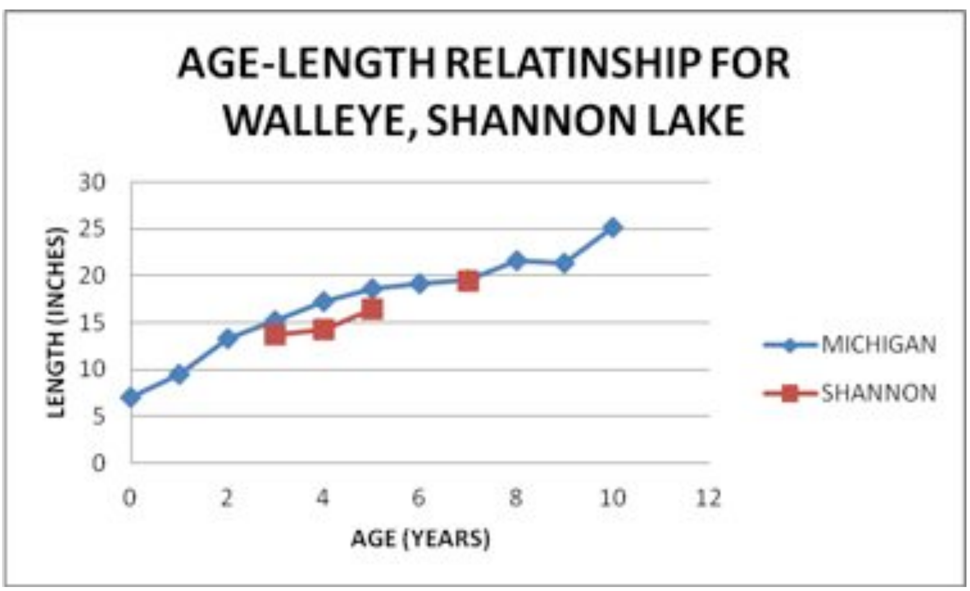


Figure 13. Growth of walleye in Lake Shannon (squares) compared with the Michigan state averages (diamonds) (see Latta 1958).

In addition, mercury is a problem in most of Michigan's inland lakes (see MDNR fishing guide for recommendations on amount of fish to eat). Most mercury comes to the watersheds of lakes through deposition from the air with most coming from power plants burning coal. The elemental mercury is converted to methyl mercury through bacterial action or in the guts of invertebrates and animals that ingest it. It becomes rapidly bioaccumulated in the food chain, especially in top predators. The older fishes, those with less fat (yellow perch, bluegills, crappies, walleyes for example), or those high on the food chain or old will carry highest levels. Studies we have done in Michigan lakes and studies by the MDNR have shown that large bluegills, largemouth bass, black crappies, northern pike, and walleyes all contain high levels of mercury. This suggests that fishers should consult the Michigan fishing guide for recommendations on consumption, limit their consumption of large individuals, and try to eat the smaller ones. It also suggests that a trophy fishery be established for large northern pike and largemouth and smallmouth bass (and channel catfish), and some of the larger individual panfish in the lake.

DISCUSSION

To summarize the results, Lake Shannon would probably be classified as eutrophic due to its shallowness (15 ft maximum depth), hypoxia on the bottom of the lake, warm-water fish population, blue-green algae blooms in summer, and probable regeneration of P and N from thick and nutrient-rich sediments. It appears also to receive excessive nutrients from development around the lake (lawn fertilization, runoff from these lawns, septic tanks) as well as large periodic inputs from the creeks and run off that enters the lake from the agriculturally dominated watershed. In addition, Lake Shannon is unusual in that we suspect that boat traffic during summer is de stratifying the lake. This results in the loss of the cool water layer in the lake, which is important for cool water fishes, such as northern pike. This has implications for the fish community, which is also a typical warm-water complex, but has the problem of the presence of common carp and the loss of cool water habitat creates a poor environment for consideration of promoting northern pike and walleyes (coolwater species) in the lake. Another problem in the lake is the presence of Eurasian milfoil, a non-indigenous macrophyte, which is abundant in the lake and undergoes intensive treatment by the lake association. Excessive exotic plant growth can lead to stunting of sunfish (not observed) and clogging of large portions of the lake, which can lead to problems which can inhibit swimming and boating in their vast beds. This problem is being dealt with by the lake association and we support their efforts to keep this exotic species in check. However, we do not support treating aquatic plants in the fall with herbicides, which appears to have happened when we were there in September 2010. A summary of the chemical and biological indicators used to characterize the lake (see Table 8 for a quick summary of items discussed above and summarized succinctly).

Table 8. A compilation of the various chemical and biological measures for Lake Shannon and a qualitative assessment (good, bad, no problem) in general. + = positive, 0 = as expected, - = negative. "See guidelines" refers to Appendix 1 – guidelines for lake residents to reduce nutrient input into the lake.

Condition Documented	Qualitative assessment	Problem Potential	Action to Take
		Physical	
Water Clarity	-	reduces visibility for fish	Secchi Disc program, reduce P
Water Depth	-	sediment buildup	Drawdown being done
Water Temp.	-	Warm up; mixes	Boat traffic?
Sediments	-	thick, highly organic	Drawdown being done
		Chemical	
pH	0	None	None
Diss. oxygen	-	hypoxia, boat traffic?	nutrient reduction
Chlorides	0	None	None
Nitrates	+	No Buildup	See Guidelines;reduce P
Ammonia	-	No Buildup	See Guidelines;reduce P
SRPhosphorus	+	No Buildup on bottom	See Guidelines;reduce P
		Biological	
Algae	-	Blue-green algae bloom	Reduce P input
Macrophytes	-	Eurasian milfoil	2,4-D,SONAR
Fish			
Northern pike	0	Seem adequate	Monitor, no stocking
Largemouth bass	+	YOY present;growing well	None; adequate spawning
Smallmouth bass	+	YOY present:excellent	None; adequate spawning
Bluegill	+	Adequate	Maintain predator balance
Yellow perch	+	Adequate	Monitor; do not stock
Common carp	-	Increase turbidity	Harvest: archers, trammel net
Walleye	+	Stressed	Stock if want; not recommended
Black crappie	+	Abundant, growing well	None; adequate spawning
Channel catfish	+	In lake; provide predation	Monitor; stock if needed
Forage fish	+	Abundant, diverse	Monitor; good outlook now

My major concerns are itemized below:

1. Fish Management

Despite probable complaints from fisherman, we do not see any major problems with most of the fish community in Lake Shannon, with the exception of two issues. The fish species complex is diverse (19 species).

A. The eutrophic (enriched) nature of the lake is a fundamental problem that on one hand contributes to the productivity of the lake, but on the other is detrimental to the fish community – namely northern pike and walleyes. High concentrations of nutrients encourage Eurasian milfoil growth and algal blooms, which produces thick cover for prey (promotes stunting) and decreases water clarity, making it more difficult for predators to catch prey. Efforts should be encouraged to reduce the nutrient input to the lake by the residents (see Appendix 1) by not fertilizing their lawns at all or at least using non phosphate fertilizers, since it is common knowledge that most lawns need nitrates not P. You should also do whatever can be done in the watershed to encourage riparian vegetation near streams to take up runoff and other best management practices to reduce runoff from agricultural fields in the watershed.

B. Catch and release for large predators (largemouth bass and any northern pike still present) should be enacted in the lake. These fish are valuable as keystone predators helping to control stunting of young fish, should be caught more than once by sport fishers, and are probably full of mercury anyway, and should not be eaten.

C. Largemouth and smallmouth bass young-of-the-year were collected and there is suitable spawning habitat for bass, hence it appears they are present in adequate numbers, are eating what we expect – bluegills, and growing similar to state averages. We can say the same for yellow perch, bluegills, and black crappies. Stocking any of these species would be a waste of your money, since they appear to be reproducing adequately. Sometimes placement of baskets of gravel into areas that are covered with soft, mucky sediments can provide spawning substrate for largemouth bass and panfish. We did not do enough work in this area (snorkeling or dredge samples) to evaluate whether there is adequate gravel and sandy substrate in the lake. From our seining it appears there are several areas with sandy substrate of this type.

D. We collected only one northern pike but believe this species is common in the lake. There certainly is adequate spawning substrate for this species. Evidence of reproduction would be the catching by fisherman of small "hammer handles". If they are then adequate spawning is ongoing, but we doubt any have been caught, we caught none in our nets, and as noted, the current conditions in the lake are degraded for northern pike (and walleye - see below). De-stratification during summer has removed a mid summer, cool-water refuge that northern pike require to flourish in a lake. Northern pike are desirable, exert good control on panfish populations, and provide a good sport fish for fisherman. The environment is too warm for them and there is no mid summer cool water refuge; hence they are expected to be present, but not grow or survive at optimum levels seen elsewhere.

E. Walleyes have been stocked into Shannon Lake and appear to have contributed to the sport fishery catches. Walleyes are not native to Shannon Lake, the water quality conditions (temperature and dissolved oxygen) are detrimental to their growth and survival (similar to northern pike), and MDNR and other studies strongly recommend that walleyes not be stocked into existing, well balanced fish communities. The lake is too shallow, too warm during the summer, and has too little dissolved oxygen on the bottom in the deeper places. They are not growing at state averages in the lake, but still persist. The recommendation is therefore to not stock anymore into the lake, but based on their survival and contribution to the fishery, and fully recognizing that many will die and growth will be poor and that they are difficult to catch by fisherman, you certainly can stock some. Just be careful not to stock too many, since I have seen that happen and the prey fish community was decimated irrevocably.

F. Lastly, common carp appear to be abundant in the lake. This is an exotic species that can increase water turbidity, compete with some native species, and may on occasion eat eggs of natives. They should be removed legally by anyone catching them on hook and line and archers should be encouraged to remove them as well.

G. Other species: it appears you have a large number of black crappies and largemouth bass in the lake that are providing excellent fishing opportunities. They appear to be spawning adequately, growing well, and controlling panfish populations. Yellow perch are probably less abundant than they could be because of fishing mortality and predator mortality, which is expected for a lake such as Shannon. Channel catfish have been stocked in the lake and we collected one large individual. This is a good predator in the lake that will help control panfish populations. More information and monitoring would be needed to determine if stocking would be recommended; at the present time no stocking should be done.

2. Eurasian milfoil (*Myriophyllum spicatum*)

We identified Eurasian milfoil as one of the fundamental problems in Lake Shannon, along with the excessive nutrients it receives, because it: 1.) affects fish by covering spawning sites, promotes stunting by preventing predators from being able to access fish, and degrades fish-food organisms normally present for fish, 2.) creates massive amounts of plant biomass that can rot and increase the amount of sedimentation in the lake, leading to dissolved oxygen depletions in the main basin, and 3.) obstructs recreational use of the lake by growing in vast beds in shallow water. The problem is being addressed by the lake association and should be continued in order to maintain at least a semblance of good habitat and open water access for recreational uses. No treatment should occur after the summer growth period.

3. De-stratification

Boat traffic on the lake we believe is de-stratifying the three layers of the lake during summer. The physical properties of water dictate that these three layers form during summer, since the coldest water is most dense and sits on the bottom, while the warmest water sits on top. This effectively seals the bottom waters from mixing and keeps fertilizers and other toxic substances on the bottom until the fall overturn. We base this finding on little difference in the water temperatures from surface to bottom, the uniform concentrations of the three nutrients (and pH and conductivity) we measured, and the boat traffic we observed when we were sampling. De-stratification results in the mixture of fertilizers into the surface waters which then leads to blue-green algal blooms and increased aquatic macrophyte growth, including Eurasian milfoil. We do not think banning boat traffic is a viable option, but do need to point out that this seems to be happening and is part of the reason why excessive algal blooms are flourishing in Lake Shannon.

4. Additional Exotic Species

You have an infestation of Eurasian milfoil, which was brought into the lake by some resident who visited an adjacent lake or Great Lake and carelessly neglected to clean off the aquatic plants from the vessel or other item used before putting it into Lake Shannon. Another route for not only plants, but also invertebrates and exotic fish, is bait buckets. Use of bait in the lake can not only spread exotic species, such as common carp, but also viral hemorrhagic septicemia, which is a virus recently implicated in killing many muskies and other fish species in Lake St.Clair. It might be a good idea to ban the use of minnows in the lake or at least make sure that minnows come from the lake or a reliable, disease-free source before they be allowed in the lake. The other highly undesirable exotic species that could be introduced to the lake is the zebra and quagga mussels, which have wreaked havoc in the Great Lakes, especially Lake Huron. In addition, we have recently worked on a lake in Oakland Co. which had starry stonewort, an aquatic nuisance species, which looks like *Chara*, a green alga. It is worse than Eurasian milfoil since it has no roots, grows massive mound of plant material, and is difficult to kill. Copper sulfate can kill it, but can cause toxicity to other organisms in the lake. Mostly it is harvested now. Hence, there should be an effort in the rules or the newsletter to inform the lake residents and/or restrict the possible entry of exotic species by making sure that water craft, SCUBA gear, or any other item is free of water and plants before they are put in Lake Shannon. This may require careful inspection, treating water in the boat with bleach (chlorine), letting items sit in the sun for a week, and not dumping bait buckets or any minnows or bait into the lake.

RECOMMENDATIONS

1. Fish Management

Most of the sports fish in Lake Shannon are growing well and seem to be have well balanced populations. Some suggestions are:

a. Do not stock any largemouth or smallmouth bass or yellow perch; all are reproducing adequately.

b. Northern pike should not be stocked, because there are adequate spawning sites in the lake. However, we do think they will not survive well because of the warm environment and lack of dissolved oxygen on the bottom in the cool water zone destroyed by excessive boat traffic and by the shallow nature of the lake.

c. Walleyes seem to be surviving, even though they are growing below state averages and like northern pike, are severely stressed by the summer lack of cool temperatures and low to no dissolved oxygen below 13 ft in the lake. They should not be stocked, but because they apparently are providing opportunity for sport fisherman, I have no problem with a decision to put more in, just so the drawbacks are realized. Just do not put too many in as the prey fish base can be disrupted.

d. Practice catch and release for large predators, mostly largemouth and smallmouth bass and any northern pike. These fish are probably contaminated with mercury anyway.

e. Remove any common carp caught by hook and line; archers should be encouraged to shoot them.

2. Eurasian milfoil (*Myriophyllum spicatum*)

Eurasian milfoil is common throughout the lake. This problem is complex, expensive to address, and is being addressed by a committed effort by the lake association. The best that can be hoped for is to reduce its presence to a manageable level. The lake association has chosen to use herbicides to attack the problem, which I support. Treatment should not however occur beyond the summer growth period.

3. Sediments

The sediments in Lake Shannon are probably very thick and rich in the main basin. When they decompose, there can be anoxia, accumulation of toxic materials (ammonia, hydrogen sulfide, lack of oxygen) and fertilizers (high nitrates, P, and ammonia), and regeneration of P. The lake association has initiated a drawdown of the lake level in fall which addresses the sediment buildup issue in the lake and will also kill Eurasian milfoil in the near shore zones, something we support.

4. De-stratification

Based on our water temperature and water quality measurements in the main basin of the lake, it appears that boat traffic in this basin de-stratifies the lake. This mixes nutrients on the bottom into surface waters where they can be used by aquatic plants and algae and destroys a cool water refuge required for good growth and survival of northern pike. Since banning boat traffic in that basin is probably not an option, this finding can only act to inform the lake association of their possible options.

5. Influx of nutrients into Lake Shannon

There are three major sources of nutrients to Lake Shannon: re cycled nutrients from the sediments, inflow from the ditches and creeks that feed the lake, and input from the residents. Little can be done with the sediment input besides dredging the lake. The runoff from agricultural activities in the watershed could be addressed with more riparian vegetation along the ditches and best management practices by the farmers in the watershed. Lastly, several things can be done by residents to reduce nutrient input to the lake (see Appendix 1 for a list). Moderate or no lawn fertilization; use only phosphorus-free, nitrogen-based fertilizer. Plant greenbelts near shore, if necessary, to retard nutrient export into the lake. Septic tanks should be cleaned often, at least once every 2 years. Waterfowl should not be fed or encouraged to hang around. Pets should be taken away from the lake or dropping cleaned up and not allowed to enter the lake. Leaves should not be burned at the edge of the lake.

6. Non-indigenous species

You already have one of the scourges of the lakes of Michigan and around the country, Eurasian milfoil. There are others you do not have yet, especially zebra mussels and starry stonewort, so you need to include as part of any newsletter or other communication with residents to be very, very careful whenever they come from a lake that "might" have veligers (the small microscopic reproductive stage of zebra mussels) or plant fragments that can lead to infestation of starry stonewort. This especially includes boats that were in a Great Lakes or infested inland lakes. Boats or equipment that might harbor these aliens should be examined and all obvious plant material removed. Boats and other equipment should either allowed to sit for a couple weeks and dry out or treat them with bleach. There might be other ways they can enter a lake as well, including SCUBA divers and their gear, bait-bucket dumping (never dump bait and bait should probably be discouraged/banned in view of the threat of VHS (viral hemorrhagic septicemia) and veliger transfer in the bait buckets of fisherman. In addition, any stocking of fish into the lake should be done from reputable dealers that demonstrate that their fish are disease free. We live in strained times, and extraordinary efforts must be made to avoid these problems.

SUMMARY OF RECOMMENDATIONS

1.) Fish

Do not stock any largemouth or smallmouth bass, northern pike, or yellow perch.
Walleyes can be stocked, but we do not recommend it.
Initiate a common carp control program encouraging removal
Establish a catch and release program for top predators

2.) Eurasian milfoil

a. Continue the control program in place to reduce the abundance of this exotic species

3.) Sediments

a. Continue drawdown to control sediments and aquatic plants and algae in near shore areas; be careful in spring to allow northern pike spawning.

4.) De-stratification

a. Boat traffic appears to be de-stratifying the lake. The obvious solution is banning boat traffic, but assuming this is not an option, managers should be aware that this is part of the problem of excessive nutrients in Lake Shannon.

5.) Influx of nutrients into Lake Shannon

a. Re-suspended nutrients from the main basin of the lake can only be dealt with by banning boat traffic (not an option) or dredging the lake.

b. Agricultural runoff can be slowed by riparian vegetation along the creeks and best management practices by farmers in the watershed.

6.) Non-indigenous Species

Prevent zebra mussels, goldfish and common carp, VHS, starry stonewort, and other exotic species from entering Lake Shannon. Consider a ban on live bait, especially minnows and crayfish. Issue warnings in newsletter. Have people dry or bleach the water in any boats or equipment that could have come from a contaminated lake. No stocking of any fish by private individuals to prevent the entry of exotic species of fishes (e.g., goldfish) and diseases, such as VHS, which could destroy the fish populations in the lake. Never dump bait buckets or unused bait into the lake.

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LITERATURE CITED

Latta, William C. 1958. Age and growth of fish in Michigan. Michigan Department of Natural Resources, Fish Division Pamphlet no. 26. Lansing, MI.

Freshwater Physicians 1977. A Limnological and Biological study of Shannon Lake, Livingston County, Mich. – Summer, 1976. 5293 Daniel Dr., Brighton, MI

APPENDICES

APPENDIX 1. Guidelines for Lake Dwellers; some may not apply.

1. DROP THE USE OF "HIGH PHOSPHATE' DETERGENTS. Use low phosphate detergents or switch back to soft water & soap. Nutrients, including phosphates, are the chief cause of accelerated aging of lakes and result in algae and aquatic plant growth.

2. USE LESS DISWASHER DETERGENT THAN RECOMMENDED (TRY HALF). Experiment with using less laundry detergent.

3. STOP FERTILIZING, especially near the lake. Do not use fertilizers with any phosphate in them, use only a nitrogen-based fertilizer. In other areas use as little as possible liquid fertilizer rather than the granular or pellet inorganic type. Do not burn leaves near the lake.

4. STOP USING PERSISTENT PESTICIDES, ESPECIALLY DDT, CHLORDANE, AND LINDANE. Some of these are now banned because of their detrimental effects on wildlife. Insect spraying near lakes should not be done, or at best with great caution, giving wind direction and approved pesticides first consideration.

5. PUT IN SEWERS IF POSSIBLE. During heavy rainfall with ground saturated with water, sewage will overflow the surface of the soil and into the lake or into the ground water and then into the lake.

6. MONITOR EXISTING SEPTIC SYSTEMS. Service tanks every other year to collect and remove scum and sludge to prevent clogging of the drain field soil and to allow less fertilizers to enter the groundwater and then into the lake.

7. LEAVE THE SHORELINE IN ITS NATURAL STATE. Do not fertilize lawns down to the water's edge. The natural vegetation will help to prevent erosion, remove some nutrient from runoff, and be less expensive to maintain. Greenbelts should be put in to retard runoff directly to the lake.

8. CONTROL EROSION. Plant vegetation immediately after construction and guard against any debris from the construction reaching the lake.

9. DO NOT IRRIGATE WITH LAKE WATER WHEN THE WATER LEVEL IS LOW OR IN THE DAYTIME WHEN EVAPORATION IS HIGHEST.

10. STOP LITTER. Litter on ice in winter will end up in the water or on the beach in the sprig. Remove debris from your area of the lake.

11. CONSULT THE DEPT OF NATURAL RESOURCES BEFORE APPLYIG CHEMICAL WEED KILLERS OR HERBICIDES. This is mandatory for all lakes, private and public.

12. DO NOT FEED THE GEESE. Goose droppings are rich in nutrients and bacteria.

From: Inland Lakes Reference Handbook , Inland Lakes Shoreline Project, Huron River Watershed Council.

APPENDIX 2. POSSIBLE USEFUL AQUATIC PLANT MANAGEMENT TOOLS

A WEED CUTTER THAT CUTS AT THE BOTTOM

An excellent hand tool cutter is the "Water Weed Cutter" which cuts a clear swath 42" wide right at the bottom. Outdoor Enterprises offers the tool (1-800-299-4198 ext 19 / 8am-4:30pm) for $129 and a special rake for $119 or both for $200. It is effective to depths of 10 feet. I don't know if they have a website; however, they advertise in the Riparian magazine.

GARDEN DIGGING FORK

Sears or Ace Hardware and probably Home Depot sell a 4-tine garden digging fork. They generally have short handles with a hand grip at the top. To remove lily pad tubers in sand/aggregate bottom areas, you will need this tool for best effect. Should be just below $20 for a good one. If the tubers are in muck, a three tined garden cultivator works; however, your situation requires the fork.

BOW RAKE

Same stores will offer a garden bow rake, about 22 inches wide, for $20. To make this rake an effective tool, you need to wrap a piece of ½" galvanized hardware screen around the rake (a piece 12" by 24" will do fine). First, for safety sake, turn over any cut edges and hammer them flat using the width of the rake head as a guide. Work the rake tines through the wire until about 1 ½" of tines are below the wire edge and fold/bend the wire over the bow and then fold/bend in the ears under the bow and wire fasten. The exposed tines will dig out shallow roots and the screen catches the roots, tubers, and stones.

FLOATING BIN

Use a plastic cement mixing trough/bin (Lowes or Home Depot) which will carry/float several bushels of weeds that can be floated to shore and sledded across land. They are cheap, nest to store, lightweight, and durable. Drill a couple of ½" holes in the edge flange and add a pull rope. Sometimes, if it is windy, a small anchor helps. These are much easier to handle and clean out than using a boat for a weed removal container.

COMPOST PILE

Compost as far from water as is practical since nutrients leach from the pile and re-enter the lake through groundwater. Consider having a convenient dump/pile area at shore and then later moving the pile elsewhere with a tractor. If you intend to create gardener compost, then you need to layer your final pile with six inch interval layers of leaves and sprinkle a shovel or two of soil over each layer to get soil organisms distributed in the pile. Alternating layers of green and brown work best although a weed pile with soil sprinkles will produce decent compost although it takes longer.