Picture 1. Ryerson Lake Native, 21 July 2021

A FISHERIES, ALGAE, ZOOPLANKTON, AND LIMNOLOGICAL

SURVEY OF

RYERSON LAKE

WITH RECOMMENDATIONS AND A MANAGEMENT PLAN

Study performed: 21- 22 July 2021
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INTRODUCTION

We were asked to perform a fishery investigation of Ryerson Lake located near Fremont, MI in Newaygo County, compare our results with an earlier study done during 2014, and update our management plans for the lake. Ryerson Lake is a eutrophic lake with mostly shallow littoral zone with an 80 - ft deep basin in the middle of the lake. The lake is ringed with many houses on the west side, but there is a large area owned by YMCA that is relatively undeveloped on the east side of the lake. There is a considerable amount of sand and gravel in and along the shores along with extensive beds of aquatic plants, which act as good habitat for insect prey and good spawning sites and refuges for sunfishes. There are four inlets and one outlet which can act as good spawning sites for spawning, migrating species, such as white suckers and northern pike, but can also bring in nutrients from the watershed.

The lake is a 292-acre lake according to MDNR. We collected 22 species of fishes: 14 during 2014 and 19 during 2021. The dissolved oxygen measurements we took showed that at the deep spot, there was a thermocline between 4 m and 5 m and there was little or no dissolved oxygen below 7 m.

HISTORY

The lake has been monitored by Progressive Engineering and the aquatic plants managed as well. Their data and ours show the lake has a considerable buildup of phosphorus and nitrogen in bottom waters during summer and probably winter stratification periods, termed internal loading. Those nutrients are then re-distributed throughout the lake during spring and fall overturn promoting aquatic plant and algae growth. We did a lake study during 2014 (Freshwater Physicians 2015), which will be compared with results from this study.

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). 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 several 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 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 sometimes run transects across a lake and record the depths if there are no data about the depths of the lakes as we did in this study. These soundings were then superimposed on a map of the lake and a contour map constructed to provide some information on the current depths of the lake.

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.

Hydrographic Map

A map of the depth contours of the lake was prepared for Ryerson Lake, since there was no prior one and because the depths changed due to dredging. We secured starting and ending GPS values for transects across the lake and then ran the pontoon boat at a consistent speed and measured the depth every 5 sec until the opposite shore was reached. These depth data were recorded and later entered on each of the transect lines drawn across a copy of the lake map showing the lake shoreline outline. The distance of the transect line (in mm) was divided by the number of observations for each transect so that the depths could be assigned accurately to the line at equal intervals. Next we interpolated contour lines based on the depth contour of interest, including lines for 5, 10, 15, 20, and 30 ft. This map will assist us in making assessments of the lake and hopefully fishers who want to fish in specific depths on the lake.

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 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 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).

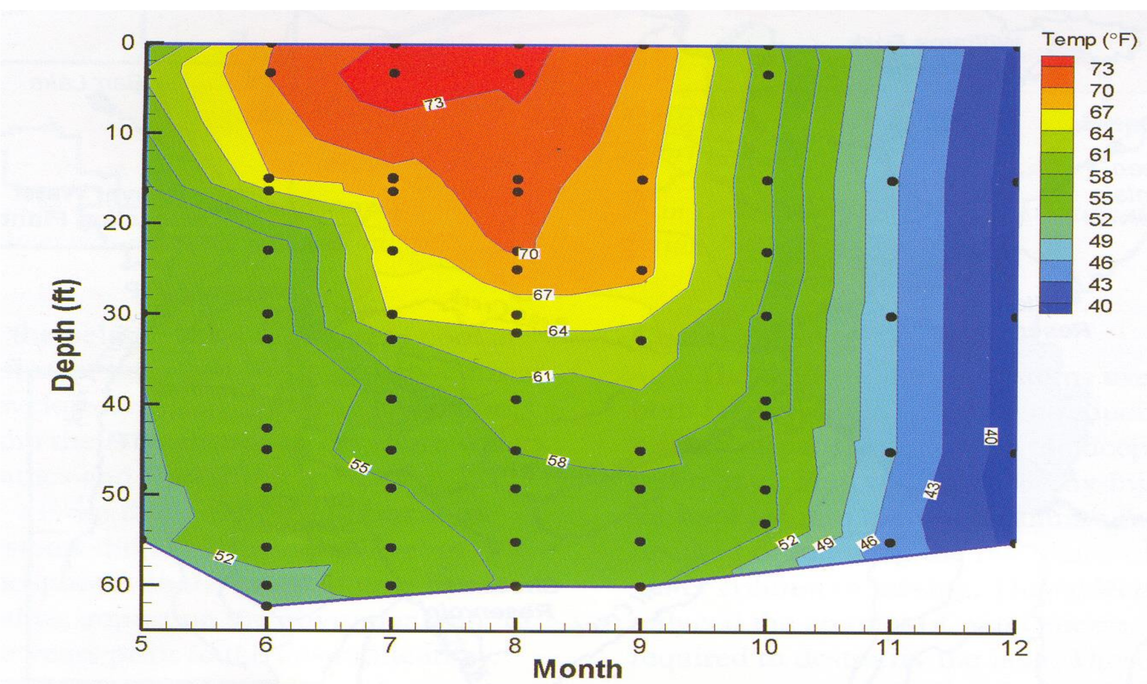

Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring)

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 lighter and floats on the denser water below, until it freezes at 32 F and seals the lake. During winter decomposition on the bottom can warm bottom temperatures slightly.

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

Dissolved Oxygen

This dissolved gas is one of the most significant chemical substances in natural waters. It regulates the activity of the living aquatic community and serves as an indicator of lake conditions. Dissolved oxygen is measured using 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).

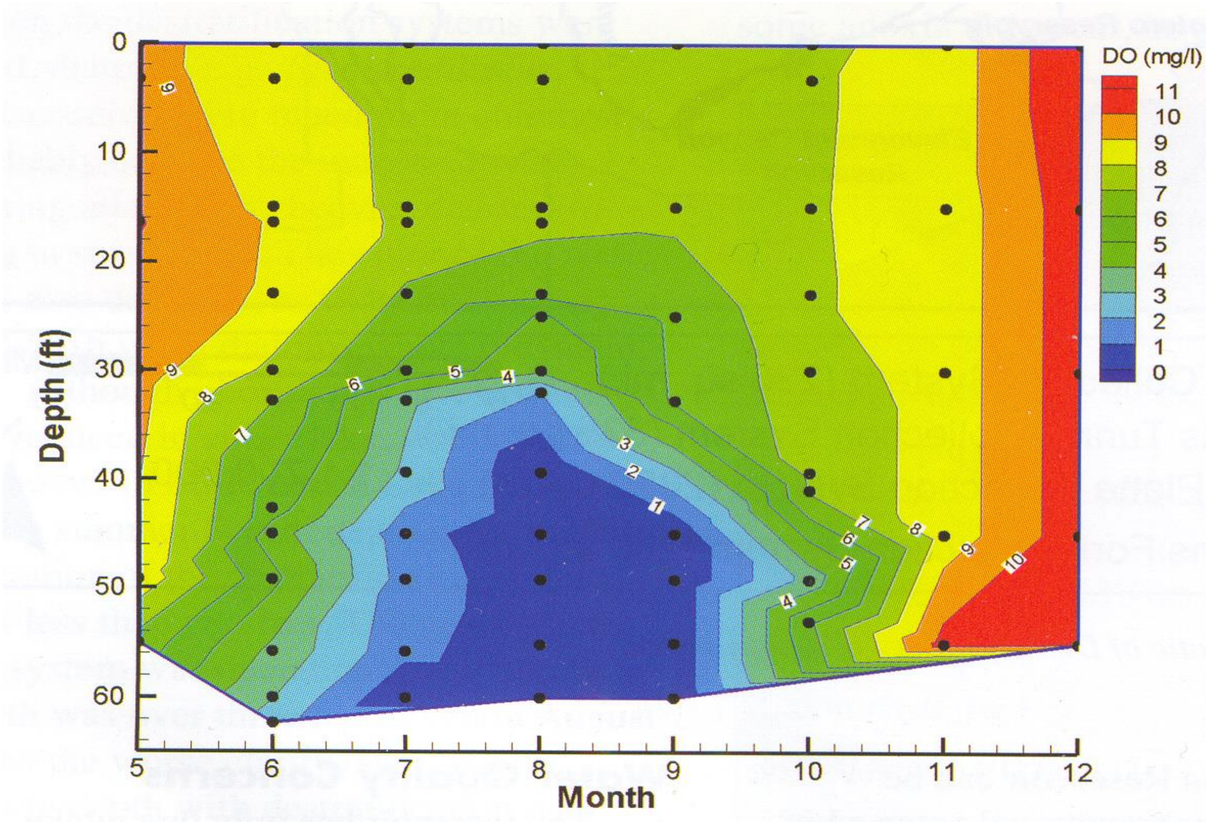

Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when 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 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 there and 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 or boat 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 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 CO_2) 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 (H_2CO_3) into H^+ ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO_2 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 CO_2 during the day in photosynthesis there is a drop in CO_2 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. In the field, pH is measured with color comparators or a portable pH/conductivity meter and in the laboratory with a 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 (CaC_{l2}), 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. 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 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) are often toxic and can fix their own nitrogen (some members) and thus out-compete more desirable forms, when phosphorus becomes scarce in late summer.

BIOLOGICAL PARAMETERS

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 several 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 can 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. 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.

Algae samples were collected on 21 July 2021 from station A in Ryerson Lake with an integrator tube that collects a sample of the algae living in the top 2 m (6.5 ft) of the water column. Algae samples were preserved with gluteraldehyde, kept from light and in the refrigerator until delivered to Dr. M. Edlund for analyses. Measured subsamples of preserved algae (~120-135 mL) were allowed to settle for a minimum of 1 week, and the algae concentrated to a volume of 10-20 mL for microscopical analysis. Well-mixed subsamples of 0.1 mL were distributed in a Palmer counting chamber and analyzed with an Olympus BX50 or Leitz Ortholux compound microscope using the Minnesota Rapid Algal Assessment method (Lindon and Heiskary 2007). In short, the sample is quickly scanned at low magnification to identify the primary algal species that are present. The sample is then counted at higher magnification (in this study, at 200x and phase contrast or oblique illumination) more slowly to estimate the biovolume of the major species present (normally those making up >5% of the assemblage). For most samples this entails counting about 400 functional algal units (i.e., cells, colonies, or filaments). For each species, a measurement of the algal biovolume is estimated based on measurements of cell or colonies using a calibrated ocular micrometer and simple shape formulas. Algal identification used standard guides (e.g., Prescott 1962, Hindák 2008). Data are reported as cells per volume of water (cells/mL) by algal groups (e.g., cyanobacteria, diatoms, green algae), total algal biovolume per volume of water (μm^3/mL) presented as algal group (e.g., cyanobacteria, diatoms, green algae), and a table of dominant types.

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)*, milfoil has 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 considering 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 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. One of those organisms is called *Hexagenia*, the large mayfly that hatches in late July and precipitates much trout fishing in our local trout streams. This organism has a 2-yr life cycle; the larval form (naiad) lives in thick organic muds making a U-shaped burrow, so it can take in algae and detritus on which it feeds. It always requires high dissolved oxygen and good water quality to survive, so when present it indicates excellent water quality is present. We examine samples from deep water stations for the presence of organisms, as certain types live in low to no dissolved oxygen conditions, whereas other kinds can only exist when their high dissolved oxygen needs are satisfied.

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

Fish

The top carnivores in most aquatic ecosystems, excluding man, are the fish. They are integrators of a vast number and variety of ever-changing conditions in a body of water. They, unlike the zooplankton and benthos, which can reflect short-term changes, are indicative of the long-range, cumulative influences of the lake or stream on their behavior and growth. The kind of fish, salmon or sunfish, can tell us much about how oligotrophic (low productivity) or eutrophic (high productivity) a lake is. We collect fish with seines, gill nets and from lucky fishermen on the lake. Most fish are weighed, measured, sexed, and their stomach contents removed and identified. Fish are aged using scales, and breeding condition is observed and recorded. The catches from our nets and age information on the fish will tell us how your length-at-age data compare with state averages and whether fish growth is good. Another problem, "stunting", can be detected using these sources of information.

Stomach contents of fish document whether 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

Ryerson Lake is in Newaygo County and is in the Muskegon River watershed. The local watershed is composed of the land surrounding the lake which has many houses located on it (see Fig. 3 and 4). There are lawns and large areas of grasses and shrubs and some forested areas, especially on the east side near the YMCA camp. In addition, there are vast acreages of agricultural land in the watershed, which can result in polluted runoff containing fertilizers, especially nitrates. We will discuss this further in the tributary inputs section. The watershed area is large, 3,847 acres and the lake to watershed ratio is 15.4, which means for each lake acre there is the potential of 15.5 acres that drain into the lake. This is not a huge ratio as occurs in some reservoirs, but because of the agricultural inputs, can be detrimental to water quality of the lake. The houses are on septic tanks and so we are concerned about septic tank effluent, which depending on soil type could end up seeping into the lake through groundwater. There is also Eurasian milfoil in the lake which can expand and cover large areas of the substrate if conditions are optimal.

The local riparian zone is very important also, especially that band right at the lake (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 (consult the Michigan Natural Shoreline Partnership for guidance and recommendations website), reducing erosion where ever it occurs, reducing or eliminating use of fertilizers for lawns, cutting down on road salting operations, not feeding the geese or ducks, no leaf burning near the lake or in the watershed, 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 (summarized in Appendix 1). Residents might also consider “no mow” in an effort to allow your grass to grow during May to allow flowers to develop, assisting our pollinators in survival.

STATION LOCATION

Ryerson Lake is a 292-acre located near Fremont, MI. We established two types of stations on Ryerson Lake for sampling various parameters in this study (Fig. 3-6, and Table 1). Water chemistry was sampled at one site (station A), while tributaries were sampled at four sites (I1=SW Trail, I2=W Sherman, I3=NW Sandbar, and I4=NE Camp). Zooplankton were sampled at station A and shallower site closer to shore. Places and times for sampling fish were set up in various locations around the lake to maximize catch of fishes (Table 1). Fishes were collected using seines at stations S1, S2, S3, and S4, gill nets at stations GN1 and GN2, and trap nets at stations TN1, TN2, and TN3 (Fig. 6).

Figure 3. Google map of Ryerson Lake showing the extensive development, especially on the west side and the undeveloped watershed on the east side.

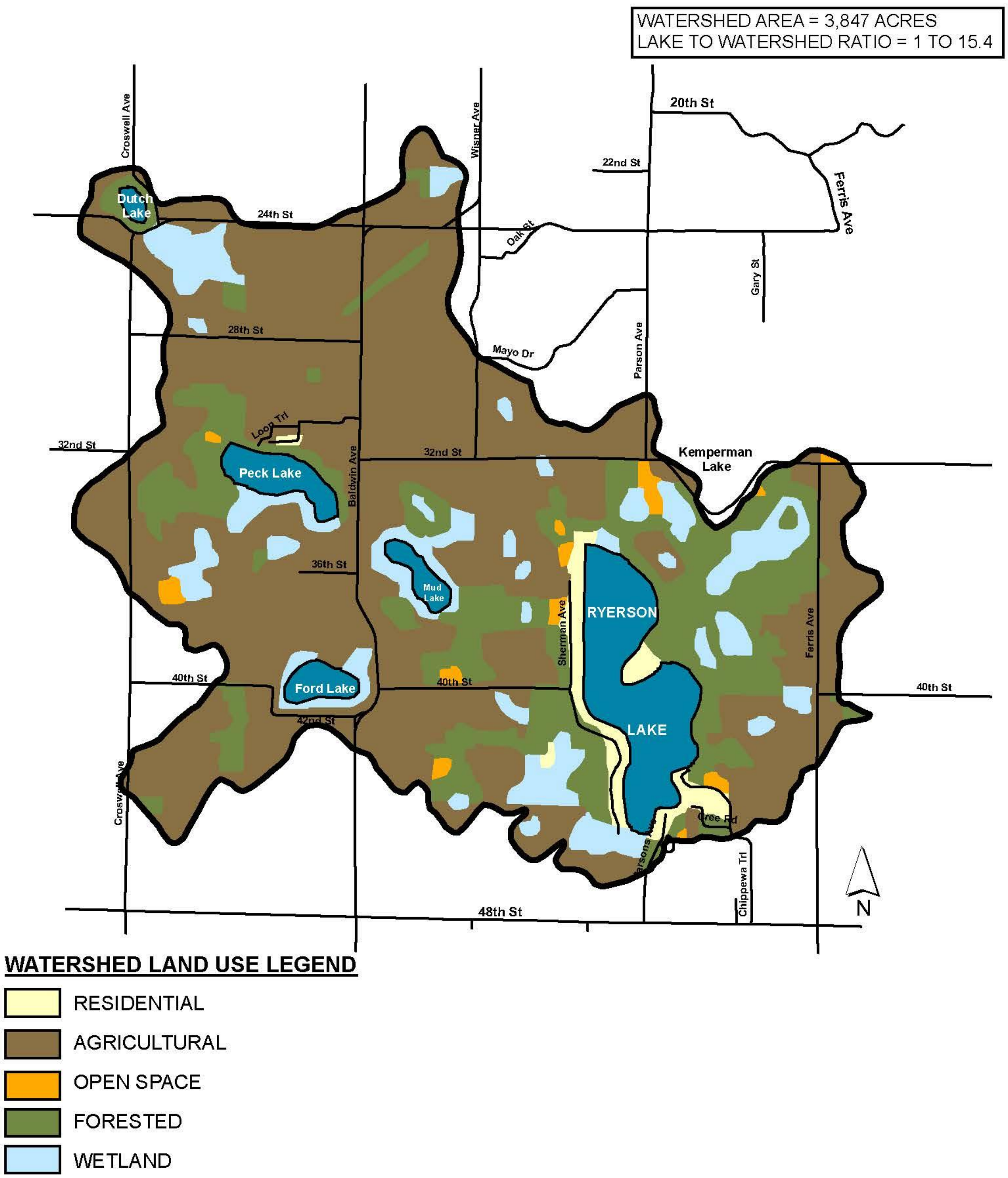

Figure 4. Map of Ryerson Lake showing the various land uses in the watershed, including the extensive development in the riparian zone, large areas of agricultural land, and areas of forested landscape and wetlands. Note: the watershed area is 3,847 acres and the lake to watershed ratio

is: 1 to 15.4. Map provided by T. Groves, Progressive Engineering AE, for which we are grateful.

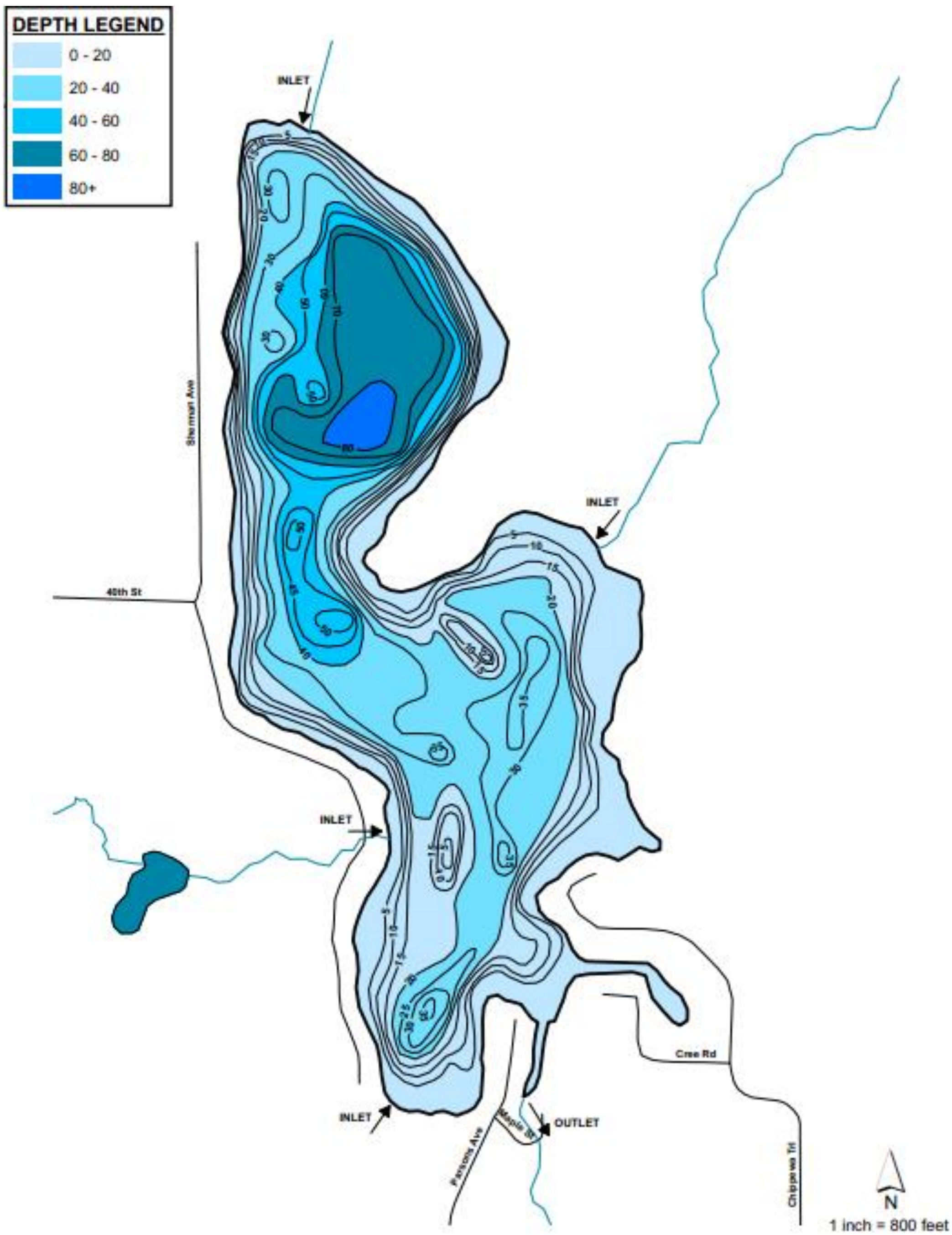

Figure 5. Hydrographic map of Ryerson Lake showing the depth contours, distribution of various depths of water, inlets, and the outlet. Map provided by Progressive Engineering AE.

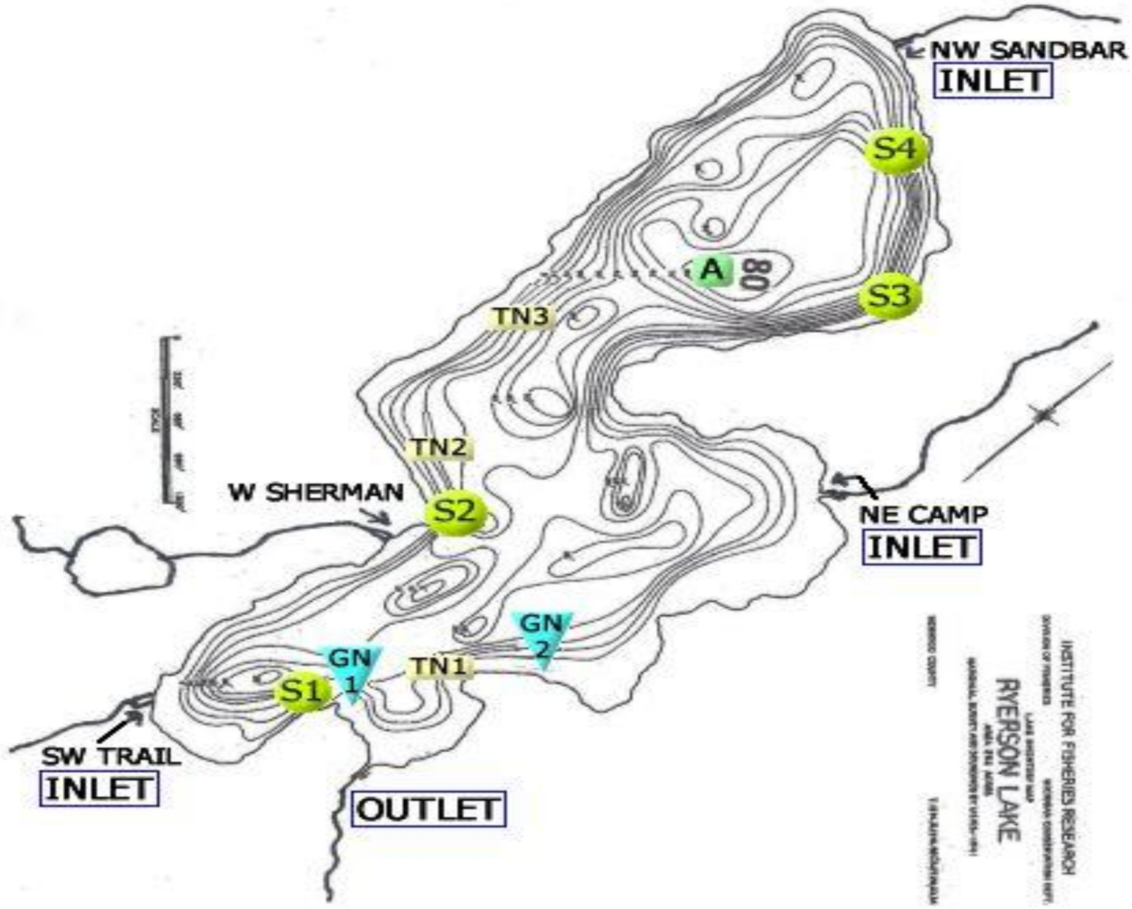

Figure 6. Map of Ryerson Lake showing the water quality 80-ft deep sampling station (A- see Table 1 for a description) and fish sampling sites for seining (S1, S2, S3, S4), gill netting (GN1, GN2), and trap netting (TN1, TN2). Inlet sites (I1-I4) where collection of water samples on 9 April 2021 occurred are also shown.

Table 1. Station code and description, time during which various gear were deployed, station depth, and sample type or fish present in gear at Ryerson Lake. G = gill net, T = trap net, S = seine, I=tributary water quality sample. See Table 10 for definition of fish codes. See Fig. 6 for map of station locations and Fig. 5 for hydrographic map.

STA	STATION DESCRIPTION	START DATE	END DATE	DEPTH (FT)	SAMPLE TYPE OR FISH PRESENT IN GEAR
A	MID-LAKE DEEP SITE	21-Jul-21	21-Jul-21	82	WATER QUALITY SAMPLE, ALGAE, ZOOPLANKTON
		1304	1500		
T1	EAST SHORE	21-Jul-21	22-Jul-21		
		1551	958	6-8	NP, BG, RB, YP. PS
T2	WEST SHORE - SOUTH	21-Jul-21	22-Jul-21		
		1542	1025	4.5-7	BG
T3	WEST SHORE - NORTH	21-Jul-21	22-Jul-21		
		1535	1038	8	BC, BG
S1	MARGE'S POINTE	21-Jul-21	21-Jul-21		
		1817	1830	4	BK, YP, LB, BG, YP, PS
S2	BOAT LAUNCH POINTE	21-Jul-21	21-Jul-21		
		1743	1800	4	BG, RB, SV, LB, PS,YP
S3	CARETAKER HOUSE	21-Jul-21	21-Jul-21		
		1630	1650	4	BG, PS, YP , LB, SV, YB
S4	N CREEK SANDBAR	21-Jul-21	21-Jul-21		
		1712	1730	4	BG, LB, YP, BC, BM, PS, HYBRID
G1-1	EAST SHORE	21-Jul-21	21-Jul-21		
		1432	2127	5-10	BC, NP, CP, LB, BG, YB
G1-2	EAST SHORE	21-Jul-21	22-Jul-21		
		2130	935	5-10	YB
G2-1	EAST SHORE	21-Jul-21	21-Jul-21		
		1442	2144	8-10	ZZ
G2-2	EAST SHORE	21-Jul-21	22-Jul-21		
		2155	913	8-10	YB, NP, BB, BG
I1	SW TRAIL CROSSING	9-Apr-22	9-Apr-22		WATER QUALITY SAMPLING IN TRIBUTARIES
I2	W SHERMAN	9-Apr-22	9-Apr-22		WATER QUALITY SAMPLING IN TRIBUTARIES
I3	NE CAMP	9-Apr-22	9-Apr-22		WATER QUALITY SAMPLING IN TRIBUTARIES
I4	NW SANDBAR	9-Apr-22	9-Apr-22		WATER QUALITY SAMPLING IN TRIBUTARIES

PHYSICAL PARAMETERS

Depth

Most eutrophic lakes we work on are shallow, but Ryerson Lake is unusual in that it has a deep basin of 80 ft (Fig. 5). There are several other deep spots in the lake which adds to the habitat diversity, but none are 80 ft. The littoral zone is extensive and highly vegetated. One of the most vegetated areas is in the north end (the NW Sandbar station) where we collected a huge number of many different species of fishes. Based on the water quality data collected at that station (Table 4 – discussed below), it seems that that tributary must drain a highly productive area, since it has very high nutrients which is probably why that area is so thick with vegetation.

Acreage

Ryerson Lake is 292 acres and is extensively developed on the west side.

Light Penetration

Water clarity on 21 July 2021 was 2 m (6.6 ft), which is exactly what we found in our last study during 2014 (Freshwater Physicians 2015), which is not a particularly good reading, but it does indicate high productivity in the lake and based on this measurement, the lake is eutrophic (<7.5 ft reading). This reflects the high concentrations of nutrients measured in the lake which results in growth of algae (some blue-green algae blooms were reported in the fall) and aquatic plants. Obvious sources of those nutrients we would speculate on would be: septic tank seepage, internal loading (decomposition of sediments during summer and winter), runoff from riparians, and input from the tributary streams.

Temperature/Dissolved Oxygen

Water temperature is intimately associated with the dissolved oxygen profiles in a lake. The summer profile is the one that most characterizes a lake, and the stratification impacts are very important. A lake goes through a series of changes (see introductory material-Temperature) in water temperature, from spring overturn, to summer stratification, to fall over turn, to winter conditions. During both summer and winter rapid decomposition of sediments and detritus occurs when bottom waters are fertile and can cause degraded chemical conditions on the bottom (internal loading - to be discussed). Because the lake is essentially sealed off from the surface when it is stratified during summer, no dissolved oxygen can penetrate to the bottom and anoxia (no dissolved oxygen conditions- a dead zone) can result. This has implications for the aquatic organisms (fish will not go there) and chemical parameters (phosphorus and ammonia are released from the sediments under anoxic conditions, which then contribute these nutrients to the lake during the fall overturn).

During 2021, dissolved oxygen was similar to findings of 2014 in that there was adequate dissolved oxygen in upper layers but not deep (Fig. 7, 8; Tables 2, 3). There was zero dissolved oxygen from 8 m to the bottom during 2014, while during 2021, anoxia was much less, starting at 19 m and extending to the bottom. This is a positive finding, but since it is early in the summer, we expect dissolved oxygen to decline even more with potentially similar ramifications from this condition resulting in both years. During summer 2014, when we measured the temperature/oxygen profile, water temperature was warm at the surface (24.4 C - 76 F), there was a thermocline (rapid change between warm and cool water temperatures) between 13 and 16 ft, and little or no dissolved oxygen at or below 16 ft (Table 3, Fig. 7). During 2021, surface temperature was 25.9 C (much warmer than during 2014) and the thermocline started at 4 m or 16 ft, which was similar to 2014 findings. Anoxia was present during both years. These data are similar to those collected by Progressive Engineering AE (2020, 2021). This has two consequences: it effectively makes the entire water volume in the anoxic zone unavailable to fish and this dead zone promotes phosphorus and ammonia regeneration from the bottom sediments, which was abundantly clear from Progressive Engineering and our datasets (see water quality data – Table 2, 3). We measured this profile prior to maximum stratification, so we expect conditions will get much worse before summer ends. This finding indicates the lake has some fertile mud or other accumulated organic material on the bottom of the lake, which degraded the oxygen levels. Most warm water fishes require at least 3 mg/L, while cool water fish, such as northern pike and walleye require 5 mg/L as well as cool water temperatures. Hence, these fish will be subject to the squeeze noted in Fig. 9: warm temperatures in surface water forces them downward, while no dissolved oxygen in the preferred bottom cool waters of the lake forces them upward into too warm surface waters. These fishes will be stressed during these periods. This point is important for fish management considerations, especially for walleyes.

Table 2. Dissolved oxygen (mg/L) and water temperature (C) profile for station A (80 ft) 21 July 2021 on Ryerson Lake, Newaygo County (see Fig. 6 for station location).

Depth (m)	Temp-C	Dissolved Oxygen - mg/L)
0	25.9	9.28
1	25.7	9.28
2	25	9.59
3	24.5	9.34
4	22.9	6.77
5	17.6	1.12
6	13.4	0.77
7	10.8	0.67
8	9.8	0.58
9	8.7	0.52
10	8	0.47
11	7.3	0.42
12	7.1	0.38
13	7	0.35
14	6.7	0.32

15	6.5	0.49
16	6.2	0.56
17	6	0.31
18	5.9	0.26
19	5.8	0
20	5.7	0
21	5.6	0
22	5.6	0
23	5.5	0
24	5.5	0
25	5.4	0
26	5.4	0

Table 3. Dissolved oxygen (mg/L) and water temperature (C) profile for station A (80 ft) 24 July 2014 on Ryerson Lake, Newaygo County (see Fig. 3 for station location).

DEPTH (M)	TEMP C	DISS OXY (MG/L)
0	24.4	8.7
1	24.4	8.6
2	23.8	8.7
3	23.6	8.5
4	21.9	5
5	15.3	0.1
6	11.9	0.1
7	10	0.1
8	8.8	0
9	8.2	0
10	7.8	0
11	7.5	0
12	7.1	0
13	6.7	0
14	6.3	0
15	5.8	0
16	5.3	0
17	4.9	0
18	4.8	0
19	4.5	0

20	4.4	0
21	4.4	0
22	4.3	0
23	4.3	0
24	4.2	0
25	4.3	0

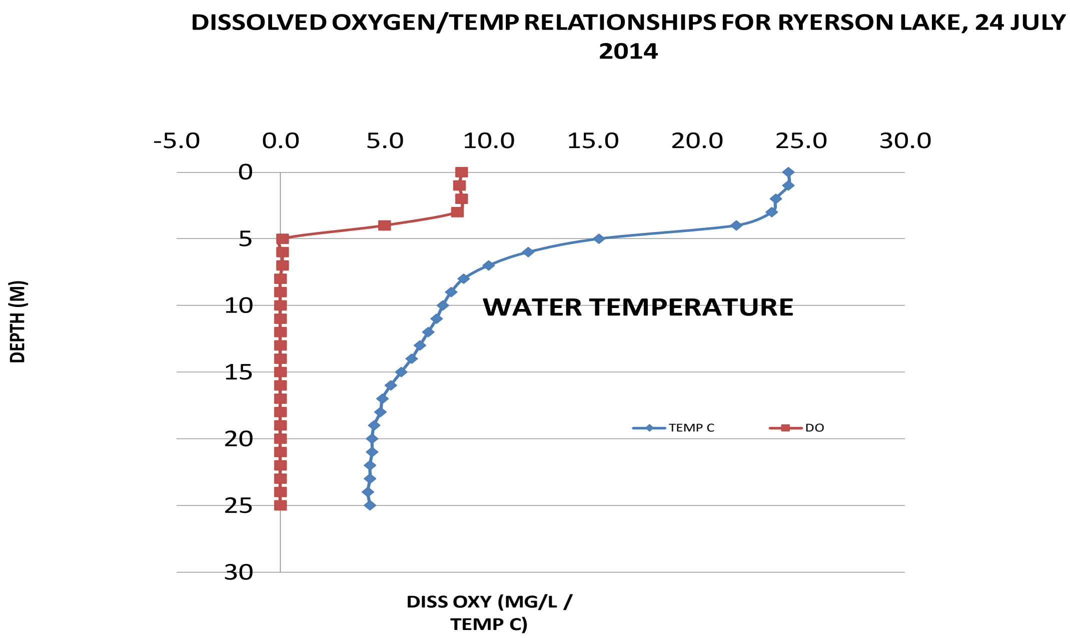

Figure 7. Dissolved oxygen (mg/L) and water temperature (C) profile for station A, Ryerson Lake, 24 July 2014.

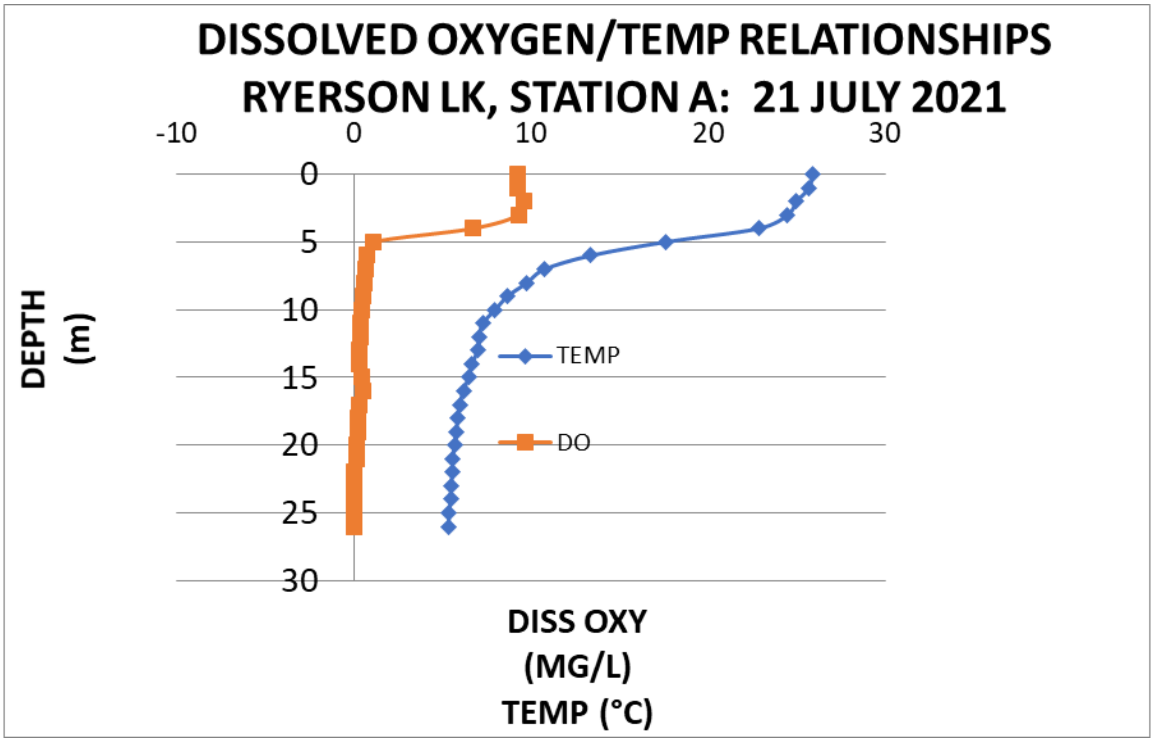

Figure 8. Dissolved oxygen (mg/L) and water temperature (C) profile for station A, Ryerson Lake, 21 July 2021.

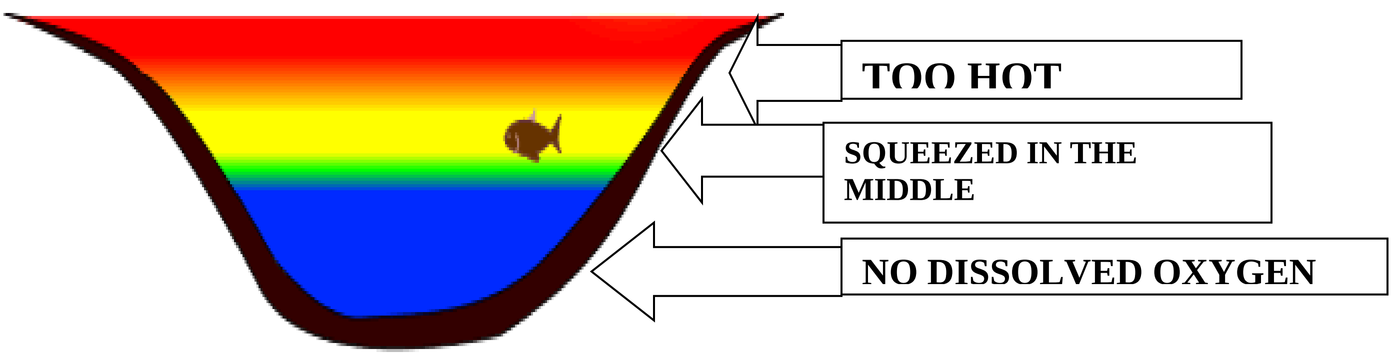

Figure 9. Depiction of the dissolved oxygen concentrations in a stratified lake, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where water temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, but has no or very low dissolved oxygen present. Cool water fishes, such as northern pike and walleyes are “squeezed” between these two layers and undergo thermal stress during long periods of summer stratification.

CHEMICAL PARAMETERS

pH

The pH (how acid or alkaline water is) for Ryerson Lake during 21 July 2021was 8.53 at the surface (high- reflective of uptake of carbon dioxide by plants), lower at mid depths (7.68, and lowest on the bottom – 7.56, indicative of decomposition processes creating carbon dioxide (acidic) (Table 4). During 24 July 2014 at station A (80 ft) showed a similar pattern matching the expected situation. The pH was highest at the surface (8.18), while it was lowest on the bottom (7.98) (Table 5). The pH at the four tributaries we sampled ranged from 8.34 to 8.57 (Table 6) which are high values.

Table 4. Conductivity (uSiemens), pH, chlorides (CL), nitrates (NO3), ammonia (NH3), soluble reactive phosphorus (SRP), and total phosphorus (TP) for Ryerson Lake, 21 July 2021. See Fig. 6 for location of station A. All concentrations are in mg/L.

DEPTH-M	pH	COND	CL	NO3	NH3	SRP	TP
0	8.53	575	11	0.03	<0.01	<0.005	0.010
12	7.68	459	11	0.35	0.07	0.048	
24	7.56	460	11	0.06	1.28	0.291	0.433

Table 5. Conductivity (uSiemens), pH, chlorides (CL), nitrates (NO3), ammonia (NH3), and soluble reactive phosphorus (SRP) for Ryerson Lake, 24 July 2014. See Fig. 6 for location of station A. All concentrations are in mg/L.

DEPTH	**PH**	**COND**	**Cl**	**NO3**	**NH3**	**SRP**
Surface	8.18	585	12	0.5	<0.02	<0.005
12 M	8.07	384	12	0.22	0.10	0.014
23 M	7.98	437	14	0.59	0.76	0.160

Chlorides

Chloride concentrations in Ryerson Lake were surprisingly low at 11 mg/L during 2021 at all depths, while during 2014 they ranged from 12 to 14 mg/L (Table 4, 5), which is one of the lowest chloride concentrations we have measured in a lake. 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. They can derive from septic tank effluent, road salt runoff, or can be naturally occurring. 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. This low a concentration indicates almost pristine conditions with no suggestion of septic tank or road salt runoff. However, our tributary sampling at four sites showed chlorides ranged from 4 to 21 mg/L (Table 6). The highest concentration (21 mg/L) came from the NW Sandbar creek, indicating a source of chlorides and nutrients are coming in from that site that are much higher than concentrations in the lake.

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. It is also important in determining internal loading, the amount of nutrients that are generated by the deep basin during summer and winter and then are released into the lake during the spring and fall overturn period. 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—usually these values are low because they are rapidly taken up by plants. Total P would be all the P in the water, dissolved and that tied up in algae or other detritus.

During summer 2021, SRP values at the deep station were low at the surface as expected (at trace levels <0.005 mg/L), increased at mid depth to 0.048 mg/L, then really were high on the bottom where 0.291 mg/L were recorded (Table 4). This bottom value is an increase over values we measured during 2014 (0.160 mg/L – Table 5). It shows that internal loading is probably an important source of nutrients for Ryerson Lake and that this process has not stabilized but accelerated over the past 7 years. The total phosphorus data were similar. TP during 2021 at the surface was 0.010 mg/L which ironically characterizes Ryerson Lake as oligotrophic; the bottom values belie this observation, since a concentration of 0.433 mg/L is 22 fold higher than the standard for eutrophic lakes (0.020 mg/L). Progressive Engineering AE (2021) have more detailed data but their bottom value during 1 September 2021 was even higher: 0.526 mg/L and more importantly they collected spring TP data. The spring data are representative of the TP concentration across the whole lake and all these data were high, 0.034 mg/L at the surface at station A and 0.034 mg/L on the bottom. These data are a clear indication of the distribution of large amounts of nutrients throughout the lake from the previous summer and winter decomposition on the bottom of the lake. Recall that values >0.020 are considered eutrophic, so Ryerson Lake is well above that cutoff value. Progressive Engineering during summer 2013 found total phosphorus to be 0.690 mg/L on the bottom in the deep spot. So, this has been a continuing problem for the lake ecosystem.

We concluded two things from these data: first, P is limiting in the lakes in surface waters during summer and will stop growth of algae and plants until more phosphorus enters the lake (limiting nutrient). Blue-green algae can fix their own nitrogen, so could dominate during limiting conditions during summer and fall. We got reports of such an outbreak, so this is one symptom of nutrient enrichment in your lake. One way for nutrients to enter the lake during summer during these periods of low concentrations of both phosphorus and nitrates is for excessive water skiing in the lake nearshore, which can stir up bottom sediments, resulting in the release of phosphorus and promotion of algal growth. It could also begin to mix the bottom, high-nutrient waters as cool water begins to break down the stratification patterns, and release nutrients to the surface waters promoting algae blooms in the fall. Such activity should be restricted to deep parts of the lake to reduce re distribution of nutrient-laden bottom sediments in the nearshore zone. Phosphorus is also coming in from the inlets as we will discuss below, from septic tank seepage into groundwater, and by lawn fertilization. Second, it confirms the finding that the bottom waters are inhospitable to fish during summer stratification. Residents need to do all they can to prevent nutrients from entering the lake to preserve the current water quality they do enjoy. See Appendix 1 for suggestions.

Nitrates

Nitrate is very important since it too 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, which usually happens during late summer and fall. Nitrates in Ryerson Lake conformed to expectations, since during 21 July 2021, nitrates were at trace concentrations at the surface, 0.34 mg/L at mid depth (12 m), and 0.06 mg/L on the bottom (a low value) (Table 4). We usually do not see much nitrate on the bottom in anoxic waters since there is no oxygen and the nitrogen form that is created there is ammonia, which usually is in high concentrations (in our case 1.28 mg/L). Hence, the low bottom nitrates are at expected concentrations. During 24 July 2014 nitrates were somewhat different and diverted from expected values. Nitrates ranged from 0.22 at the surface to 0.59 mg/L on the bottom (Table 5). So even though concentrations are high, there must have been enough dissolved oxygen in bottom waters earlier to allow high concentrations to develop. As noted above, we usually see trace concentrations of nitrates in the surface waters. There were high ammonia concentrations on the bottom however, as expected.

Ammonia

Ammonia is also a plant nutrient, but it can be toxic to fish in high concentrations, which is exactly what we observed on the bottom during summer 21 July 2021, since we found trace amounts in surface waters (expected since most ammonia is converted to nitrates) (Table 4). At mid depths ammonia levels were also low 0.07 mg/L, but on the bottom we measured 1.28 mg/L, which would be toxic to fish, if the lack of dissolved oxygen would not kill the fish first.
Results from 2014 were similar, but there were lower values on the bottom (0.76 mg/L), so conditions as we have seen with other parameters, were worse during 2021 than what we found during 2014 (Table 5). Ammonia is formed by the decomposition of bottom sediments under low or no oxygen present and we expect that conditions of anoxia will get worse later in the year promoting even more ammonia than we measured here.

Hydrogen Sulfide

Hydrogen sulfide is a toxic substance produced under conditions of no dissolved oxygen (anoxia) from the decomposition of organic matter on the bottom. We did not measure it during 2021, but it was measured during 2014 and found to be zero on the bottom on 24 July, which was unexpected with the lack of dissolved oxygen measured.

Conductivity

Conductivity is a measure of the ability of water to conduct current and is proportional to the dissolved solutes present. During 2021 and 2014, although variable, the general pattern was for highest conductivity to be in surface waters. It was 575 uS in the surface during 2021 and similar in bottom waters (459-460 uS – Table 4), while during 2014 conductivity was 384-437 uS in surface-mid-depth waters and 585 uS on the bottom (Table 5). While it might be intuitively obvious that higher concentrations should occur on the bottom during summer due to decomposition producing many negative ions, and sometimes we find that; in Ryerson Lake we think that some other mechanism is contributing to this disparity in values. We suggest that the lake is stratified and that the bottom waters (hypolimnion) are cut off from surface waters (epilimnion). In addition, the temperature difference creates a physical barrier to transport of material between these two distinct water bodies. Hence, the higher conductivity in the epilimnion may be the result of input and runoff from houses and attendant land in the watershed during the stratification period. Because of the large difference between these two layers of water, which was consistent between years, it appears that input from these sources is probably a substantial source of nutrients into the lake.

Tributary Water Quality

We measured water quality in four tributaries (creeks and streams) coming into Ryerson Lake on 9 April 2021 (see Fig. 6 for locations of sites 1 – 4) in attempt to characterize the magnitude of nutrient input from outside sources in the watershed. The pH varied from 8.34 to 8.37, all high values, suggesting considerable amount of photosynthesis ongoing in the streams (Table). Conductivity varied from 352 to 523 uS, the latter value close to maximum values in the surface in the lake proper (575-585 uS – Tables 4, 5), which we suggested was derived from runoff from the watershed. The highest value was at site 2, which enters under Sherman Road, which rings the western riparian edge of Ryerson Lake, and which also contained high concentrations of total phosphorus. As we noted above, chlorides were some of the lowest we ever measured in a lake, ranging from 11 to 14 mg/L (Tables 4, 5) and it appears that concentrations in the watershed are not much different (4 to 21 mg/L) with the low values almost characteristic of pristine water and suggestive of the runoff being mostly rain which has very low chlorides. It also suggests that winter salting operations are not having much effect on the concentrations in the lake, so must be low. However, the one higher concentration at site 3 (NW Sandbar) is consistent with the highest TP and nitrates found in any of the tributary samples, suggesting this site is a problem area for contaminating Ryerson Lake. The nitrate data are important since nitrates are usually the second-most critical nutrient in lake dynamics and high values are often associated with excessive fertilization on agricultural lands. They ranged from trace (0.03 mg/L at site 1 – SW Trail Crossing) to an amazing 7.88 mg/L, which could be the highest we have ever measured. It could be used as fertilizer!! It was found at the NW Sandbar, which as we have noted drains a large agricultural area (see Fig. 6), which apparently is contributing large amounts of this important nutrient to Ryerson Lake. Site 4, the NE Camp site also had moderately high concentrations at 0.83 mg/L, suggesting that the agricultural landscape near that tributary is leaking fertilizer into Ryerson Lake as well. Ammonia, which as we have noted is usually converted to nitrates in the presence of oxygen, was uniformly low at all four sites ranging from trace to 0.016 mg/L. Lastly, our primary concern is input of phosphorus from these tributaries. The SRP concentrations were low at all four sites, but TP was very high

(0.120-0.190 mg/L at three sites – 1-3) and moderate (0.051 mg/L) at one (site 4 – NE Camp). So, obviously the NW Sandbar overall had the worst tributary water quality of all four sites, having the highest chlorides (21 mg/L), the highest nitrates (7.88 mg/L), the highest SRP (0.016 mg/L), and the highest TP (0.190 mg/L). The lake association needs to ask those farmers to enact best management practices in their fields to keep fertilizers from running off during the winter and entering Ryerson Lake. It appears that the lake has reacted to these increased nutrient sources by growing a vast bed of macrophytes (station S4 – Fig. 6, Picture 1), which are probably absorbing much of the input from this area. Hence, care needs to be taken not to destroy or degrade these plants (herbicide treatments) from continuing to remove nutrients.

Lastly, the Lake Boards for Pickerel and Kimball Lakes, which are downstream of Ryerson Lake, have retained a person from the Newaygo Conservation District to conduct a preliminary survey of the Pickerel and Kimball Lakes watershed (that includes Ryerson – see watershed map – Fig. 10) to identify potential problem areas. Ryerson Lake folks should contact this person and the boards to obtain a better documentation of the importance of agricultural inputs in the watershed and ways (best management practices) to reduce the impact of nutrient inputs to Ryerson Lake.

Table 6. Conductivity (uSiemens), pH, chlorides (CL), nitrates (NO3), ammonia (NH3), soluble reactive phosphorus (SRP), and TP (total phosphorus) for Ryerson Lake tributaries, 9 April 2021. All concentrations are in mg/L. Sites are tributaries to Ryerson Lake: 1=SW Trail Crossing, 2=W Sherman, 3=NW Sandbar, 4=NE Camp. See map, Fig. 6 for locations of these sites.

Site	pH	Cond	Cl	NO3	NH3	SRP	TP
1	8.44	352	4	0.03	<0.01	<0.005	0.120
2	8.57	523	14	0.21	0.03	<0.005	0.120
3	8.34	467	21	7.88	<0.01	0.016	0.190
4	8.35	407	7	0.83	<0.01	<0.005	0.051

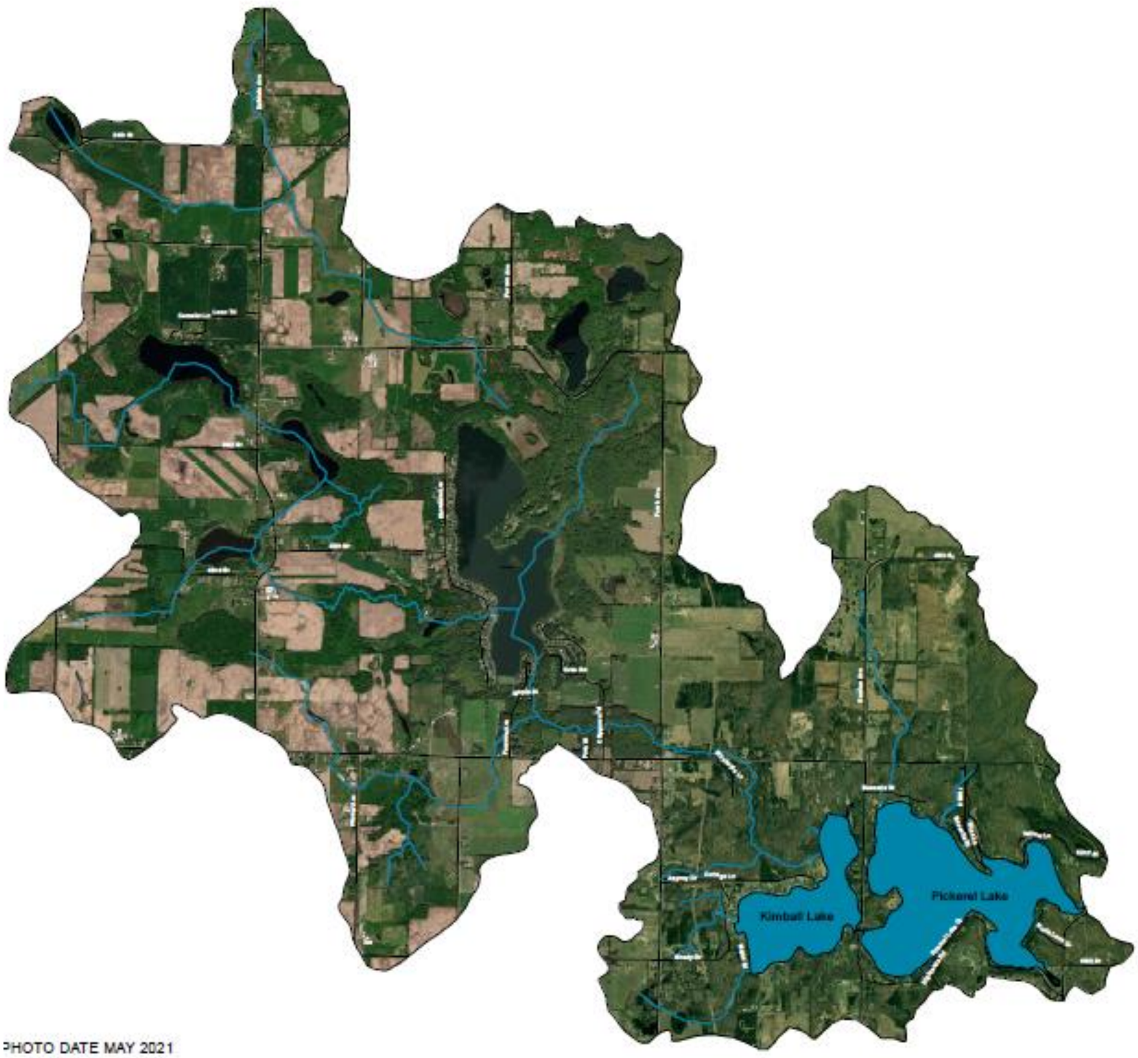

Figure 10. Watershed map for Kimbell, Pickerel, and Ryerson lakes. Map contributed by Progressive AE.

BIOLOGICAL PARAMETERS

Algae

We collected algae from the surface of station A during 21 July 2021 using a 2-m long, plastic tube that samples the top 2 m of the water column. The algae consist of many biological groups of organisms that do not represent a single lineage on the evolutionary tree of life, but are linked by function—freshwater algae are generally small, photosynthetic, and do not have organized tissues like higher plants (flowers and trees). From an ecological perspective the algae are critical to the functioning of the earth (algae account for about 50% of the photosynthesis—hence half the oxygen we breathe) and form the base of the food web in most lake and river systems. The different algal groups are separated based on their cell structure (bacterial type or prokaryotes—the Cyanobacteria; or true cells or eukaryotes—the rest of the algal groups), storage products (starch, lipids, proteins), pigments, cell wall or membrane structure, cellular organization, and life history types. The major groups of algae that we encountered at the two sampling stations in Ryerson Lake in July 2021 (Table 7) included:

Cyanobacteria—the blue-green algae are photosynthetic bacteria and are common in lakes, streams, and even wet soils. The blue-green algae are well adapted to living in lakes that have a wide range of nutrients. They can adjust their buoyancy in the water column (get light and nutrients as needed), they often grow in large colonies that are not preferred food by zooplankton, and they are most notorious for their production of toxins under certain growth conditions (e.g., cyanobacteria in Lake Erie caused the shutdown of the Toledo water supply in 2015). Cyanobacteria made up over 73% of Ryerson's Station A algal biomass in July 2021. The deep station cyanobacteria community comprised mostly small-celled non-nuisance forms (e.g., *Aphanocapsa* and *Aphanothece*, Fig. 11A, 11B), but one species of concern was noted in low abundance in Ryerson Lake (*Microcystis*).

Bacillariophyta—the diatoms are characterized by having a cell wall made of opaline silica or biologically produced glass (see Fig. 11C for picture on right). The size, shape, and ornamentation of the cell wall provide clues for species identification. Diatoms are generally found in two major ecological groups. The planktonic forms are either round (small *Cyclotella* or *Aulacoseira* in Ryerson Lake) or long and spindle-shaped (the *Fragilaria/Ulnaria* species in Ryerson Lake) and are common during spring and fall turnover, but may be maintained in the water column in the summer. Benthic forms are found living attached to plants, rocks, and sediment, but can be found in the water column if there is sufficient mixing due to wave action, wind, or boating. Diatoms were an abundant group in the station A samples from Ryerson Lake in July 2021 making up 26% of the algal biomass at Station A (Fig. 11B).

Chrysophytes—the golden brown algae or chrysophytes live in small motile colonies or as single cells. Many of the forms have small silica scales that cover their cells (*Synura*, *Mallomonas*) or live in organic vase-shaped structures (*Dinobryon*). The chrysophytes are typically common in cooler months of the year but can be found in the summer as they are motile in the open water. The few cells of *Dinobryon* that were found in Ryerson Lake made up <1% of the algal biomass at station A.

Green algae or Chlorophytes—the green algae range in size from single cells to large filamentous forms that are common on rocks and logs along the shorelines of many lakes. The green algae are often common in mid-summer, but can produce nuisance accumulations in the spring following ice-out. In Ryerson Lake, single-celled and colonial forms that are suspended in the open water can be common; in Ryerson Lake, low levels of *Scenedesmus* were encountered at <1% of the algal biomass at station A.

The late summer algal flora of Ryerson Lake (sampled 21 July 2021) was dominated by cyanobacteria and secondarily by diatoms (Fig. 11A and 11B). Algal biomass in July 2021 was about 628,000 µm^3/mL at Station A, which included nearly 79,000 cells per ml of mostly tiny cyanobacteria at station A (Fig. 11A). The dominant cyanobacteria were small-celled forms of *Aphanocapsa* and *Aphanothece*, which are not commonly associated with cyanotoxin production. There were minor levels of *Microcystis* in Ryerson Lake; this cyanobacterium can reach bloom conditions and can become a toxin producer under the right environmental conditions especially in late summer and fall. A good rule of thumb for lake users is when water clarity is low and there is a blue-green hue to the water, lake users should be cautious. They may experience skin sensitivity, should avoid ingesting any water, and should not allow pets in the water.

Table 7. Predominant (>5% of total algal biovolume, µm^3/mL) algal species or genera in Ryerson Lake, 21 July 2021. Abbreviations of algal groups: CY = cyanobacteria, BA = diatoms, GR = greens, DI = dinoflagellates, CH = chrysophytes, CR = cryptomonads, EU = euglenoids.

Ryerson Lake	**Dominant algae**
July 2021	*Ulnaria acus* (BA), *Aphanocapsa* (CY), *Aphanotheca* (CY).

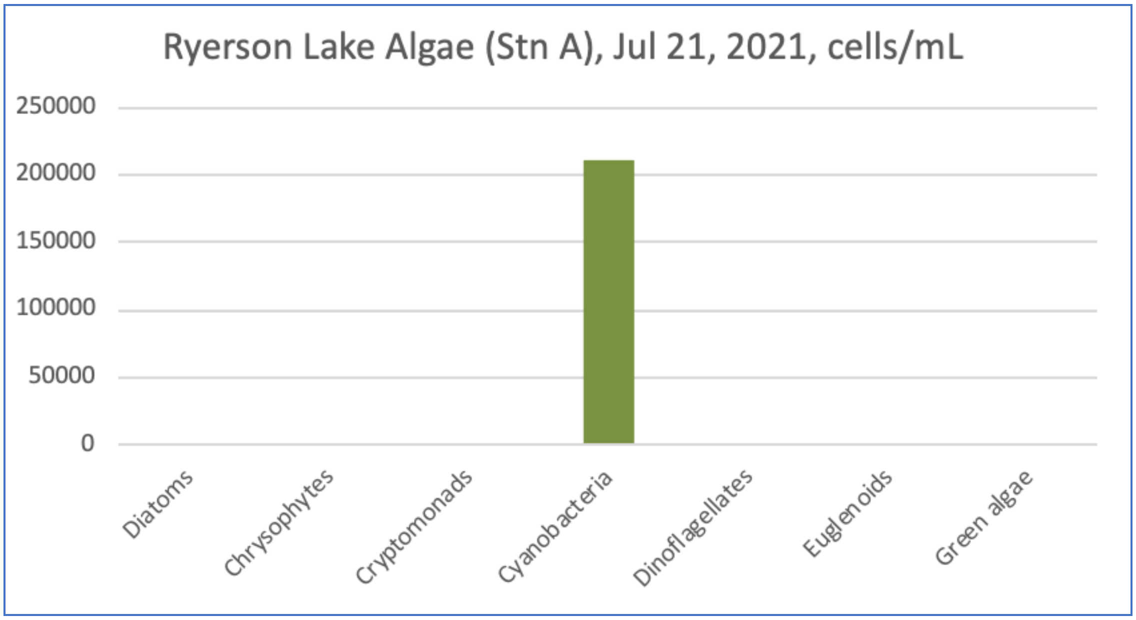

Figure 11A. Abundance of algae (cells/mL) by algal group for Ryerson Lake, station A, 21 July 2021.

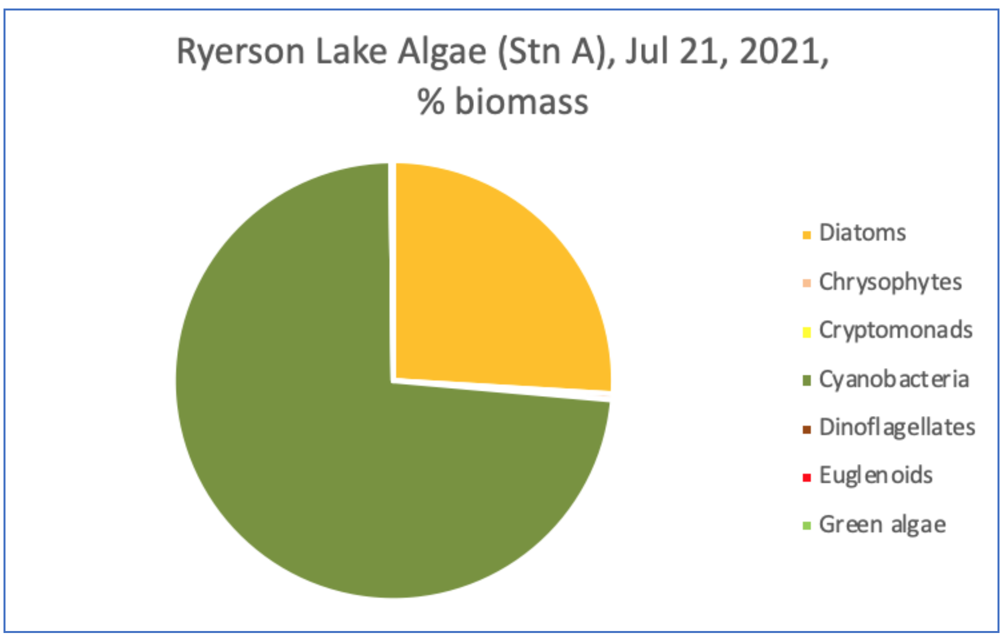

Figure 11B. Proportion of algal biovolume or biomass by algal group for Ryerson Lake, station A, 21 July 2021.

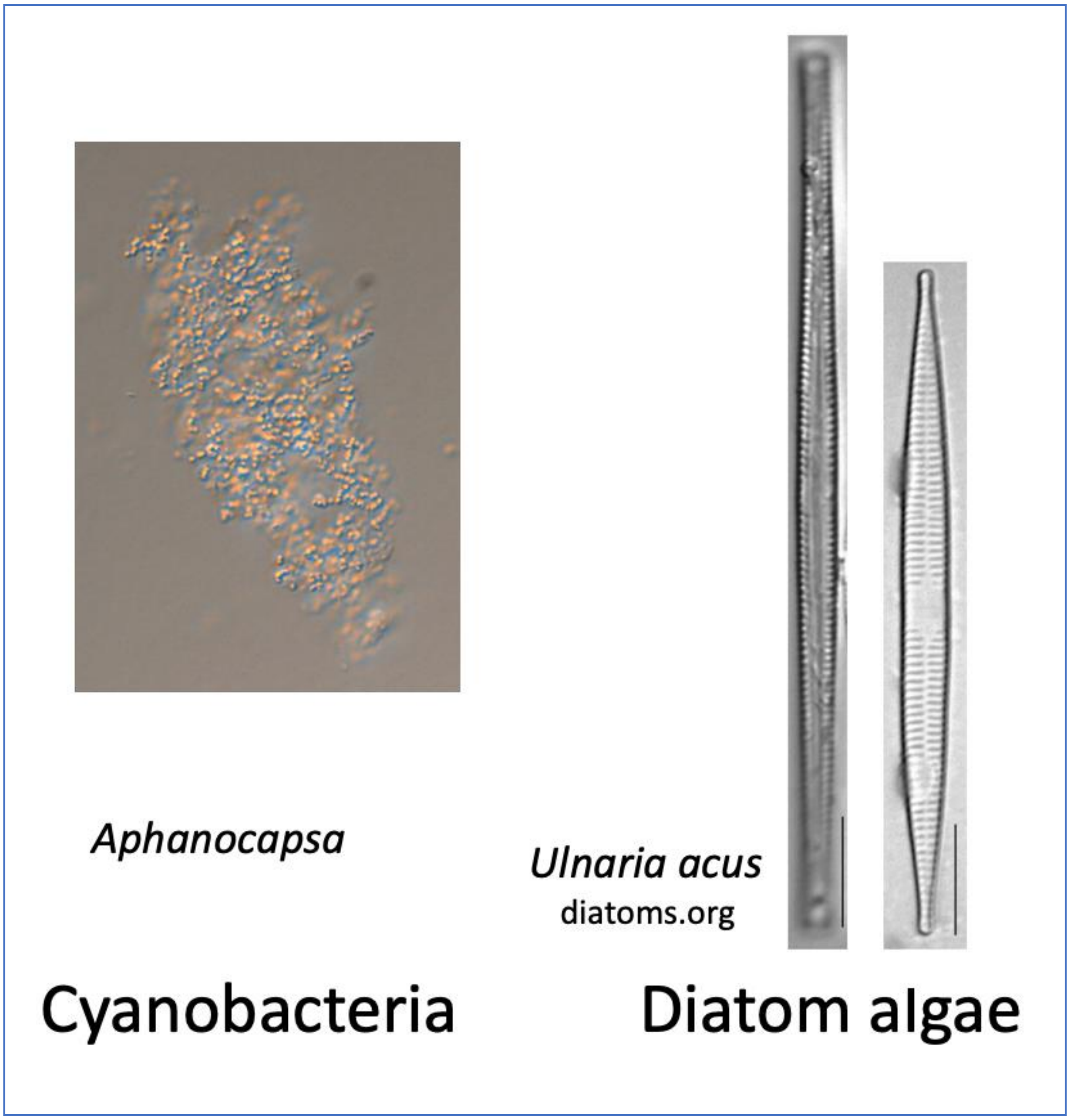

Figure 11C. Predominant algae in Ryerson Lake in July 2021 were the cyanobacteria including small-celled, non-nuisance forms (*Aphanocapsa, Aphanothece*), and a diatom species that lives in the water column called *Ulnaria acus*.

We received notification during last summer-fall of blue-green algae blooms on the lake. This again is a manifestation of the nutrient enrichment problem in the lake from many sources, and we concur with the explanation Tony Groves of Progressive Engineering AE gave. In this case the internal loading in the deep basin was probably the immediate source of the nutrients utilized by the algae. SRP, the soluble form most usable to algae, was limiting (very low concentrations present) in surface waters and so were nitrates and ammonia. Blue-green algae can fix their own nitrogen, so have an advantage over more "acceptable" algae, such as green algae. Hence, as the stratification pattern we discussed that separates the hypolimnion from the epilimnion broke down due to fall winds and falling temperatures and probably aided by boat traffic, some of the water of the hypolimnion mixed with surface waters and entered the epilimnion (surface waters). As we discussed in the phosphorus section, there are very high concentrations of phosphorus (0.160-0.433 mg/L) on the bottom being generated by decomposition of the accumulated sediments on the bottom in the 80-ft basin (Tables 4, 5). These nutrients mixed into surface waters, which then aided in the proliferation of these blue-green algae blooms.

We also wanted to ensure that residents be on the lookout for an exotic species, called starry stonewort (Picture 2), which has been observed in many Michigan lakes in the past few years. Note this species is an alga, and is a very destructive plant. It looks a lot like *Chara*, another green alga but is somewhat different in that stems are tubular, does not have the gritty surface accumulations (calcium carbonate deposits) that *Chara* does, and when it reaches dense mats looks like tumble weed. If seen, it should be reported to the board and follow up studies done to confirm identification and begin treatment before it reaches nuisance levels.

Picture 2. Starry stonewort

Aquatic Macrophytes

Ryerson Lake was populated with many species of macrophytes based on observations during the 2014 and 2021 study. They are a very important component of the lake ecosystem serving several functions. They are shelter and nurseries for young fish, they are spawning substrates for some species (e.g., minnows), they produce many insects which are important food for fishes, and help to retard wave action from producing and re-suspending sediments from wave action. In addition, as we have pointed out in the Tributary Section, vast macrophyte beds on the NW end of the lake are probably acting as wetlands and absorbing large quantities of nutrients entering from the agricultural land that tributary drains. Those aquatic plants we observed (not an exclusive list) include one invasive species: Eurasian milfoil *(Myriophyllum spicatum)* and several native species including: lily pads *Nymphaea*, cattails *Typha*, bulrushes *Scirpus*, eel grass *Vallisenería*, and thin-leafed naiads N*aijas* spp. We also found the alga *Chara*, which looks a lot like an aquatic macrophyte. Invasive species such as Eurasian milfoil need to be treated to keep populations from flourishing.

Zooplankton

Zooplankters are small invertebrates present in most lakes and ponds (See Picture 3 for an example of a copepod). 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 during 2014 from a vertical tow at station A, the deep basin (see previous report: Freshwater Physicians, 2015), was comprised of very few species (five), indicating that there was not a diverse group of these organisms in Ryerson Lake. These species included: *Daphnia* (see Picture 4), *Mesocyclops*, *Sida crysalina*, *Skistodiaptomus oregonensis*, and *Chydorus* (Table 8). The two dominant groups were *Daphnia* (45% by number*)* and *Skistodiaptomus oregonensis* (also 45%), which has two implications. First, one of the things we look for is the presence of the large species of zooplankton: *Daphnia* especially. *Daphnia* is slow, energy-rich, large, and an easy target for fishes. Therefore, since we found large quantities of these large zooplankters present in the lake it indicates that at least during summer fish predation is not intense, as is often seen in lakes dominated with planktivores (zooplankton eaters), such as small bluegills, yellow perch, and black crappies. Our fish sampling confirmed that there were moderate numbers of small bluegills present during 2014, but they were confined to the near shore zone in the aquatic plants, and apparently did not go offshore into the open water during our sampling in July. *Daphnia* are also known to do diel vertical migrations and come to the surface areas at night to feed, while staying in the anoxic water during the day to avoid fish predation. As we will note, phantom midge larvae (members of fly family) do this same maneuver.

Second, *Daphnia* is more efficient than copepods (a smaller, faster group of zooplankton – *Skistodiaptomus orgegonensis* is an example and was abundant) at filtering algae from the water column. Since *Daphnia* were so abundant, they are helping to control algae in the surface waters promoting clearer water. Copepods are also not fed on as often by fish since they are faster, unless other large zooplankters are rare.

Table 8. A listing of the abundance (% composition based on counting a random sample of 100 organisms) of zooplankton species (see Picture 3-4) collected from station A in Ryerson Lake, 2014 (see Fig. 5 for station locations). *Chaoborus* are insects in the family Diptera (flies) called phantom midges. The larval form lives in lakes on or near bottom and they feed on zooplankton. They are usually eaten quickly by fish, but can survive in lakes with no dissolved oxygen in the bottom waters, which is the case here.

Group*	Abundance
***Daphnia* spp.**	**45%**
***Chydorus* spp.**	**Rare**
Sida chrysallina	**Rare**
Mesocyclops edax	**Rare**
Skistodiaptomus oregonensis	**45%**

Many Chaoborus present

During 2021, the composition of the samples was much different, and *Daphnia* composed only 1.9% of totals in the shallow area (ca. 10 ft where fish predation would be expected to be more severe) and 1.2 % in the deep basin (Table 9). This contrasts with the % composition during 2014 at the deep site—45%. Checking fish diet information (Table 11) shows that black crappie YOY, bluegills 4-7 in, and yellow perch YOY were all feeding on zooplankton during 2021. One could only conclude that *Daphnia* are being severely preyed on by bluegills, yellow perch, and black crappies, and probably other fish, in the 2021 era, much more than they were during 2014. Since northern pike were more numerous and probably the dominant predator during 2014, one might expect a dramatic reduction in prey fish, leading to reduced predation on zooplankton. With what we believe to be a reduced population of northern pike and more largemouth bass during 2021, apparently there was less impact on those prey fish that feed on zooplankton and more on minnows leading to the observed zooplankton reduction we documented during 2021. It should also be noted that *Bosmina* and *Eubosmina* are also large members of the *Daphnia* group, which are also targeted by planktivorous fishes, and they were very abundant in samples.

Lastly, *Chaoborus*, an insect larva called phantom midges in the Diptera (fly) family was also present in the zooplankton samples in large numbers during 2014 from the deep station A. During 2021 we sampled at a shallow and a deep station and found that there was more caught at the deep station than the shallow station. This is an intriguing finding, since it is known that these larvae are not present in lakes with dissolved oxygen present in bottom waters during summer since they are eaten by fish, but we did not expect to see them in shallow water, suggesting less fish predation there. The fact that they are so abundant in our zooplankton tows from the deep basin shows that these organisms, which can live in anoxic conditions which protects them from fish predation, were present and moving up and down in the water column during this period. They will be subject to predation when the lake overturns in the fall, but some were eaten in large numbers by black bullheads and large black crappies during 2021 (Table 11).

Table 9. A listing of the abundance (% composition based on counting a random sample of at least 100 organisms) of zooplankton species (see Picture 3-4) collected from station A (deep) and station B (shallow – ca. 10 ft of water) in Ryerson Lake, 21 July 2021 (see Fig. 6 for station locations). *Chaoborus* were present in both samples. They are insects (larval form) in the family Diptera (flies) called phantom midges. They are usually eaten quickly by fish, but can survive in lakes with no dissolved oxygen in bottom waters (a refuge), which is the case here.

Species*	Station A No.	Shallow %	Station B No.	Deep %
Alona spp.	1	0.6		0.0
Bosmina	71	45.8	16	9.2
Cyclops spp. immature	22	14.2		0.0
Cyclops spp. F	4	2.6		0.0
Cyclops spp. M	1	0.6		0.0
Daphnia spp.	3	1.9	2	1.2
Diaphanosoma spp.	2	1.3	14	8.1
Diaptomus immature	15	9.7	63	36.4
Diaptomus oregonensis - F	16	10.3	16	9.2
Diaptomus oregonensis - M	2	1.3	9	5.2
Epishura F		0.0	1	0.6
Epishura M		0.0	1	0.6
Eubosmina	18	11.6	3	1.7
Eurytemora F		0.0	6	3.5
Eurytemora M		0.0	4	2.3
Mesocyclops edax immature		0.0	19	11.0
Mesocyclops edax - F		0.0	9	5.2
Mesocyclops edax - M		0.0	10	5.8

**Chaoborus* were present in both samples, but more were in the deep sample.

Picture 3. A copepod (zooplankter).

Picture 4. *Daphnia*, a large zooplankter, adept at eating algae.

Fish

Fish Species Diversity

We collected fish during 2014 and 2021 using three trap nets (stations TN1, TN2, TN3) (Fig. 6, see Picture 5) with some of the resulting fish caught during 2021 shown in Picture 6. A 50-ft seine (stations S1, S2, S3, S4 – Fig. 6, Picture 7), and two gill nets (shown as stations GN1 and GN2 – Fig. 6, Picture 8) were also deployed in the lake. The nets were used during the daytime on 24 July 2014 and on 21 July 2021; the gill nets were picked up and reset, while the trap nets were left overnight. Seining with a 50-ft seine was done at four sites on the lake in different habitats. Most fish were released; we kept enough for an adequate sample for ageing and diet analyses. We never want to kill too many fish, especially top predators, as they are so important to fish community balance in a lake. We could have used a few more large fish (especially largemouth bass), but the ones we did catch and those that were donated by fishers provided a good sample for some basic information on the lake. We thank Charles Yonker for providing these extra fish scale samples during 2021.

There were 22 species of fishes collected during the 2 years of study (2014 and 2021) (Table 10). The lake has a high diversity of fish species, some of which were stocked (walleye) and one is invasive: common carp; most were native. We collected 19 species in our sampling efforts during July 2014 (Table 10) plus common carp *Cyprinus carpio* which were reported to us as being in the lake. During 2021, we collected only 14 species, a considerable fewer number of species, despite sampling in the same areas and times as our 2014 study. Most of those not collected were minnows that were rare during 2014. There was a huge year class of northern pike in the lake during 2013, since we collected and were given many fish in the 19-24-inch range. The high abundance of northern pike prompted MDNR to expand fishing opportunities for this species in the lake, which is justified based on how many we caught and the slow growth rate measured during the 2014 era; however, that has changed during 2021 with fewer northern pike presumably in the lake. In addition, there are three other important top predators in the lake: largemouth bass, black crappie, and walleye. In addition, rock bass and yellow perch also are predaceous at larger sizes and act as top predators, along with yellow, black, and brown bullheads. It appears from what we know about northern pike and walleyes and our diet information, that northern pike are having a depressing effect on yellow perch in your lake, since they are a preferred prey item, if not enough soft-rayed fishes (minnows) of sufficient size are available. Our sampling also reflected a dearth of larger yellow perch during both 2014 and 2021, which would also be expected. It was surprising to us that walleyes can even survive in the lake, with the degraded water quality environment in which they are forced to live during summer, but since they are present during the whole year, and because the lake is so productive, they grew well during the cooler periods of the year.

In addition to a suite of top predators, the lake also contains a good population of bluegills and black crappies. A few green sunfish and pumpkinseeds were also documented. As noted, yellow perch sizes appear to be truncated; there were many young of the year (YOY) indicating excellent reproduction (same for largemouth bass), but few yellow perch appear to be making it to larger sizes, undoubtedly due to northern pike and walleye predation with some contribution by largemouth bass and probably bullheads as well. There are a few rock bass and we found three species (black, brown, and yellow bullheads) in the lake. There were also an amazing seven species of minnows captured (most during 2014): emerald, bluntnose, spotfin, golden, mimic, blacknose, and blackchin shiners; only one, the bluntnose minnow was captured during 2021. During 2021, we caught a species -- banded killifish not seen during 2014. Overall, this is an excellent diversity of predators and prey, but the loss of six species of minnows is perplexing. The only predator that would account for this loss of diversity is the largemouth bass. They are voracious predators and may have increased their population in the absence of large numbers of northern pike seen during 2014, but much less so in 2021.

It appears that there is adequate spawning substrate for yellow perch and largemouth bass (sandy gravel areas) and a diversity of habitats that support the high number of other species of minnows during 2014 which also had adequate populations during 2014. The northern pike situation is interesting. It appears there was an outstanding year class formed probably 7-8 years ago which resulted in the lake being overrun with northern pike. This infers that there is or can be great spawning somewhere in the lake, mostly likely the four inlets and outlet creeks, when conditions are optimal (high water or flooding). Since we did not find any or few other small pike nor any huge ones (there are reports of a few in the lake), it indicates that there was poor recruitment in other years, and they seemed to be in much lower abundance based on our smaller catches during 2021. Usually, one should see many hammer-handle pike (juveniles) in years with successful reproduction, which fisherman would report, and we would sample.

Lastly, we noted two species of larval mayflies (*Hexagenia* and Baetidae) and caddisflies in the diet items eaten by various sunfish during 2014. This is a good indication of the high water quality of the lake, since these aquatic insects can only survive in areas with high dissolved oxygen over at least 1 year as well as appropriate substrate and water temperatures.

Picture 5. One of the trap nets used at station TN-1 (Fig. 6, Table 1) Ryerson Lake, 24-25 July 2014. Trap nets were set at similar sites during 2021.

Picture 6. Fishes captured in Ryerson Lake, 21 July 2021.

Picture 7. Deployment of the 50-ft seine in the near shore zone at station S4 (See Fig. 6).

Picture 8. Experimental gill net with fish being brought into the boat.

Table 10. Fish code, common name, and scientific name of the fishes collected from Ryerson Lake, 24-25 July 2014, 2021, and if collected in both years then BOTH. Abundance is defined as: R=Rare, C=Common, A=Abundant. Walleyes were only caught during 2014, but we saw evidence of some being caught by fishers, so they were still present during 2021. Common carp were not caught during 2014 but were seen and we caught one during 2021.

CODE	COMMON NAME	SCIENTIFIC NAME	ABUNDANCE
BK	BANDED KILLIFISH	*Fundulus diaphanus*	R-2021
BB	BLACK BULLHEAD	*Amerius melas*	R-BOTH
BC	BLACK CRAPPIE	*Pomoxis nigromaculata*	R,C-BOTH
CP	COMMON CARP	*Cyprinus carpio*	R-BOTH
ND	BLACKCHIN SHINER	*Notropis heterodon*	R-2014
NH	BLACKNOSE SHINER	*Notropis heterolepis*	R-2014
BG	BLUEGILL	*Lepomis macrochirus*	A-BOTH
BM	BLUNTNOSE MINNO	*Pimephales notatus*	R-BOTH
CP	COMMON CARP	*Cyprinus carpio*	R-2021
SV	BROOK SILVERSIDES	*Labidesthes sicculus*	R-BOTH
BN	BROWN BULLHEAD	*Amerius nebulosus*	R,C-BOTH
ES	EMERALD SHINER	*Notropis atherinoides*	R-2014
GL	GOLDEN SHINER	*Notemigonus crysoleucas*	R-2014
GN	GREEN SUNFISH	*Lepomis cyanellus*	R-2014
HY	HYBRID SUNFISH	*Lepomis*	R-BOTH
LB	LARGEMOUTH BASS	*Micropterus salmoides*	C-BOTH
MC	MIMIC SHINER	*Notropis volucellus*	R-2014
NP	NORTHERN PIKE	*Esox lucius*	C-BOTH
PS	PUMPKINSEED	*Lepomis gibbosus*	C-BOTH
RB	ROCK BASS	*Ambloplites ruprestis*	R-BOTH
SF	SPOTFIN SHINER	*Cyprinella spiloptera*	R-2014
WL	WALLEYE	*Sander vitreus*	R-2014
YB	YELLOW BULLHEAD	*Amerius natalis*	R,C-BOTH
YP	YELLOW PERCH	*Perca flavescens*	R-BOTH

Fish Diets

Diets of fishes were examined during 2021 for a representative sample of species we collected. We caught one black bullhead that was 9.3 in and had eaten a large number of phantom midges and some algae and a chironomid (Table 11). These two insects are members of fly (Diptera) family and we found large numbers in our zooplankton tow at the deep station A. As we noted in the 2014 report, these insects use the anoxic waters in the depths at station A as a refuge, since fish cannot go there. However, they probably drift to other areas of the lake, where fish can access them as this black bullhead did.

The one brown bullhead we caught was 12.6 in and had eaten a crayfish and three bluegills 52- 60 mm long.

We caught 11 black crappies with a wide range of sizes (3.7-10 in); small fish 3.7-4.6 in were feeding on zooplankton (Table 11), which is similar to what we found during 2014 (Freshwater Physicians 2015). The large specimens from 8 to 10 in were eating insects: phantom midges and chironomids. As noted, phantom midges were abundant in our zooplankton tows during 2014 around station A, the deepest basin in the lake. We suspect that black crappies are eating these organisms during the night when they rise to the surface to feed on zooplankton. Chironomids are usually on or near bottom, so black crappies are either eating them when they move above bottom or stirring up the sediments and eating them there. Usually large black crappies eat fishes, which is what they did during 2014 studies when bluegills and unknown fish were found in stomachs.

We sampled many bluegills from 1.2 in to 6.9 in and received another six specimens from C. Yonker, which were important for age and growth, but no diet information was available from these larger fish. The fish we sampled were mostly insectivorous, but some were eating invertebrates. There was a wide array of organisms eaten including: chironomids, water mites (spiders), mayflies (Baetidae – a great sign of good water quality), damselflies naiads, caddisflies another sensitive insect, zooplankton, *Hyalella* fairy shrimp, and isopods (Table 10). This is a rich and diverse food supply which should provide good growth for these fishes. These findings were similar to 2014 data, where fish also ate dragonfly naiads and some algae, but they also ate some *Hexagenia*, the large mayfly of AuSable River fame, which are bellwethers of good water quality in the lake.

We caught many YOY largemouth bass as well as some larger individuals up to 12 inches during 2014 and 23.9 in during 2021 (Table 10, 11). The abundance of YOY suggests that there was good reproduction of this species, and their abundance may account for the lack of minnows caught which we noted during 2021 sampling compared with 2014 data. However, there were no minnows we found in the diets of fish from 2021, but those from 2014 were eating minnows. During 2021, YOY up to 2.8 in were eating *Hyalella*, an amphipod, mayflies and one ate a bluegill. Largemouth bass 4-8 in were mostly piscivorous and mostly consumed YOY largemouth bass, but some banded killifish, yellow perch, and unknown fish were also consumed. It was surprising not to see any bluegills, a major prey, that were eaten by this size group. Crayfish were also eaten. Fish 8-15 in were eating more bluegills, largemouth bass, yellow perch, and the occasional crayfish. The larger fish all had empty stomachs. Considering how abundant largemouth bass YOY and older fish were, it could be possible they are preying on minnows and reducing their numbers in the lake. We have seen a lake that winterkilled regularly that did not have any largemouth bass in it during our first study, but did have a large diversity of other species, such as mud minnows, other minnows, pumpkinseeds, yellow perch and bluegill. The lake was dredged, and largemouth bass were stocked, and they eliminated all other prey species except bluegills. This species is a voracious predator.

We collected only five northern pike during 2021 (during 2014 we caught 31); these five fish were eating only one bluegill – 3.8 in); the rest were empty (Table 11). The fish caught during 2014 had a more diverse diet, including a golden shiner, largemouth bass, yellow perch, and bluegills. Obviously, northern pike and largemouth bass are the major predators in Ryerson Lake.

We studied 10 pumpkinseeds during 2021 from 3 to 6.6 in. Pumpkinseeds are known mollusk and snail eaters and these fish were also eating some fingernail clams (Sphaeriidae), but several insects as well. Treatment of algae with copper sulfate can kill mollusks and snails reducing growth of this species. Prey included dragonflies, chironomids, mayflies (Baetidae), biting midges (Ceratopogonidae), and the amphipod *Hyalella*. Pumpkinseeds examined from 2014 were eating similar insect prey, but also some large mayflies - *Hexagenia*. The presence of *Hexagenia* is a substantial finding, since it shows your water quality is excellent to support this fragile mayfly. Unfortunately, we did not find any *Hexagenia* in the stomachs examined during 2021.

The four rock bass we collected ranged from 5 to 11.7 inches and were eating YOY bluegills. This fish is also an important predator in the lake, but appears to be in low abundance. We caught several yellow bullheads that ranged from 8 to 10 in that were eating bluegills and crayfish and some unknown fish. These bullheads are important predators in the lake as well and help control the bluegill population.

Small yellow perch were common in the nearshore zone and those from 2.1 to 5.1 in were eating zooplankton, mayflies (Baetidae), and the fairy shrimp *Hyalella*. The larger fish (5.2-10.4 in) were eating similar organisms including one that ate an unknown fish. We never caught very many large yellow perch, although there are enough large individuals to produce a large population of YOY fish, which were common in our seine hauls. The dearth of larger fish is probably due to predation by the northern pike and largemouth bass. Walleyes also prefer yellow perch and since they are probably stressed during summer, they do well during the cooler parts of the year. In fact, a large one was caught through the ice during 2022 and released.

Table 11. Listing of the species collected, length (in), weight (oz), sex, and diet information for fishes from Ryerson Lake, Newaygo County, MI, 21- 22 July 2021. G=gill net, S=seine, TN=trap net. SF=caught by sport fishers. M=male, F=female, 1=gonads poorly developed, 2=moderately developed, 3=well developed, 4=ripe running. See Table 10 for fish code definitions. MT=empty stomach.

GEAR	SPEC	LEN (IN)	WT (OZ)	SEX	DIET
					<u>BLACK BULLHEAD</u>
G2-2	BB	9.3		M1	800 PHANTOM MIDGES (SOME ALIVE)
					ALGAE, 1 CHIRONOMID
					<u>BLACK CRAPPIE</u>
S4	BC	3.7	0.40	II	ZOOPLANKTON

	BC	3.9		II	ZOOPLANKTON?
S4	BC	4.4	0.68	II	ZOOPLANKTON
S4	BC	4.6	0.64	II	ZOOPLANKTON
TN1?	BC	6.5	2.21	M1	MT
G1-1	BC	6.8		M1	MT
TN1?	BC	8.1		M1	300 PHANTOM MIDGES, 1 CHIRONOMID
S1	BC	8.2		F1	CHIRONOMIDS, INSECT PARTS
TN1?	BC	8.8		M1	200 PHANTOM MIDGES, 250 CHIRONOMIDS
G1-1	BC	8.9		F2	MT
G1-1	BC	10.0		F2	400 CHIRONOMIDS, 2 PHANTOM MIDGES
					<u>BLUEGILL</u>
S4	BG	1.2		II	
T2	BG	1.9			
T2	BG	2.1			
T2	BG	2.2			
T2	BG	2.3			
T2	BG	2.3			
T2	BG	2.3			
T1	BG	2.4	0.12		
T2	BG	2.4			
T2	BG	2.4			
T2	BG	2.5			
T2	BG	2.5			
T2	BG	2.5			
T2	BG	2.5			
T2	BG	2.5			
T1	BG	2.6	0.15		
T2	BG	2.6			
S1	BG	2.6	0.14	II	MT
T2	BG	2.6	0.14	II	MT
T2	BG	2.6			
T2	BG	2.6			
T2	BG	2.6			
T2	BG	2.6			
T2	BG	2.6			
S1	BG	2.6	0.14	M2	EGGS
T2	BG	2.6			
T2	BG	2.6			
T1	BG	2.7	0.12		
T1	BG	2.7	0.17		
T1	BG	2.7	0.18		
T2	BG	2.7			
T1	BG	2.7			

T1	BG	2.7	0.13		
T1	BG	2.7	0.17		
TN1?	BG	2.8	0.17	II	MT
T2	BG	2.8			
S1	BG	2.8	0.16	II	MT
T2	BG	2.8	0.18	II	3 CHIRONOMIDS
T1	BG	2.8	0.18		
T1	BG	2.8	0.17		
T2	BG	2.8			
T2	BG	2.8			
T2	BG	2.8			
T2	BG	2.8			
T2	BG	2.8			
T2	BG	2.8			
T2	BG	2.9			
	BG	3.0			
T2	BG	3.0			
T2	BG	3.0			
T2	BG	3.0	0.24	II	MT
T2	BG	3.0			
S2	BG	3.1			
T2	BG	3.1			
T2	BG	3.2	0.28	II	DETRITUS
T2	BG	3.2	0.30		WATER SPIDER (HYDRACHNIDIA), INSECT PARTS
T1	BG	3.5	0.34	II	CHIRONOMID
	BG	4.0		M1	8 Baetidae (Mayflies)
S1	BG	4.1	0.78	II	ISOPODS, SNAILS, INSECT PARTS
S4	BG	4.4	0.62	II	ZOOPLANKTON
S3	BG	5.0	1.16	F1	MAYFLIES
G1-1	BG	5.2		F2	MACROPHYTES
S4	BG	5.2	1.43	F1	
S4	BG	5.6	1.59	F1	BEETLE, CHIRONOMIDAE
S3	BG	5.6	1.69		75 HYALELLA
S3	BG	5.6	1.93		2 CHIRONOMIDS, SNAIL, WASP
S4	BG	5.6	1.99	F1	PLANTS, ANT
S3	BG	5.7			10 CHIRONOMIDS, 30 BAETIDAE, 1 CADDISFLY
S3	BG	5.7	1.99		CHIRONOMIDS, HYALELLA, BAETIDAE
S4	BG	5.7	2.14		DAMSELFLY NAIAD, 5 HYALELLA, PLANTS
S3	BG	5.9	2.23	F2	8 HYALELLA, 2 BAETIDAE,
S4	BG	6.0	2.00	F1	MAYFLIES
S3	BG	6.0			5 HYALELLA, 1 WASP, CADDISFLY
T2	BG	6.1	2.28	F1	MAYFLY - BAETIDAE, CHIRONOMIDS, PLANTS, HYALELLA
S2	BG	6.2	2.53	F2	LARGE TERRESTRIAL BEETLE

G1-1	BG	6.9		F1	ZOOPLANKTON, 1 CHIRONOMID, 2 HYALELLA
SF	BG	7.0			
SF	BG	7.5			
SF	BG	7.5			
SF	BG	7.8			
SF	BG	8.0			
S2	BG	8.5			
					<u>BANDED KILLIFISH</u>
SF	BK	2.0	0.06		?BG
S1	BK	2.2	0.07		
					<u>BLUNTNOSE MINNOW</u>
S1	BM	2.5			
S3	BM	2.7	0.08		
					<u>BROWN BULLHEAD</u>
T1	BN	2.6	0.10		
S4	BN	12.6		M1	CRAYFISH, 3 BG 52,60,55 MM
					<u>COMMON CARP</u>
S4	CP	17.1		M2	DETRITUS
					<u>LARGEMOUTH BASS</u>
S3	LB	1.5			
S3	LB	1.5			
S3	LB	1.5			
S3	LB	1.6		II	12 HYALELLA
S3	LB	1.6			
S3	LB	1.7			
S3	LB	1.7			4 HYALELLA
S3	LB	1.8			
S1	LB	1.8			9 HYALLELA
S3	LB	1.9			
S3	LB	2.0			
S3	LB	2.0			
S3	LB	2.0			
S3	LB	2.0			
S3	LB	2.1			
	LB	2.1			
S1	LB	2.2	0.06	YOY	XX FISH
S3	LB	2.4	0.10		MAYFLIES, HYALELLA
S1	LB	2.4	0.09		BG 67 MM
S1	LB	2.4			
S1	LB	2.5	0.10	II	MT
	LB	2.5			
S3	LB	2.8	0.15	II	MT
S4	LB	4.3	0.56	M1	MT

S1	LB	4.4	0.52	F1	MT
S1	LB	4.6	0.68	M1	XX FISH
	LB	5.0	0.83	F1	XX FISH
S3	LB	5.0	0.90		1 BK 160 MM
S4	LB	5.0	0.87	F1	MT
G1-1	LB	5.0	1.48	F2	PLANTS
S4	LB	5.2	1.02	F1	
S3	LB	5.3	1.11	M1	CRAYFISH
S2	LB	5.3	1.17		1 YP 45 MM
S2	LB	6.2	1.34	F2	?YP 35 MM
S4	LB	6.4	1.76	F1	1 LB 36 MM
S4	LB	6.5	2.17	F2	1 LB 34 MM
S1	LB	6.9	2.51	F1	XX FISH
S1	LB	7.0		F1	XX FISH
S1	LB	7.1	2.76		LB 38,37,46,37 MM
S4	LB	7.3	1.42	F1	3 LB 37,35,29 MM;XX FISH
S2	LB	7.3	3.02	M1	CRAYFISH
S3	LB	7.5		M1	MT
S4	LB	7.5	3.18	M1	MT
S3	LB	7.9	4.02	F1	3 LB 52,63,48 MM
S3	LB	8.0		M1	1 LB 38 MM
S4	LB	8.0		F1	MT
S3	LB	8.4		M1	XX FISH
S4	LB	8.5		F1	3 LB 46,45,51 MM
S4	LB	8.5		M1	2 BG 52,81 MM
S3	LB	9.3	6.38	F1	MT
G1-1	LB	10.7			8 BG 25-30 MM
S3	LB	10.8		M1	YP 57 MM, 2 BG 30, 63 MM
G1-1	LB	10.9		F1	XX FISH
S1	LB	11.7		M1	CRAYFISH, XX FISH 24.4 G
S1	LB	13.0		M1	8 BG 30-40 MM
G1-1	LB	14.8		F2	MT
S4	LB	15.0		M1	MT
S1	LB	15.1		F5	MT
G1-1	LB	16.9			MT
G1-1	LB	22.5		F1	MT
G1-1	LB	23.9			MT
					<u>NORTHERN PIKE</u>
G2-2	NP	19.1		F1	MT
G2-2	NP	19.1		F1	BG 97 MM
G2-2	NP	19.3		M1	MT (JIG IN GUT)
G1-1	NP	20.1		F1	MT
S2	NP	21.1		M1	MT

					<u>PUMPKINSEED</u>
T1	PS	3.1	0.30	II	DETRITUS
T1	PS	4.1	0.79	M1	MT
S3	PS	4.2		F1	MT
S4	PS	4.4	1.20	F1	?DRAGONFLY
S2	PS	5.2	1.74	F2	CERATOPOGONIDAE, CHIRON, FINGERNAIL CLAMS,BAETIDAE
S1	PS	5.2	1.64	M1	MT
S3	PS	5.4	1.90	F1	MT
S2	PS	6.0	0.58		20 CHIRONOMIDS, 2 HYALELLA
T1	PS	6.5	4.02	F2	FINGERNAIL CLAMS
S4	PS	6.6	3.84	F2	MT
					<u>ROCK BASS</u>
T1	RB	5.8	2.05	M1	MT
T1	RB	6.5	2.61	M1	1 BG 48 MM
S1	RB	7.5	5.30	M1	4 BG 58,55,20,45 MM
S2	RB	11.7	7.20	M1	MT
					<u>BROOK SILVERSIDES</u>
T1	SV	3.5	0.15		MT
S1	SV	3.8	0.15		
S3	SV	3.8	2.08		
S2	SV	1.8	0.02		
S2	SV	4.1	0.18		
					<u>YELLOW BULLHEAD</u>
G2-2	YB	8.4		M1	MT
G2-2	YB	9.3		F1	XX FISH (ATE FISH IN GILL NET)
G2-2	YB	9.9		F1	CRAYFISH
G1-1	YB	10.0		F1	XX FISH
G2-2	YB	10.0		F1	1 BG 96 MM
S2	YB	10.1		F1	XX FISH - BG?
					<u>YELLOW PERCH</u>
S4	YP	2.1	0.05	II	ZOOPLANKTON
	YP	3.5			
S1	YP	4.1			
S1	YP	4.3			
S1	YP	4.4	0.54	M1	MT
S2	YP	4.4	0.51	F1	TERRESTRIAL FLY
S1	YP	4.5	0.52	M1	MT
S1	YP	4.6	0.63	II	1 MAYFLY (BAETIDAE), DETRITUS
S1	YP	4.8	0.62	F1	3 BAETIDAE
	YP	4.9	0.55	F1	MT
S1	YP	4.9		M1	5 HYALELLA, 1 Baetidae, snail
S4	YP	4.9	0.96	F1	10 HYALELLA, 25 BAETIDAE, ISOPOD
S3	YP	4.9	0.63	F1	2 BAETIDAE (MAYFLY)

S1	YP	5.1	0.82	F1	ZOOPLANKTON, BAETIDAE
S3	YP	5.2	0.91	M1	8 HYALELLA, 4 BAETIDAE
S4	YP	5.2	0.80	M1	MT
S4	YP	5.2	0.97	M1	MT
G2-2	YP	5.3		F1	5 HYALELLA, 10 BAETIDAE
S3	YP	5.4	0.94	F1	7 BAETIDAE
S4	YP	5.5	1.01	F1	4 HYALELLA, 5 BAETIDAE
S4	YP	5.8	1.32	M1	MT
S4	YP	5.9	1.29	F1	MT
S2	YP	6.1	1.38	F1	MT
G1-1	YP	10.4			XX FISH (ATE FISH FROM GILL NET)

During 2014 we collected an amazing seven species of cyprinids (minnow family) in our nets (see Freshwater Physicians 2015). These included the following species: Mimic shiner, bluntnose minnow, blackchin shiner, blacknose shiner, emerald shiner, spotfin shiner, and the golden shiner. The golden shiner is a particularly important minnow, since they are omnivorous eating zooplankton, insects, detritus, and algae and grow to large sizes providing excellent prey for the larger predators in the lake, which can often have a limitation on the number of large prey they require as they grow bigger. Golden shiners do best in turbid lakes, which apparently reduces the effectiveness of visual predators like bass and pike. Ryerson Lake is relatively clear and therefore probably has increased predation on this species as a result. Minnow species are an excellent addition to the fish fauna, since they utilize resources that none of the other fish species consume (algae and detritus and probably some insects) and they add an important forage fish for top predators, such as yellow perch, northern pike, and largemouth bass. These species contribute to the high species diversity we noted in the fish community, which is important for maintaining stability under the different stressors of the environment and varying population swings of the predators in the lake. The analogy to a diverse stock portfolio is apt here. One of the interesting findings from the 2021 data is that only one minnow (ignoring common carp that are the largest minnow we have) was found, while seven were found during 2014. Our best hypothesis is that the largemouth bass population was much larger during intervening years due to declining northern pike predation, abundance of YOY largemouth bass, and many small largemouth bass appearing in diets of top predators, resulting in loss or a great depression of the abundance of these minnow species.

Lastly, there is another common species that is probably confused with minnows in the lake called the brook silversides. They have a 2-year life cycle, grow up to 2-3 inches, and can be seen feeding at the surface, sometimes jumping out of the water when they are chased by predators. Again, this is another good member of the fish community adding another prey species to the wide diversity in the lake.

We caught one common carp during 2021, which is an invasive, destructive species; however, they do not appear to be common. With so many predators most of their young are probably consumed. This is a destructive species and should be killed or removed if caught or shot by archers. The predators we documented will probably eat large numbers of their young, but adults should be targeted by humans by any legal means possible to reduce their numbers.

Mercury in fish

We included this section in the 2014 report, but it bears repeating in this report. Mercury is a problem in most of Michigan's inland lakes. 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 that are less fatty, or those high on the food chain will carry the 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. More fatty fishes, such as common carp and bullheads, carry lower mercury levels but high PCB concentrations. 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 largemouth bass, northern pike, walleyes, and some of the larger individual bluegills and black crappies in the lake.

Fish Growth

Growth of the fishes we collected was determined by ageing a sample of fishes of various sizes using multiple scales and comparing the age of fish from Ryerson Lake with Michigan DNR standards (Latta 1958, DNR pamphlet no. 56). We plotted the data from 2014 with that from 2021 to detect changes in growth between years. Bluegills are common in Ryerson Lake and those we aged during 2021 were growing at or slightly above state mean lengths which is similar to findings during 2014 (Table 12, Fig. 12). The fish we aged during 2021 ranged from 2.8 to 8.5 inches (similar to the range in 2014), so there is a good size range of fish present, suggesting a well balanced population in control by the large numbers of predators in the lake. The scattered aquatic plant beds present in the lake, the good diversity and abundance of benthos, and abundance of large zooplankton are apparently providing food and good habitat for bluegill shelter and sufficient food for adequate growth. We should note that during 2021 we did not catch any large bluegills; the larger ones were supplied by C. Yonker. During 2014 we seined a number of large bluegills near the boat launch, but not during 2021. The larger fish may have been out deeper away from our gill net sets. However, it may be an indication of fewer large bluegills in the lake. The warmer climate conditions we are experiencing may also have warmed the water causing offshore movements. With all the modern equipment used by fishers these days, the plea would be to voluntarily reduce the catches of these tasty fish allowing more to survive, grow bigger, spawn, and allow more fishers to experience catching large specimens. This is the common practice with many sport fishers towards larger predators, such as walleyes, northern pike, and largemouth bass. Perhaps it should be extended to panfish as well, since they appear to be growing well, are not stunted, and do not need to be reduced in abundance to promote better growth.

Table 12. Growth of selected fishes collected from the Ryerson Lake, Newaygo Co., 21 July 2021 and some fishes from later in the year provided by fishers (SF). Fishes were collected in seines, gill nets, and trap nets, scales removed, aged, and total lengths at various ages compared with Michigan state mean lengths for various fishes at those same ages (see Latta 1958). Shown is the age (years) of the fish, its total length (inches) based on MDNR state of Michigan mean lengths, and the mean length-at-age of Ryerson Lake fishes along with sample size (N) in parentheses for 2021. See Figs. 12-17 for graphical display of these same data compared with the 2014 dataset.

MDNR Age (yr)	MDNR Len (in)	RYERSON Len (in)
BLUEGILL		N=26
AGE	MDNR	RYERSON
0	2.1	2.7(5)
1	2.9	3(6)
2	4.3	4.7(5)
3	5.5	5.6(3)
4	6.5	6.3(3)
5	7.3	7.5(1)
6	7.8	7.9(2)
7	8	8.5(1)
8	8.5	
9	8.5	
10	9.2	
LARGEMOUTH BASS		N=30
AGE	MDNR	RYERSON
0	3.3	2.4(8)
1	6.1	5.8(8)
2	8.7	7.8(6)
3	10	10.7(5)
4	12.1	
5	13.7	15(1)
6	15.1	15(1)
7	16.1	15(1)
8	17.7	
9	18.8	
10	19.8	
11	20.8	

YELLOW PERCH		N=15
AGE	MDNR	RYERSON
0	3.3	2.1(1)
1	4	4.5(3)
2	5.7	5.3(10)
3	6.8	
4	7.8	
5	8.7	
6	9.7	10(1)
7	10.5	
8	11.3	
9	11.7	

BLACK CRAPPIE		N=11
AGE	MDNR	RYERSON
0	3.6	4(3)
1	5.1	4.6(1)
2	5.9	6.6(2)
3	8	8.2(2)
4	9	8.9(2)
5	9.9	10(1)
6	10.7	
7	11.3	
8	11.6	

PUMPKINSEED		N=9
AGE	MDNR	RYERSON
0	2	
1	2.9	3.1(1)
2	4.1	4.1(2)
3	4.9	5(1)
4	5.7	6.3(2)
5	6.2	
6	6.8	
7	7.3	
8	7.8	6.5(1)

NORTHERN PIKE		N=12
AGE	MDNR	RYERSON
0	7.9	
1	15.5	16(1)
2	19.4	18.7(3)
3	22.2	21.2(5)
4	23.9	23.3(3)
5	25.4	
6	27.7	

7	32.5	
8	37.1	
9	34.8	
10	44.4	
ROCK BASS		N=4
AGE	MDNR	RYERSON
0	1.5	
1	3.2	
2	4.3	
3	5.2	5.8(1)
4	6.2	6.5(1)
5	7.3	7.5(1)
6	7.9	
7	8.8	
8	9	
9	9.9	12(1)
10	10.5	

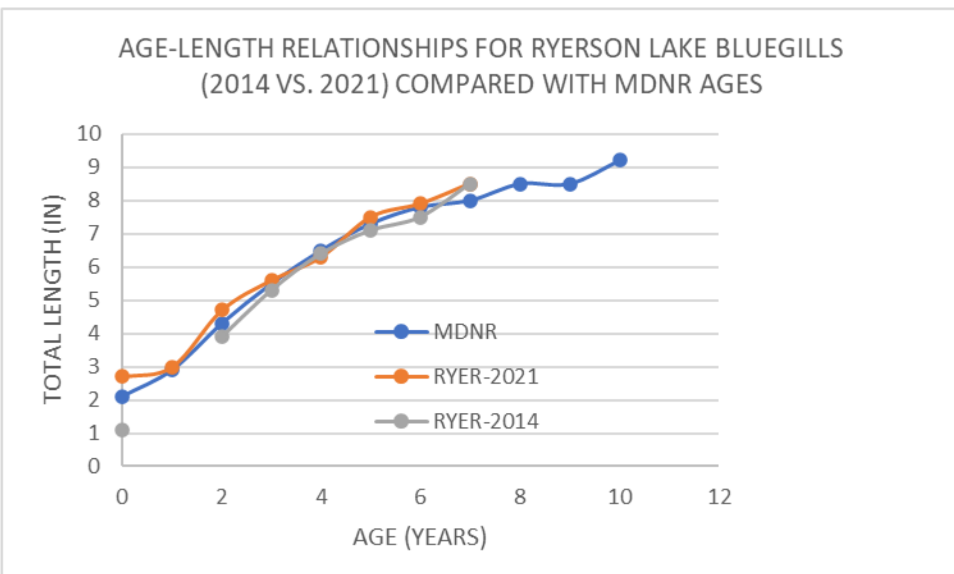

Figure 12. Growth of bluegill in Ryerson Lake during 2021 (red circles) and 2014 (gray circles) compared with the Michigan state averages (blue circles) (see Latta 1958). Fish were collected on 21 July 2021 (n=26) and 24 July 2014. See Table 12 for raw data.

Largemouth bass were also common in Ryerson Lake, especially YOY, but we never saw very many very large fish during both years. Fish collected ranged from 2.2 to 23.2 in during 2021 (Table 13) and 1.3 to 18 inches during 2014 (see Freshwater Physicians 2015). The age-length relationship for Ryerson Lake bass (Fig. 13) was mostly similar to the growth rates of Michigan DNR's fish, so there do not appear to be any growth issues with your fish. There was a tendency for largemouth bass collected during 2014 to be growing slightly faster than fish collected during 2021. This species is one of the keystone predators in your lake and responsible for keeping the bluegills in check, so the big fish should be left in the lake to the degree possible. Those hooked seriously and will die should of course be kept. The other reason, as noted elsewhere, is that large individuals are probably contaminated with mercury and should not be eaten often anyway. We concluded the following: first, they are generally growing at state averages or slightly above, and second, based on our findings of large numbers of young-of-the-year fish caught during both 2014 and 2021 (personal observations; Table 10), we think that largemouth bass are reproducing adequately in the lakes. We explored and experienced the bottom while seining the near shore zone in the lake, and there definitely was considerable gravel/sand bottom along shore that is good spawning substrate for the sunfish family members, including largemouth bass.

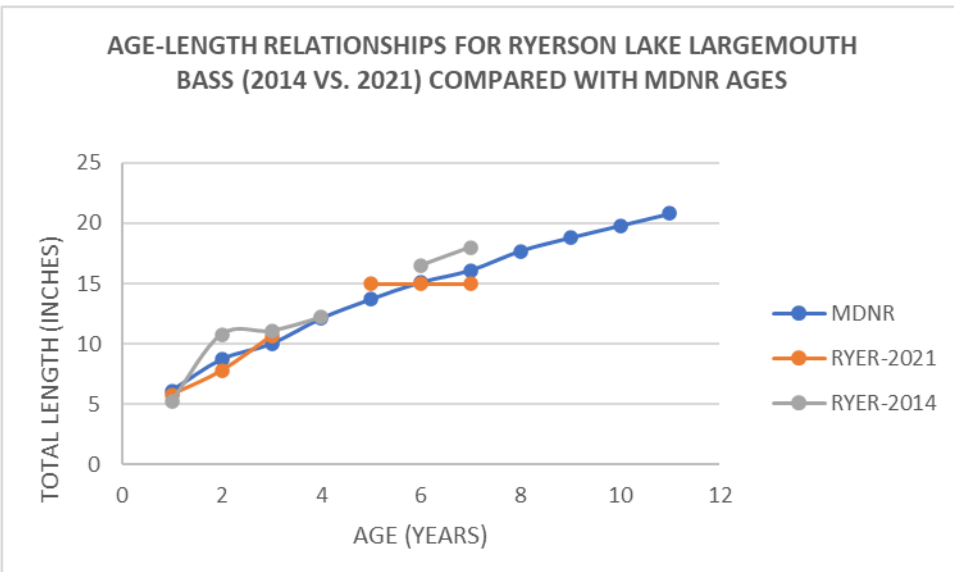

Figure 13. Growth of largemouth bass in Ryerson Lake during 2021 (red circles) and 2014 (gray circles) compared with the Michigan state averages (blue circles) (see Latta 1958). Fish were collected on 21 July 2021 (n=30) and 24 July 2014. See Table 12 for raw data.

Yellow perch seemed to be scarce in the lake based on our collections during both 2014 and 2021 and fishers' reports. Those we caught during 2014 ranged from 2 to 6.7 inches (N=15), while during 2021 they (N=15) ranged from 2.1 to 10 inches (Table 12, Fig. 14). YOY fish from both years seemed to be growing below state averages while the rest of the fish age groups seemed to be growing at or above Michigan DNR averages. Yellow perch are important prey fish that are usually not too susceptible to largemouth bass predation, but they are preferred prey by walleyes and northern pike in the absence of an abundance of minnows. They are outstanding table fare for people. Hence, we would like to have seen more of them in the lake, but there is little to do to improve survival with your predation pressure in the lake. We do not think stocking yellow perch would contribute much to increasing the population for this reason.

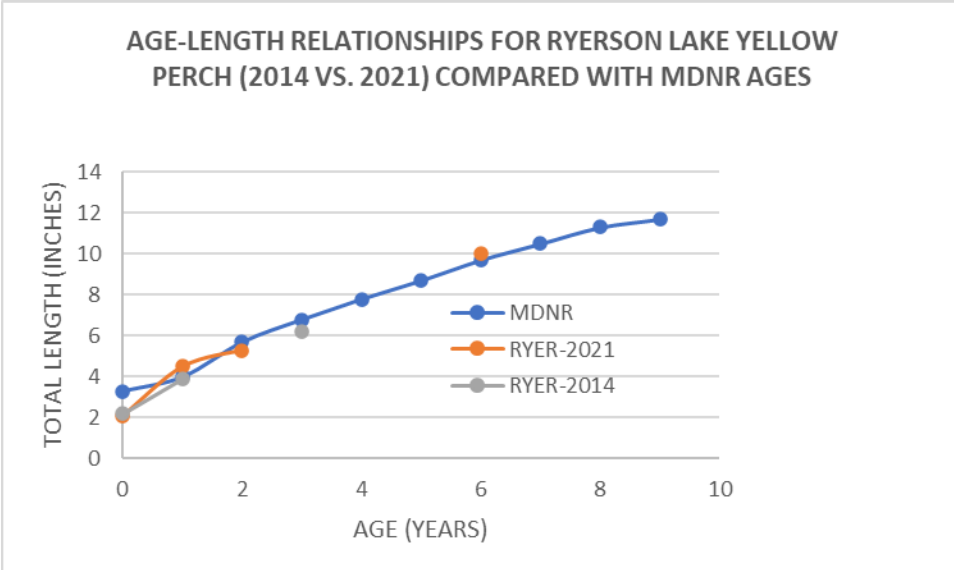

Figure 14. Growth of yellow perch in Ryerson Lake during 2021 (red circles) and 2014 (gray circles) compared with the Michigan state averages (blue circles) (see Latta 1958). Fish were collected on 21 July 2021 (N=15) and 24 July 2014. See Table 12 for raw data.

We analyzed pumpkinseeds from collections during 2021 (N=9); fish ranged from 3.1 to 6.5 in. During 2014, these fish ranged from 3.2 to 5.6 inches (Table 12, Fig. 145). They also grew approximately at MDNR state averages for this species during 2014, but during 2021 the 4 -yr olds were growing slightly faster than state averages, while the 8-yr old was far below state averages. The older the fish, the more difficult it is to determine accurate ages.

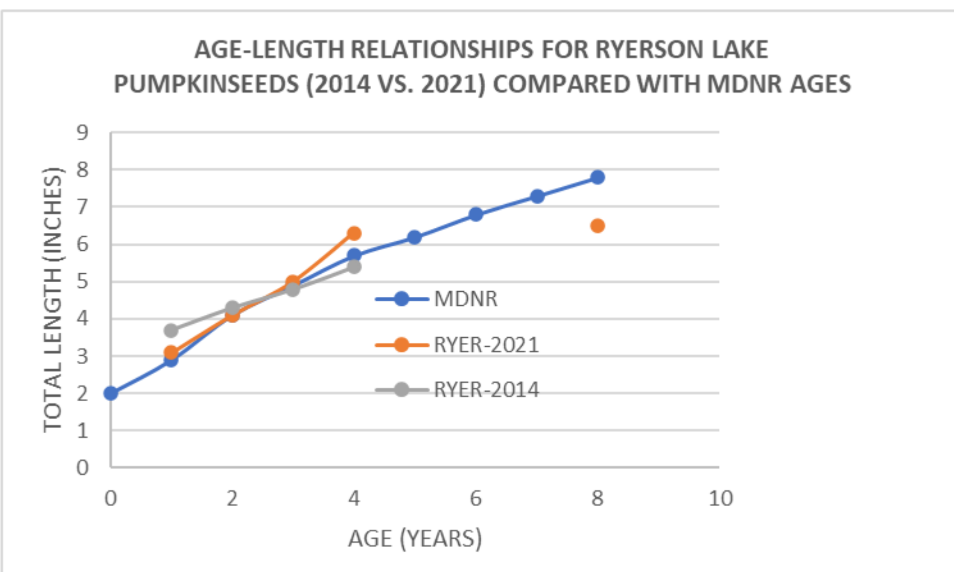

Figure 15. Growth of pumpkinseeds in Ryerson Lake during 2021 (red circles) and 2014 (gray circles) compared with the Michigan state averages (blue circles) (see Latta 1958). Fish were collected on 21 July 2021 (n=9) and 24 July 2014. See Table 12 for raw data.

Walleyes have been stocked into Ryerson Lake. As we have previously noted in the 2014 report, we believe this is an activity that runs contrary to fish management principles. They are not native, habitat will allow survival of some, but conditions in Ryerson Lake are stressful during summer since it is too hot in surface waters and there is no or low dissolved oxygen in deep waters (hypolimnion), and walleyes will compete with native predators, reducing their growth. We captured five walleyes during 2014 (see Fig. 16) and these fish were growing at state averages. Walleyes, as we noted are cool water fishes, so they will be stressed during the summer but do well during other cold periods of the year, which fosters good growth. We did not capture any walleyes during 2021, but saw a picture of a large one caught through the ice. So, a few are still present in the lake.

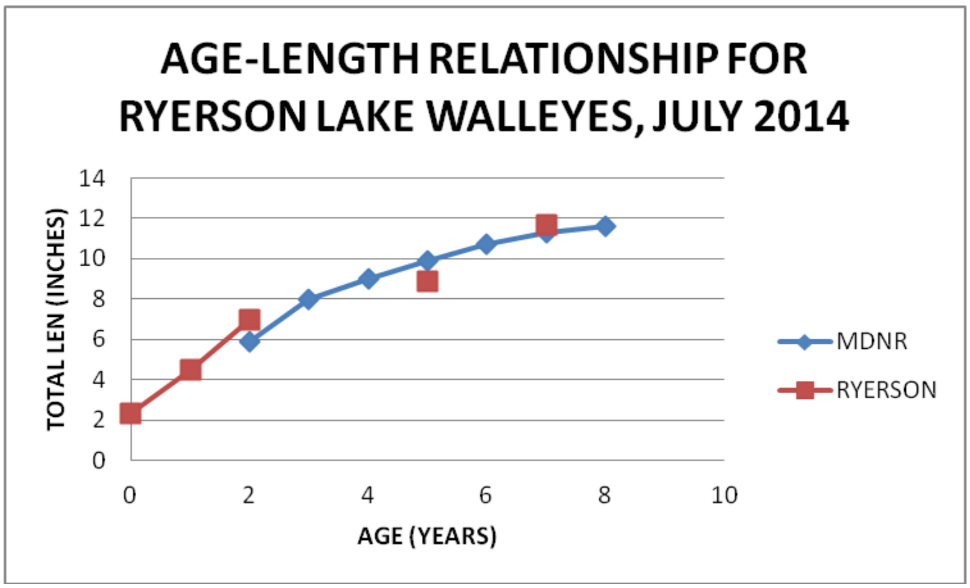

Figure 16. Growth of walleyes in Ryerson Lake (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958), 24 July 2014.

Northern pike may have been the most abundant fish predator in Ryerson Lake during 2014, but we do not think so for 2021. Largemouth bass may have replaced them. We collected 12 fish during 2021 ranging from 16 to 24 inches (Table 12), while during 2014 we collected 28 fish (some provided by sport fishers). The fish aged during 2021 were growing at state averages while those caught during 2014 were below state averages, so growth has improved over that period (Fig. 17). Northern pike are an important component of the Ryerson Lake predator community and are helping to maintain balance among the prey fish, especially bluegills. Unfortunately, they also prey heavily on yellow perch which we believe has resulted in a reduction in their abundance based on the few we collected in seines and gill nets. Ryerson Lake appears to have optimal habitat for successful spawning which probably occurs in the four inlet streams, along shore in macrophytes, and perhaps the outlet. More attention should be paid to finding out if there are northern pike runs in these streams and whether there are marshes which can act as nurseries and in which northern pike are growing and then enter the lake.

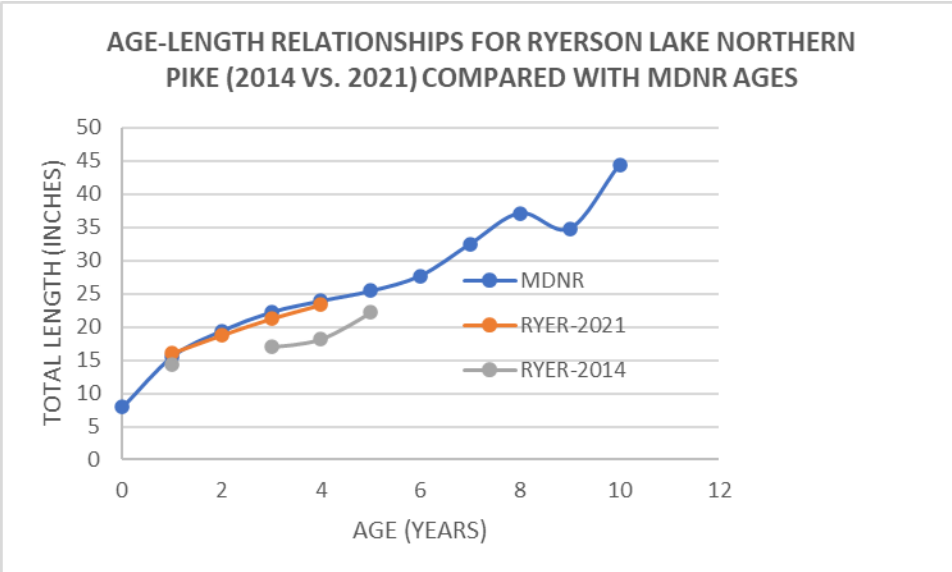

Figure 17. Growth of northern pike in Ryerson Lake during 2021 (red circles) and 2014 (gray circles) compared with the Michigan state averages (blue circles) (see Latta 1958). Fish were collected on 21 July 2021 (n=12) and 24 July 2014. See Table 12 for raw data.

Fish management Recommendations

There were 22 total fish species collected during 2014 and 2021. This is an excellent diversity and Ryerson Lake should be appreciated as a wonderful resource as an overall recommendation. Ryerson Lake has an abundance of great habitat for fishes in the varying depths, types of vegetation (extensive lily pad beds and macrophytes), input tributaries that provide different habitat and probably spawning sites, and a very deep basin. This deep basin is both a problem and a positive feature, in that internal loading is providing more nutrients to the lake during turnovers and is anoxic during summer preventing fish from occupying those depths. After fall turnover, during winter, and early spring before the lake stratifies, the bottom insects that were protected from fish predation, are available for consumption and provide good food for prey fish. Two groups, the chironomids (the adults of which the purple martins are now eating as well) and *Chaoborus* the phantom midge, are particularly important organisms for fish prey during these times. The deep basin also provides more water volume to absorb chemical insults from riparian runoff, lawn fertilization, and septic effluent seepage into the ground water and the tributaries, which have been shown in this study to be contributing high concentrations of nitrates to the lake during our one spring sampling event. One could conclude that phosphorus and nitrogen also enter from these tributaries in large amounts during other times and after severe rain events. An ongoing study of the watersheds of the three lakes in the area is ongoing and may provide more information on the sources of nutrients and ways for farmers to utilize best management practices to reduce their concentrations in runoff that enters area lakes.

Those 22 fish species include a good group of top predators, an array of sunfish species, bullheads, stocked walleyes, and seven species of minnows (at least during 2014). It also contains common carp that should be eliminated whenever encountered. These fishes provide an important character to the lake fish community: diversity. The fishes noted fill an impressive number of niches: predators, insect feeders, algae eaters, snail consumers, and detritovores. This is great for fish community stability. One aspect of our data shows that of the seven species of minnows found during 2014 (excluding common carp), only one was found (bluntnose minnow) during 2021. What happened to those other six species is a mystery. We can only speculate based on experience and literature that there must have been a large increase in largemouth bass (perhaps due to lack of northern pike predation that was probably more prominent during 2014) and the larger population of largemouth bass that developed, which are very capable of decimating minnows. Largemouth bass could easily be responsible for the loss of minnow diversity. We have observed this in one other lake we sampled.

Fish management strategies emanating from these data include the following. First, we suggest that the northern pike population does not seem over populated now and growth has improved supporting this finding, hence the increased limit recommended by MDNR should probably be decreased to normal limits.

Second, we always are a proponent of catch and release of the bigger largemouth bass, say those > 15 inches, northern pike, and walleyes, so they (except for walleyes) can reproduce and control the prey fish population and more can successfully spawn. We always encourage people to put back large predators to maintain good fish community balance. We must appreciate how many years it takes to grow one of the large predators to catchable size and allow more than one person to catch them. This allows the larger, mature predators to spawn successfully, promotes good growth of bluegills, and prevents fish stunting in the lake, and they are probably contaminated with high concentrations of mercury any way (see M*ercury in Fish* for a discussion).

Third, as we pointed out, walleyes (this is true for northern pike as well) are stressed in Ryerson Lake during summer stratification by too warm water at the surface and no dissolved oxygen on the bottom where cooler waters reside (see the Fish Squeeze – Fig. 10). This results in poor growth during summer and probably some fish die as a result. As we noted above, during the cooler periods of the year, these cool water species can make up for growth lost during the summer, and as we found for walleyes, still exhibit good growth. In addition, as pointed out stocking walleyes into Ryerson Lake violates at least four principles of fishery science: 1. The fish is not native and most likely will not spawn, 2. The existing fish community is a co – evolved, warm-water fish community and should not be de-stabilized by introduction of another keystone predator, 3. Water quality conditions, warm surface water and no dissolved oxygen in cool bottom waters, are not conducive nor optimal for a cool water fish, 4. You are playing ecological roulette with stocking, since you could introduce diseases (VHS see below), parasites, or non-indigenous species through stocking of fish, especially if done by non-professionals. We therefore recommend against stocking any more walleyes into Ryerson Lake and suggest if fishers want walleyes (they are difficult to catch anyway) they go to Saginaw Bay or Lake Erie where world-class fisheries exist.

Fourth, there was good spawning by the sunfish family, yellow perch, and by northern pike some years back. Hence, because of the favorable substrate (sand and gravel) for sunfish spawning, there is no need for stocking any of these species. Northern pike would be an exception if their populations declined to unacceptable densities. However, we would make this plea for reducing harvests of panfishes. A nice 8-in male bluegill takes 7-8 years to grow to catchable sizes. It represents surviving through an unforgiving gauntlet of mortality from egg to adult. Note that only two fish need to survive to replace their parents and maintain a stable population. Yes there is natural mortality that will naturally reduce their numbers even at the adult stage, so it makes sense to harvest some of them since they will die anyway. Overfishing has been a perennial problem with fishery management, with the cod fishery a great example- despite warning from fishery biologists, overfishing was allowed by government officials who did not listen to expert advice. Modern fishers are savvier, have high-tech equipment that can pinpoint locations where fish were caught before, depths where fish were caught, lures that worked, and they have larger and faster boats and can relay precise location and success to fellow fishers. SONAR can pinpoint where in the water column fish are congregating and are used during ice fishing to see fish approaching their bait. Most of these fishers practice catch and release for larger predators, but not for panfish or for example, yellow perch. So, the plea is to yes continue harvesting panfish but exercise some restraint in attaining limits or accumulating large amounts of these fish for later consumption. Appreciate the resource.

DISCUSSION AND RECOMMENDATIONS

To summarize, Ryerson Lake is a eutrophic lake with a very deep area in the center of the northern end of the lake. That deep area during summer stratification generates an anoxic, dead zone near bottom devoid of dissolved oxygen and this zone generates products of decomposition, including high concentrations of nutrients (soluble reactive phosphorus and ammonia) as well as carbon dioxide rendering this area off limits to fishes. Interestingly, chlorides, an indicator of septic tank leakage and road salt runoff was extremely low, a sign of good water quality in the lake. Unfortunately, the buildup of nutrients on the bottom (internal loading) contributes to the eutrophication (nutrient enrichment) in the lake each year after spring and fall turnover, fueling algae and the extensive macrophyte beds that ring the littoral zone. Fortunately, algae samples from Ryerson Lake in late July showed the presence of low densities of blue-green algae, mostly of non-nuisance groups. However, the potential exists for more blue-green outbreaks in the fall as has been reported by residents. Riparians also contribute to the lake’s enrichment through lawn fertilization and septic tank seepage into the ground water. To reduce the footprint of residents, no lawn fertilization should be done, but if necessary only nitrogen-based fertilizer should be used. Sewers are recommended. Septic tanks should be pumped at least once every 2 years in the interim to protect groundwater. See Appendix 1 for other suggestions to reduce nutrient input.

In addition, spring sampling C. Yonker did of the four tributary inputs, showed that overall, this is a probable high source of incoming nutrients. Conductivity ranged from 352 to 467 uS, which is moderate (the lake had comparable values 459-575 uS) and chlorides were also low (4-21 mg/L) continuing the trend of low chlorides in the watershed, since lake values were also comparable (11 mg/L). The nutrients of interest, P and N, showed some very high readings coming in from some of the tributaries. Ammonia is often found in the bottom of lakes in high concentrations since it is produced with the decomposition of sediments under anoxic conditions and then mixed into the entire lake during turnover in the spring and fall and under oxygenated conditions it is most often converted to nitrates. For example, in Ryerson Lake the ammonia in the bottom sample from station A was a very high 1.28 mg/L, while at the surface it was at trace levels. With this background, the tributary ammonia concentrations ranged from trace to 0.03 mg/L, low values. However, nitrate concentrations in the tributaries ranged from 0.03 to 7.88 mg/L, an extremely high concentration and indicative of runoff from fertilization activities in the agricultural watershed that drains into Ryerson Lake. The high value of 7.88 mg/L came from station NW Sandbar, which is the tributary on the north end of the lake. For contrast, lake values at station A ranged from 0.03-0.35 mg/L. Concentrations of SRP, the soluble, useable fraction of phosphorus, ranged from trace to 0.016 mg/L, modest concentrations, signaling much uptake and removal by the plants ringing and in the creek. In contrast, the lake value on the bottom of station A, where decomposition was ongoing during summer, was 0.291 mg/L, a high value. Total phosphorus, all the P in a given amount of water (detritus, SRP, algae, etc.), in tributary samples was 0.051 to 0.190 mg/L, also high values, but again, the bottom TP in Ryerson Lake value was 0.430 mg/L. This discussion points out two of the sources of nutrients to Ryerson Lake that should be addressed if possible to reduce nutrient input to the lake: internal loading from the lake and tributary inputs from agricultural activities. One would have to do some calculations of the volume of anoxic water vs. the discharges that come in from the creeks to determine which loading of nutrients is larger, but efforts to reduce them should be aimed at both sources.

The remainder of the lake has variable depths, while the littoral zone is shallow with extensive plant beds, including lily pads, bulrushes, and submerged aquatic plants. The bottom has extensive areas of sand and gravel which act as good spawning substrate for sunfish, especially largemouth bass. Algae populations were dominated by blue-greens, but they were low compared to other more eutrophic lakes and mostly composed of non-nuisance species. Our zooplankton (small invertebrates in the water column) sample showed that a large species, *Daphnia*, composed over 50% of the zooplankton present in the sample during 2014, but that percentage declined to <2% during 2021. This indicates that there is probably increased predation on the zooplankton over the deep hole and in shallow water, since lakes with an abundance of planktivores, such as small bluegills, usually consume most of the *Daphnia* present, leaving only smaller species. In fact, examination of the diet information in Table 11 shows that black crappies 4-7 in, bluegill YOY, and yellow perch YOY were all eating zooplankton. We expected to see more predation in the near shore zone because of the abundance of planktivores there, but *Daphnia* were present in comparable numbers during 2021 in both environments. Among the benthos, insects and mussels that inhabit the bottom sediments, we found that the large mayfly *Hexagenia* was present during 2014. This information was based on the appearance of this mayfly's naiad in diets of black crappies and bluegills. The fact this mayfly is present indicates that Ryerson Lake is a high, water quality lake with adequate dissolved oxygen present throughout the year, probably in the near shore zone where there is abundant organic sediments necessary for this species to build circular burrows in the mud where they move water through their burrows with abdominal, feather-like gills and filter it of detritus.

We collected 22 species of fishes including the common carp, which avoided being collected during 2014, but was obtained in 2021 collections. This is excellent biodiversity. Members of the sunfish family (Centrachidae) dominated the species collected, while other predators included northern pike which were the most numerous predators collected during 2014, largemouth bass, and walleyes, which apparently were stocked into the lake. In addition, there were seven species of minnows also found in the lake during 2014 but not 2021, when only bluntnose minnows were collected. The presence of golden shiners during 2014, which are highly favored because they grow to large sizes (up 8 inches), will provide forage for some of the larger predators, if they persist in the lake. Ryerson Lake also had brook silversides, rock bass, and bullheads present, completing a diverse fish fauna. We believe the high diversity is due to the high diversity of habitats: varying depths, near shore zone with abundant vegetation, but also some areas of gravel and sand, four inlets and one outlet, and the prey food supply, zooplankton and benthos, appears to be sufficient to feed the diversity of small fishes present, without eliminating the *Daphnia* from the zooplankton community. Diets of fishes reflected the species, life stage, and feeding strategy of the fish. Small fishes were feeding on zooplankton and benthos, while the large specimens of predaceous fishes were feeding on fishes and sometimes crayfishes. They ate a wide variety of forage, including the young of yellow perch, largemouth bass, bluegills, brook silversides, and minnows. In fact, we believe that the feeding of the abundant northern pike along with walleye predation is probably having a depressing effect on yellow perch survival, since they appeared to be uncommon in the lake during both 2014 and 2021. Growth of the fishes we examined generally was at MDNR state averages for a given age, except for northern pike, which appeared to be growing below state averages during 2014, but not 2021, when we collected fewer northern pike. We think the low growth of pike during 2014 may be related to the stress that northern pike (and walleye) undergo during the summer "squeeze" (Fig. 9) stratification period and the unusually high abundance of this predator in the lake during this period.

From the data we collected we make the following recommendations.

First, appreciate your lake: it is a beautiful lake, not fully developed with much forested and undeveloped space, an excellent fishery, and although it has experienced some blue-green algae blooms, they have not dominated the lake, as we have seen in many lakes during 2021.

Second, reduce nutrient input to the lake by reducing or eliminating lawn fertilization, get on sewers, but in the interim clean septic tanks at least once/2 yr.

Third, address internal loading. This is difficult, but one technique, which has been successful in other states and at least one lake in Michigan, is alum treatments which bind sediment phosphorus to aluminum and form insoluble compounds, which are costly but can be effective for long periods (years) at a time. Another costly technique is hypolimnetic aeration, essentially aerating ONLY the bottom waters of the lake. This technique has also been successfully used in California reservoirs.

Fourth, some, especially the NW Sandbar tributary, and probably most of the tributaries entering Ryerson Lake drain agricultural watersheds and are contributing very large volumes of nitrates and moderate amounts of phosphorus to the lake. Some is being taken up by wetland and lake vegetation and shoreline plants, but much may be entering the lake and excessive vegetation dies and accumulates in the deep basin, producing the anoxic conditions seen there. As noted, there is an ongoing watershed study that may provide more information and potential solutions to this problem.

Fifth, northern pike appear to be less abundant and are growing better during 2021 than they did during 2014. It may be time to relax the higher catch limits on this species.

Sixth, catch-and-release of large largemouth bass (>15 inches) is recommended so they can continue to have high reproductive rates to help control the bluegill and other forage fish populations and larger ones are probably contaminated with mercury anyway.

Seventh, you should consider banning bait from outside the lake (live fish, crayfish) from being used by fishers to prevent entry of exotic species, parasites, and diseases. We are worried about viral hemorrhagic septicemia (VHS)-infected bait and introduction of other non-indigenous species, such as quagga mussels or VHS, coming into the lake from outside sources.

These introductions should be prevented by careful examination of boats, SCUBA gear, or bait coming from infested lakes or rivers. Dry or treat ballast water left in boats with bleach.

Lastly, we cannot recommend any further stocking of walleyes into the lake, especially by lake residents who might inadvertently introduce VHS into the lake. We discussed the reasons for this: 1. Walleyes are not native species, 2. The lake has a co evolved fish community that has been in existence for thousands of years and is not out of balance, 3. There is a potential for introduction of VHS with stocked fish, and 4. The fish will be severely stressed during summer due to the "squeeze" of warm surface water and cool preferred bottom water that is devoid of dissolved oxygen during the summer stratification. If the board still wants to stock fish, be sure to use a certified VHS-free source, do not stock large numbers, and stock them at large sizes (at least >8 inches) during spring or fall.

SUMMARY OF RECOMMENDATIONS

Recommendations are summarized more concisely below:

1. <u>Nutrient inputs</u>

Nutrients are entering Ryerson Lake via tributaries, from runoff in the watershed, and being regenerated by anoxic sediments (internal loading). Problem areas and suggested solutions follow:

A. Septic tanks: they seep into the groundwater through permeable sand. They must be pumped often, at least once every 2 yr. Switching to sewers is the best alternative.

B. Sediments can generate nutrients near bottom in the deep basin during decomposition processes in winter and summer (internal loading). Reducing nutrient input from riparians, so less organic material accumulates on the bottom is one thing riparians can do along with reducing tributary inpus of nutrients (see C below). More expensive, but proven, solutions include: alum treatments and hypolimnetic aeration (aerating only the bottom nutrient rich water).

C. Tributary inputs. We documented large amounts of nitrates (7.88 mg/L) in the NW Sandbar tributary in spring. High concentrations of nitrates and phosphorus were also recorded in the other four tributaries. Some of these nutrients are being taken up by wetland vegetation, shoreline plants, and macrophytes in the lake near the tributary mouths. However, these sources are a problem year round and probably substantial sources of eutrophication (nutrient enrichment) in Ryerson Lake. Obviously, since there are large agricultural lands in the watershed feeding these tributaries, they would appear to be the source of most of these nutrients. Hence, there should be an attempt to persuade farmers directly in the watershed to follow best management practices to reduce nutrient runoff from their fields. There are Michigan State Extension agents that might be able to assist in this effort. In addition, attention should be directed to the mouths of these tributaries to maintain a dense macrophyte bed to absorb nutrients – exercise care in any herbicide treatments of these plants. Finally, consult the results of the ongoing study of the watershed being conducted by nearby lake associations.

D. Runoff, lawn fertilization, and other activities by residents contribute nutrients: Observe suggestions in Appendix 1 – greenbelts, no fertilization of lawns, ban pet wastes from lawns, no leaf burning at the lake, reduce impermeable surfaces, etc. Consider the no mow vow for spring to promote pollinators; reduce runoff from rain events.

E. Waterfowl, such as Canadian geese, need to be discouraged from visiting, nesting, or hanging around the lake eating lawns.

2. Northern Pike

We think northern pike are now not as abundant during 2021 as they were during 2014 and they appear to be growing at state averages. We would support a return to normal catch limits for this species.

3. Largemouth Bass

We recommend catch and release for all largemouth bass > 15 inches, unless fish are foul hooked and would die. They help control stunting in sunfish populations, despite that we think they may be responsible for the loss or diminution of six species of minnows.

4. Yellow perch

Yellow perch were not very abundant during 2014 or 2021, but there were quite a few young in the near shore zone so they still are reproducing at acceptable levels. Many top predators fed on them, so not much can be done. If the northern pike population is reduced, perhaps we may see increases in survival of this species to larger sizes.

5. Walleye

Walleye have been stocked into Ryerson Lake. Amazingly many have survived, providing a small fishery. We oppose further stocking, because they are not native, they are difficult to catch, they will not spawn, stocking may introduce diseases, and most importantly, they will be severely stressed during summer stratification.

6. Prevent Exotic Species from Entering Ryerson Lake

Prevent exotic species, besides Eurasion milfoil which has already been introduced, from entering the lake. Consider banning bait from outside the lake to avoid the introduction of more exotic species, such as quagga mussels and VHS. Fishers and skiers need to dry out boats and gear that come from other lakes that might be contaminated with exotic species, such as zebra mussels.

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APPENDIX

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 liquid fertilizer as possible; instead use 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, PLANT GREEN BELTS. Do not fertilize lawns down to the water's edge. The natural vegetation will help to prevent erosion, remove some nutrients 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 spring. Remove debris from your area of the lake.

11. CONSULT THE DEPT OF NATURAL RESOURCES BEFORE APPLYING 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.