Picture 1. Lake Sherwood Zooplankton Sample

A WATER QUALITY, ALGAE, AND ZOOPLANKTON SURVEY

OF LAKE SHERWOOD, 2023

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INTRODUCTION

Freshwater Physicians was asked to conduct a water quality, algae, and zooplankton survey of Lake Sherwood, which we executed on 16 August 2023 with the able assistance and guidance from Dan Devine. We sampled dissolved oxygen and temperature at two deep stations and collected an algae sample at station 1. Unfortunately, the zooplankton sample we collected got lost (see Picture 1), so we will use 2020 data instead. Secchi disk measures and water samples were collected at seven stations (1-7) spread out across the lake.

From Fusilier (2010): Lake Sherwood is a 258-acre, moderately hard-water to hard-water impoundment created about 1956-57 when a dam was constructed across the outlet from Teeple Lake (the Wildwood River). The lake consists of a 144.8-acre main body, plus an 18.7-acre series of canals north of Commerce Road (Wildwood Canals) and another 94.5-acre group of canals east of the main body of the lake (East canals). The lake is in sections 6, 7, 8, Commerce Township (T2N R8E), Oakland Co., MI. The lake has five islands totaling about 2 acres, so the area of the water surface is 256 acres.

There are at least three invasive species in the lake: Eurasian milfoil, starry stonewort, and zebra mussels. Schneider (2003) noted that Eurasian milfoil covered 90% of the surface area of the lake during 2003. The macrophytes are currently being treated with herbicides, while the zebra mussels seem to have declined to low abundances.

There are at least four major reports on Lake Sherwood done in the past. Freshwater Physicians (2012) did an extensive limnological study during summer 2011 and 2020, Fusilier (2010) has extensive data covering 1994-2010 data (limnological, macrophyte, sediment data), and there are two prior fish studies (Merna 1981 and Schneider 2003). These data sets were helpful in providing conclusions on long-term changes in various parameters and will provide a rich background and bench marks from which to assess any ecological changes to the lake in this report and in the future.

Our approach in this report was to document the status of the various components assessed for this study, discuss previous datasets for each parameter, and present the current condition of the lake and means of improvement. Some other issues of concern were also addressed.

HISTORY

The Lake Sherwood impoundment was created about 1956-57 when a dam was constructed across the stream (Wildwood River) that originates far upstream at Teeple Lake. There is a supplemental well (currently inoperable) on the north end that was used for lake augmentation when water levels are low. The lake is also drawn down each fall around 18 in to promote sediment drying, macrophyte control, and allows residents to clean up beaches. Some dredging activities were ongoing in the past in the Wildwood River which flows into Lake Sherwood. There is a history of algae and macrophyte control of the extensive plants that occupy the lake. There is a warm-water fishery in the lake and walleyes have been stocked in the past to provide another predator for sport fishers.

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. We sometimes run transects across a lake and record the depths if there are no data about the depths of the lakes. These soundings can then be 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 used to show where we sampled, important areas, tributaries, and depth contours. This map will assist us in identifying where past stations were sampled in prior studies and in making assessments of 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 Petite Ponar sampler is used to sample bottom sediments for examination. It is lowered to the bottom, tripped with a weight, and it "grabs" a 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. Secchi disk measurements also dictate what trophic state: eutrophic, mesotrophic, or oligotrophic a lake has. The criteria for this Secchi disk measurement are as follows: <7.5 ft = eutrophic, 7.5-15 ft = mesotrophic, and >15 ft = oligotrophic.

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.

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).

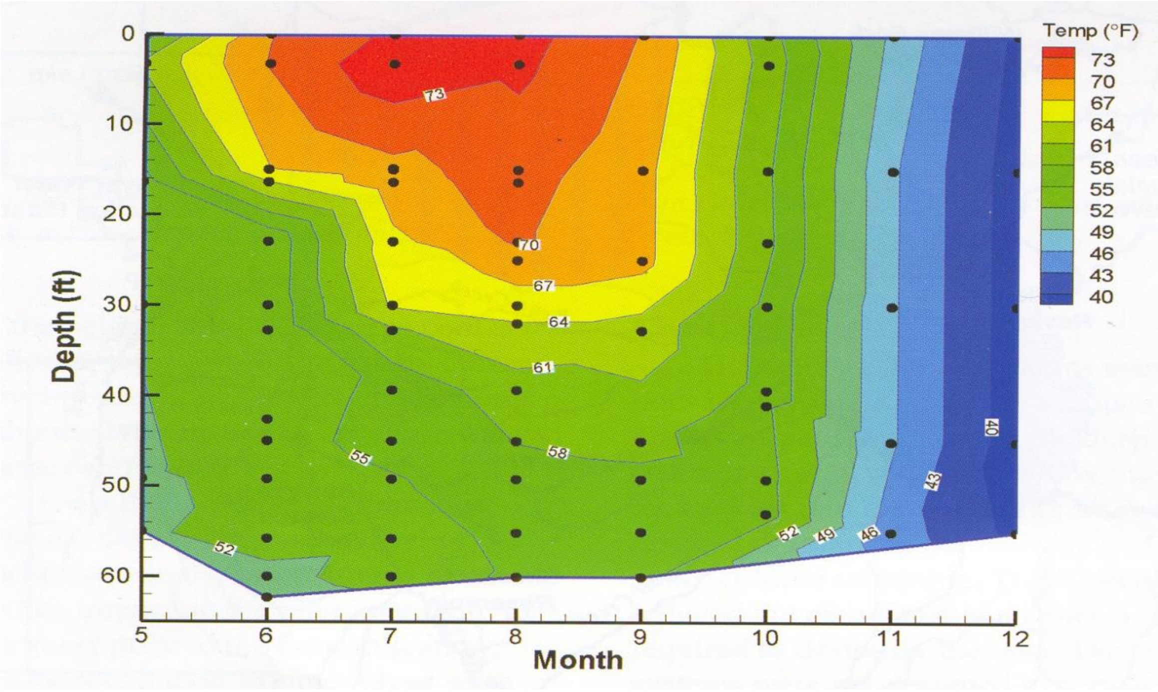


Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red yellow and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during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

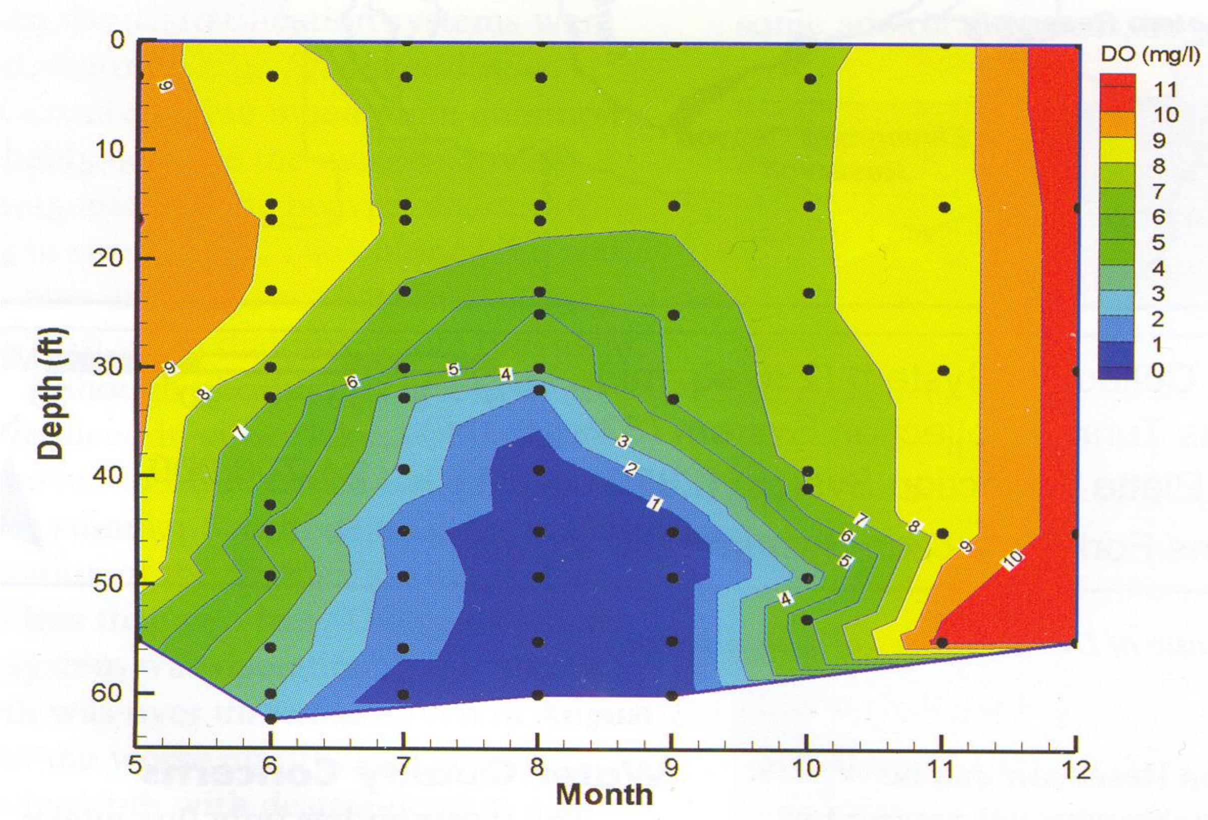


Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when 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 (consumed 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). In eutrophic lakes, the surface waters can be too warm for cool-water fish, while the optimal cool waters in the hypolimnion are devoid of oxygen, squeezing fish in a thin layer in the middle. Fish like northern pike can be stressed, while more sensitive species, such as lake herring can perish when the dissolved oxygen levels decline too much (see Fig. 3).

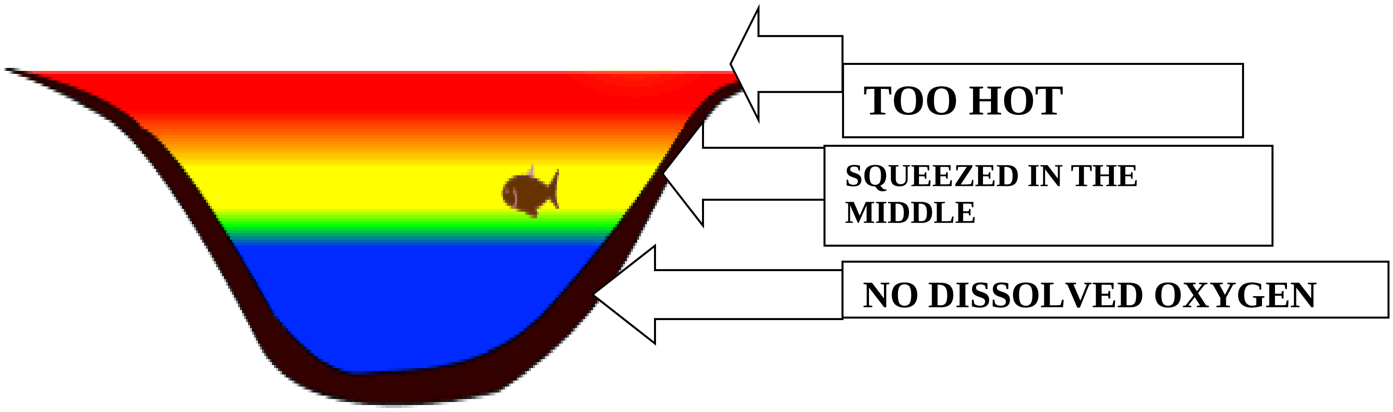


Figure 3. Depiction of the dissolved oxygen concentrations in a stratified lake during summer, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, 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.

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

Stratified lakes will mix in the fall because of cooler weather, and the dissolved oxygen content in the entire water column will be replenished. During winter the oxygen may again be depleted near the bottom by decomposition processes. As noted previously, winterkill of fish results when this condition is caused by extensive 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 like 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.

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 (NH3), is usually formed in the sediments in the absence of dissolved oxygen and from the breakdown of proteins (organic matter). Thus, high concentrations are sometimes found on or near the bottom under stratified, anoxic conditions. Ammonia is reported as mg/L as N and is toxic in high concentrations to fish and other sensitive invertebrates, particularly under high pHs. With turnover in the spring most ammonia is converted to nitrates (NO3=) when exposed to the oxidizing effects of oxygen. Nitrite (NO2-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured. Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. Nitrates, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about succession of algae species, which usually proceeds from diatoms, to green algae to blue-green algae. Blue-green algae (an undesirable species) can fix their own nitrogen (some members) and thus out-compete more desirable forms, when phosphorus becomes scarce in late summer.

BIOLOGICAL PARAMETERS

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 (long and stringy), 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. Starry stonewort *Nitellopsis obtusa* (see Picture 2) is an exotic invasive alga that looks like *Chara*. It is important to identify it in lakes since it can dominate large areas of the lake and damage spawning sites and prevent boat access and fishing in areas where it is present. It is spread from lake to lake on boats and other equipment from infected lake. Hence, it is important to prevent its spread by having good education of lake residents and signage at boat launch sites to prevent its spread. 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 plant management plans.

Picture 2. Starry stonewort, an alga.

Algae samples were collected on 16 August 2023 from one station (Station 1) 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 Edlund for analysis. Measured subsamples of preserved algae (~120-135 mL) were allowed to settle for a minimum of one 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/Leitz Ortholux/Leica DM2000 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. Aquatic plants are important spawning substrate, habitat for fish, nursery areas for small fish, they produce aquatic insects, and they are important for stabilizing sediments. They can slow down currents and prevent re suspension of sediments, which contain nutrients, which can be released into the upper water column and fuel algal blooms.

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 since they are 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 (153 microns) 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.

RESULTS

WATERSHED

Lake Sherwood is in Oakland County in Commerce Township, Mi and is about 256 acres. The watershed, not including the lake. is 6,974 acres (see Fig. 4, 5). The drainage area, which includes the lake and the watershed, is 7,232 acres; the watershed to lake ratio is 27 to 1, which is high for a Michigan inland lake, but normal for a lake created by damming a stream (Fusilier 2010). There are two main inlets: Wildwood River and Cranberry Lake inlet, both entering the lake from the north (Fig. 5, 6). The outlet is on the southeast corner of the lake. Water from the outlet flows to the Huron River east of Milford. The Huron River flows into Lake Erie at Monroe, MI. The lake has 65,254 ft of shoreline not including the shorelines of the islands. Elevation is 925 ft above sea level. It has two deep basins around 15 - 20 ft (Fig. 6). There are areas where macrophytes are common to abundant, including Eurasian milfoil in several areas as well as starry stonewort. These plants have been treated with herbicides in recent years, decimating their populations.

The local riparian zone, as we noted above, is important, especially that band right at the lake. There are 630 residences in the area around the lake; 320 are riparians. Residents in the watershed need to eliminate lawn fertilization and plant green belts to retard runoff into the lake among other recommendations (see Appendix 1).

STATION LOCATION

Lake Sherwood is a 256-acre, shallow, eutrophic lake with two basins located in Oakland County, MI. The overall view of Lake Sherwood is provided by a Google map (Fig. 4) and shows the complex nature of the lake with its many arteries and channels and there is an inlet stream on the north side. Also, there are islands and the lake is well developed with many houses (320 riparians), paved roads, and other developments in the watershed. Water quality was measured at stations 1-7 during summer 2020 and 2023 (see Figs. 4, 5, 6,7; Table 1 for station locations). These stations were established by Fusilier (2010) and include station 7 in the incoming inlet stream (Wildwood River) on the north end which eventually flow out of Teeple Lake (see Fig. 5 for the watershed which is large, Fig. 6 for station locations, and Fig. 6 for a contour map).

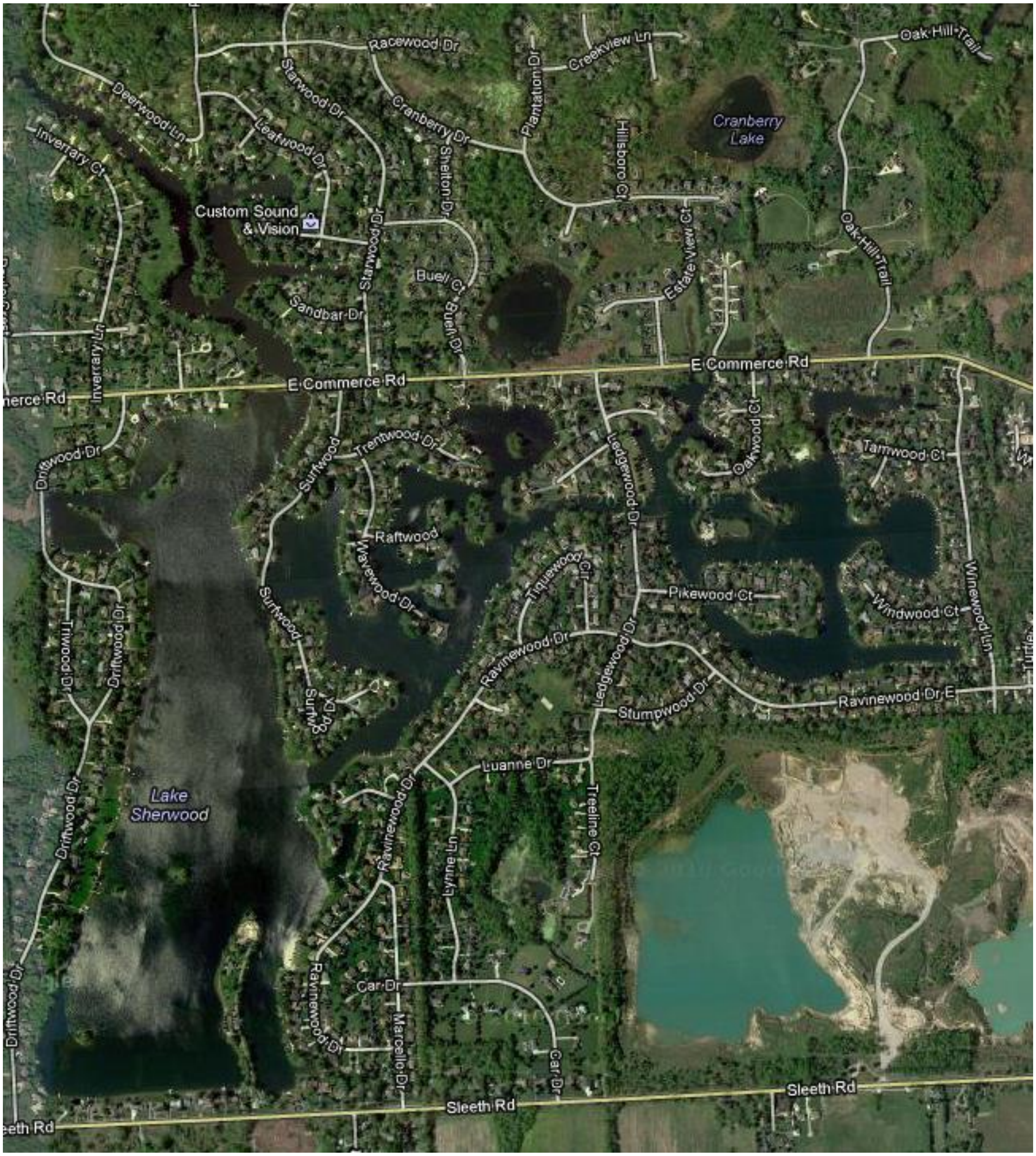


Figure 4. Google map of Lake Sherwood showing the extensive development around most of the lake, the diverse channels and canals, and the inlets and outlet.

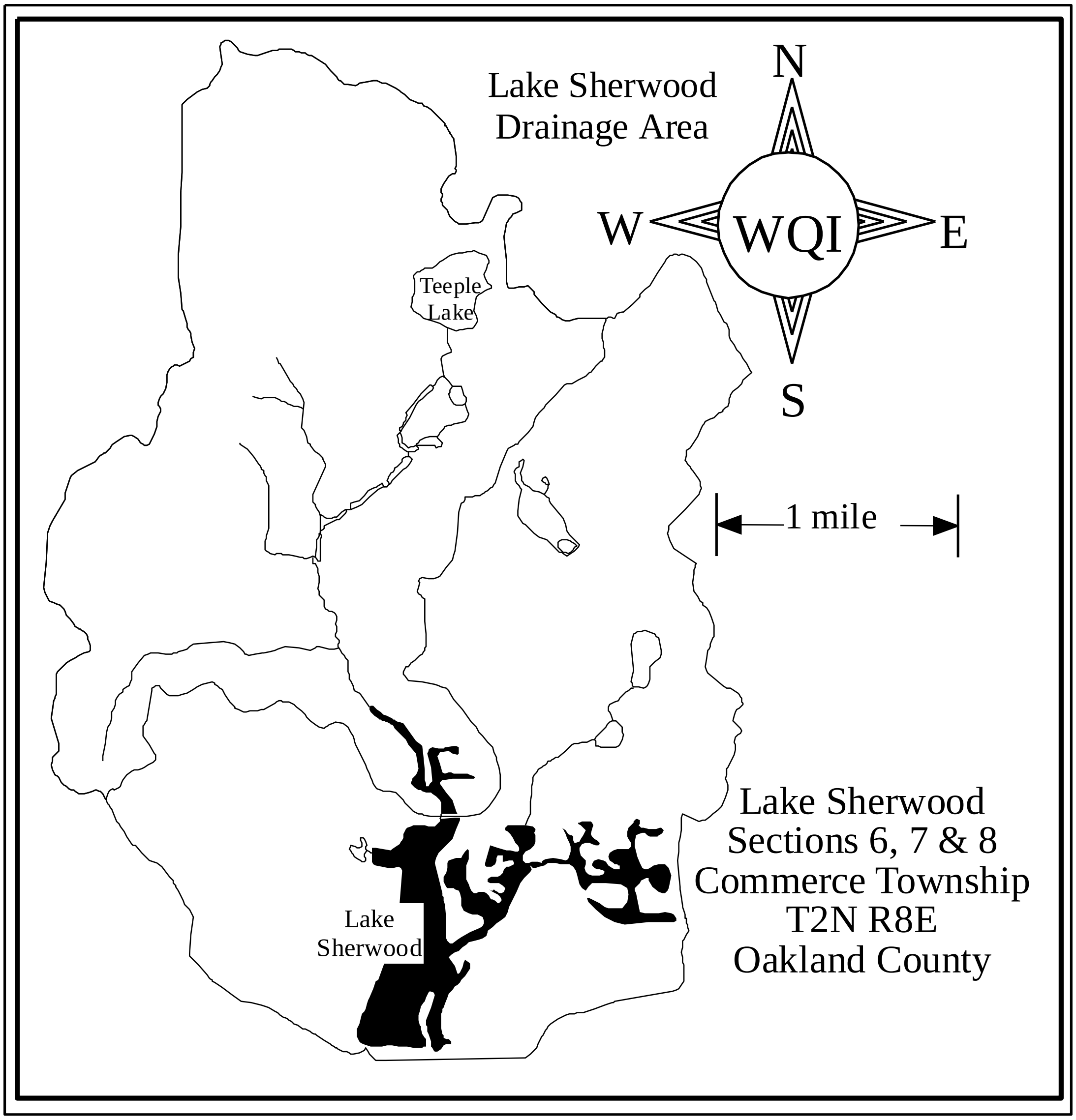


Figure 5. Map of Lake Sherwood showing the watershed of the lake. Adapted from a map provided by Fusilier (2010).

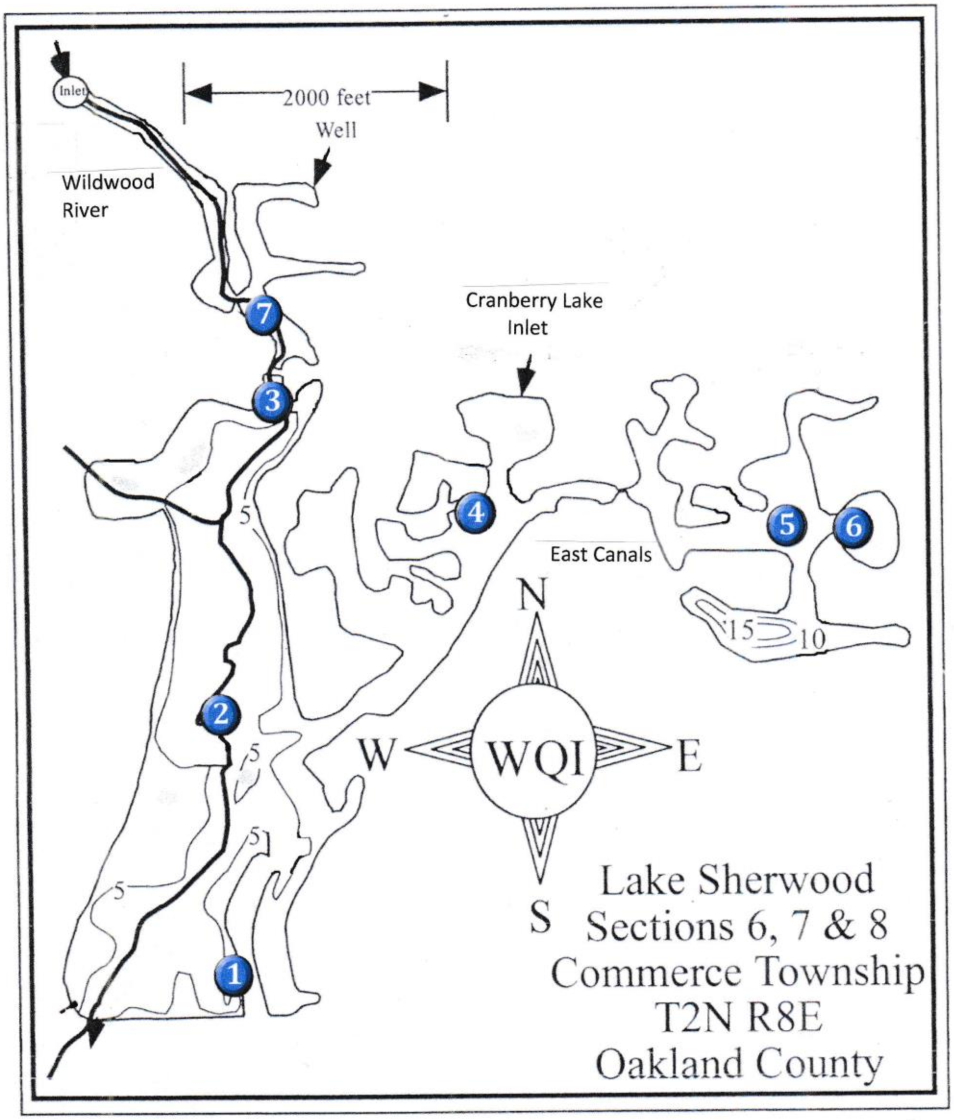


Figure 6. Map of Lake Sherwood showing the water quality stations 1 – 7, inlet stream (Wildwood River which flows out of Teeple Lake some distance away), inlet from Cranberry Lake, and the islands. Adapted from a map provided by Fusilier (2010).

Table 1. Stations on Lake Sherwood sampled for water quality parameters. Provided is a description and GPS locations. See Fig. 4-7 for station and Google maps.

Station	Description
1	Master station deepest - 19.8 ft; near dam; S end of lake GPS: N 42 34.975 W 83 33.028
2	Mid - lake; 8.5 ft deep GPS: N42 35.248 W33.149
3	N end of lake; S of road bridge;7 ft GPS: N 42 35.753 W 83 32.967
4	Middle of first section of Wildwood Canal; 14.9 ft GPS: N 42 35.566 W 83 32.575
5	Center of second section of Wildwood Canal; 10.2 ft GPS: N42 35.600 W 83 32.065
6	East most station of Wildwood Canal; 10.6 ft GPS:N 42 35.597 W 83 31.912
7	N most station on lake; close to inlet stream (Wildwood River) GPS:N 42 35.870 W 83 33.013

PHYSICAL PARAMETERS

Depth

Lake Sherwood is a shallow lake with one deep spot (station 1 – ca. 20 ft) (Fig. 6). The mean depth of the main lake is about 5.4 ft and the water volume is 779 acre-feet (Fusilier 2010). The main lake flushes about once every 47 days. The mean depth of the north (Wildwood) canal is about 2.5 ft and the volume is 48 acre-feet. The north canal flushes about once a week. The mean depth of the east canal system is also about 2.5 ft and the volume is 235 acre ft. This canal system flushes about once every 63 days.

Acreage

Lake Sherwood is 256 acres (see Fig. 5 map). The lake is extensively developed in the watershed (see Fig. 4) with 320 houses ringing the lake. Because it is so circuitous, it has room for many houses, where a lake more roundish (measurement called Shoreline Development) would have many fewer houses and thus less impact on the lake.

Sediments

We did not sample the bottom sediments of Lake Sherwood, but expect them to be muck, flocculent in the deep areas, and have deep accumulations in the deep basins. However, Fusilier (2010) measured samples from various areas in the lake during 1994. He found that the % mineral content varied from 76 to 92, which indicates a buildup of organic material, which was not expected, since the lake is relatively young having been flooded during 1956. The major content of the sediments is clay, probably derived from home building and runoff, input from roads, or the bottom soils at flooding were mostly clay.

Light Penetration

1980-2010: Fusilier (2010). An examination of the prior data summarized in Fusilier (2010) from 1980 to 2010 (an impressive Secchi disk record), showed Secchi disk trends generally decreased (10-12 ft to 4.8 ft) from 1980 to 2000, then during 2005 there was a dramatic increase in average values from 2002 to 2005-2006, when the mean value increased to 14.8 ft. Could this be due to zebra mussels? However, after 2006 values decreased to 8.3 ft during 2010 and the average we calculated for the 2011 data set (8 ft) was similar continuing the trend of decreasing Secchi disk values. We are unaware of how abundant zebra mussels were in the lake, but typically when they enter an ecosystem, they increase water clarity, which results in more dense aquatic plant growth. Second, because they selectively remove edible algae from the water, blue-green algal blooms (e.g., *Microsystis*) (inedible by zooplankton) become prevalent. People should be aware of this and report any surface accumulations that look like green paint scum, something we noted in a few areas around the lake during 2023. The algae data strongly suggest the lake is dominated by blue-green algae, some the blooming kind and some that can, under the right conditions, produce toxins. Keep pets from drinking such water and humans need to be aware and stay out of the lake if there are obvious “green paint” accumulations. In addition, we do not know if there has been an increase in boat traffic over the years, but boat traffic in general can destratify a lake, putting nutrients into the upper layers and since the lake is so shallow, sediments are constantly being disturbed and re-suspended into upper waters, also providing a source of nitrogen and phosphorus. This would foster algal blooms since the nutrient data show that both N and P are limiting at times in Lake Sherwood, especially during summer, but total phosphorus (that measurement that would include any algae blooms) was high.

2009-2011: Devine dataset. These data (Table 2) taken in the south end of the lake, with appreciation to Dan Devine who collected them, show that the average value of the readings over the period 2 May-9 October have declined over the years from 10.9 ft in 2009, to 8.7 ft in 2010, to 8 ft in 2011. All these values would classify the lake as mesotrophic (like Lake Michigan not Erie or Superior), since the cutoff value is >7.5 ft. Considering that zebra mussels are present and that there are ongoing efforts to reduce nutrient input to the lake, this trend is disappointing. Examination of the general seasonal trends over years shows that water clarity was high in spring, declines during summer algal blooms, then increases again in the fall. During 2009, as noted above, water clarity was moderately high compared with 2010-2011, and values varied from 10 to13 ft from 17 April through 6 October, with exceptions on 14 June (9 ft) and 4 August, when values were lowest of the year at 7 ft (Table 2). We would expect algal blooms may have been responsible for the loss of water clarity on these dates. During 2010, from 5 May through 23 July, Secchi disk values varied from 9 to 14 ft. The high value of 14 ft on 14 June 2010 was the highest recorded during the 3-year period. Thereafter, values declined to 6-9 ft during 4 August through 14 September and remained low for the rest of the period at 5-6 ft from 22 September to 6 October. This is contrary to the usual pattern we observed during other years, when Secchi disk values increased during late summer-fall; however, sampling further into October may have shown this trend. During 2011 from 4 May through 2 June, Secchi disk values varied from 9 to 12 ft, declined to 7-8 ft during 27 June through 26 August, then decreased to 5-6 ft from 10 September through 2 October. From 9 September through 26 October, Secchi disk values increased from 7 to 11 ft.

Table 2. Secchi disk values (ft) for Lake Sherwood during 2009, 2010, and 2011. Data provided by Dan Devine.

2009		2010		2011	
18-Mar	Ice Out	19-Mar	Ice Out	2-Apr	Ice Out
17-Apr	11	5-May	11	4-May	9
2-May	10	22-May	10	12-May	10
7-May	12	1-Jun	12	17-May	10
16-May	13	14-Jun	14	21-May	11
25-May	12	21-Jun	12	25-May	12
5-Jun	11	1-Jul	11	30-May	11
14-Jun	9	5-Jul	9	2-Jun	9
26-Jun	10	13-Jul	10	27-Jun	8
9-Jul	12	15-Jul	10	20-Jul	7
13-Jul	11	23-Jul	11	23-Jul	8
22-Jul	10	4-Aug	9	4-Aug	8
31-Jul	10	16-Aug	8	16-Aug	8
4-Aug	7	21-Aug	9	26-Aug	7
25-Aug	12	9-Sep	6	10-Sep	6

5-Sep	10	14-Sep	8	17-Sep	6
25-Sep	11	22-Sep	6	22-Sep	6
26-Sep	12	25-Sep	6	25-Sep	6
6-Oct	13	28-Sep	5	28-Sep	5
		2-Oct	5	2-Oct	6
		4-Oct	5	9-Oct	7
		6-Oct	6	13-Oct	9
				21-Oct	11
				26-Oct	10

2011: Freshwater Physicians (2012). Secchi disk measurements during 14 August 2011 varied from 3.3 to 5.6 ft among the seven stations we sampled (Freshwater Physicians 2012) causing the lake to be classified eutrophic (like Lake Erie). Lake Sherwood stations (1, 2, 3, 7) had Secchi disc readings that varied from 3.3 ft to 5.6 ft, with the highest values observed at main lake stations, while the station 7 reading near the inlet stream (Wildwood River) was the lowest at 3.3 ft, indicating some intense coloring due to algal blooms or turbidity. These values found in Lake Sherwood are low and indicate a lake undergoing an algal bloom at this time.

2020: Freshwater Physicians (2022). Water transparency at stations 1-7 during fall 2020 on 16 September was 1.8-1.9 m (5.9-6.2 ft) or an average of 6.1 ft. These values are moderate and an indication of moderate degradation of the lake with more algal blooms and makes the lake eutrophic, since Secchi disk measures are <7.5 ft. Lakes are mesotrophic if the Secchi disk reading is between 7.5 and 15 ft, which has happened during specific times during various years.

2023 (this study): Secchi disk values during 16 August 2023 averaged 4.2 ft (Range: 3.6-5.2 ft, N=7). These are the lowest values measured in the datasets and are clearly eutrophic (<7.5 ft). Since Secchi disk measurements are so closely linked with algal blooms, one hypothesis is that nutrient inputs to the lake may have increased or zebra mussel populations have declined, resulting in reduced Secchi disk values.

1980-2020: See sources above. We combined the data from 1980 to 2020 described in detail above, to provide an overall view of the long-term changes that occurred in Lake Sherwood over this period. As we noted above, the cutoff value for a lake to be eutrophic is to have readings <7.5 ft. Examination of the data (Fig. 7) showed that most early, average values were greater than 7.5 ft and sometimes they were over 14 ft. The overall conclusion is that the lake has mostly mesotrophic readings, which is very good. However, the overall trend in water clarity starting from 1980 declined from values of 10-14 ft down to around 4.8 ft during 2000; the readings then increased up to a maximum of around 15 ft on 2005, but began to decline again. Our 6.1 ft reading on 6 September 2020 is close to the lowest Secchi disk reading for the whole period and shows that water transparency at least during September was declining. The 2023 data set was even more alarming, averaging 4.2 ft with a range of 3.6-5.2 ft. One obvious conclusion is that while we were sampling throughout the lake during 2023, we noticed very few macrophytes in several areas, something residents probably demanded. However, it appeared that one upshot of that effort is that blue-green algae in summer and fall now dominate the lake (over 60% by volume) by taking up the nutrients released by the demise of macrophytes. There must be a balance maintained in a shallow, fertile lake like Lake Sherwood, between decimating all the macrophytes and leaving native plants and *Chara* (an alga) so that they can sequester the nutrients, since macrophytes are easier to control rather than algae which are very difficult to control and could be dangerous to residents if toxin-producers dominate the algae population (to be discussed below). In addition, we have worked on two lakes recently, that have also decimated the macrophytes to such a degree that algae now dominate the lake ecosystem, a switch from macrophyte-dominated to algae-dominated. Once that starts, algae will grow earlier in the year than macrophytes and shade them out, continuing the cycle of algal domination.

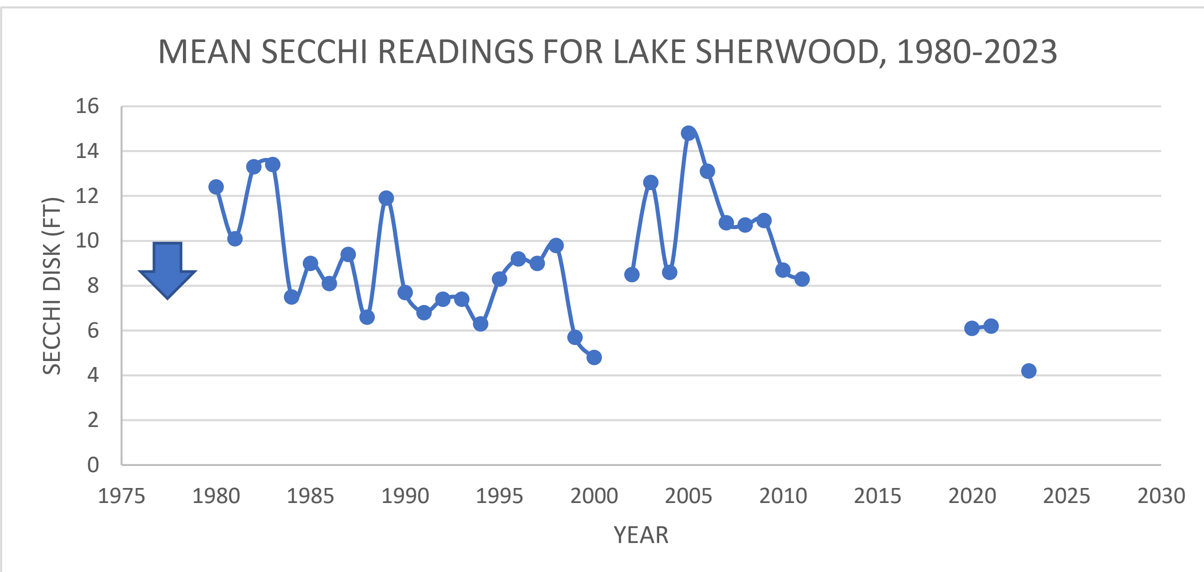


Figure 8. Water transparency data for Lake Sherwood, 1980-2023. Data from 1980-2010 (Fusilier 2010), 2009-2010 (D. Devine), 2020 (Freshwater Physicians 2021), and 2023 (this study). Blue arrow shows the point (<7.5 ft) that designates a lake eutrophic.

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 anoxic (no dissolved oxygen) 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 (a dead zone) can result. This has implications for the aquatic organisms (fish cannot go there) and chemical parameters (phosphorus and ammonia) are released from the sediments under anoxic conditions; these nutrients are then mixed into the lake during the fall and spring overturn fueling plant growth.

There were ten dissolved oxygen-temperature profiles performed from 1994 to 2008 (Fusilier 2010) during summer; six of them showed no stratification and no dissolved oxygen anoxia on the bottom. The four times when anoxia was found, the lake was stratified and dissolved oxygen was zero at 17-19 ft in the deep hole in the south part of the main lake. One can conclude from these data that Lake Sherwood is a shallow lake and that wind and motorized watercraft activity can disrupt stratification in the main body at the deep basin and re-oxygenate bottom waters but also re-distributing the nutrients that are generated during anoxia and leading to increased algae and macrophyte growth. This seldom happens in deeper eutrophic lakes; however, we have seen it happen in a shallow lake because of boat activity disrupting stratification, which could also happen on Lake Sherwood. The upshot of this is that occasionally Lake Sherwood is going to generate phosphorus and ammonia from decomposition of bottom waters during those quiet times when the lake stratifies during summer (internal loading). Obviously, instead of the distribution of nutrients from this source which normally occurs during fall over turn, these nutrients generated will be distributed into the lake and provide nutrients during times when the supply of N and P may be low and limit plant growth. It of course could be worse and happen more often but needs to be taken in consideration when looking at nutrient sources and how to control them in Lake Sherwood.

The lake was not stratified during summer 2011 (Freshwater Physicians 2012), but dissolved oxygen was severely depleted to 0.5 mg/L on the bottom at station 1 in the main lake. During 16 September 2020 (Freshwater Physicians 2021), there was adequate dissolved oxygen from surface to bottom. This is a good sign, indicating that the decomposition is not so active that it depresses dissolved oxygen in Lake Sherwood often, which we have seen in other lakes we work on and occurs periodically in Lake Sherwood when conditions (calm weather) occur as we documented above. During 16 August 2023, dissolved oxygen at the deep hole in the main lake (station 1) was similar, around 9 mg/L, from surface to bottom (Fig. 8), a possible indication of de stratification of the water column from excessive boat activity. It was a hot day with surface temperature almost 24 C (75F) and bottom temperature 22.5 C (72 F); it should be noted that these temperatures are stressful for cool water fishes, especially walleyes and northern pike. In contrast the dissolved oxygen data from station 5 on the east side showed that on the bottom, anoxia had set in (Fig. 9). It may illuminate the point made earlier, that in the open lake, boats are allowed to reach maximum speeds, while in the canals, speeds are no wake and disturb the stratification patterns less, leading to decomposition causing anoxia on the bottom. Some of this probably also occurs in the main lake at night and on occasions when boat traffic is light, wind calm, and temperatures high.

This internal loading (anoxia-generated nutrients on the bottom), when it occurs, could be a major source of nutrients to Lake Sherwood along with that contributed by the stormwater drains, especially the Wildwood River inlet stream, and riparians through lawn fertilization, runoff of nutrient-laden water, erosion, and inappropriate disposal or burning of leaves in the watershed (see Appendix 1 for prevention guidelines). Thus, since Lake Sherwood is on the edge (tipping point) of losing its dissolved oxygen on the bottom, all efforts to control nutrients entering the lake need to be pursued.

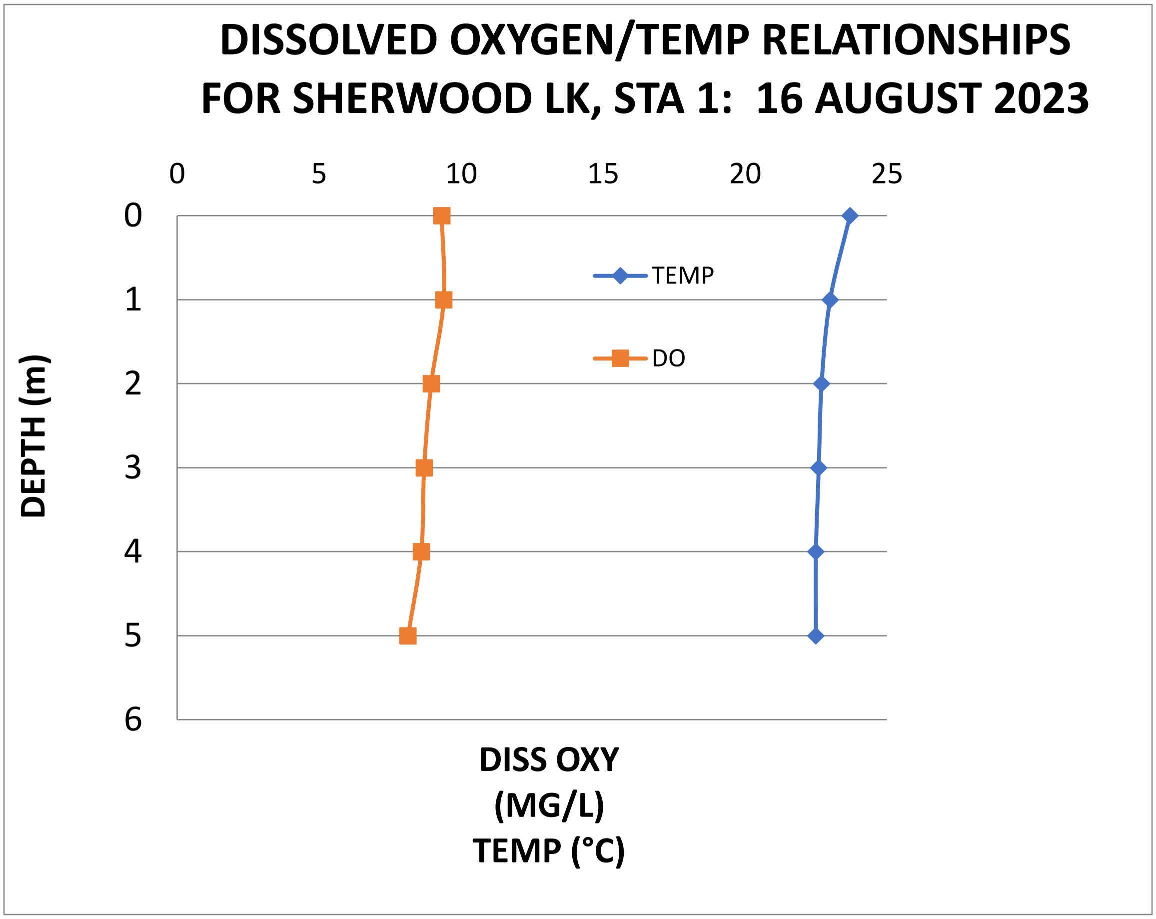


Figure 9. Dissolved oxygen-temperature profile for station 1 (main lake, south side – See Fig. 6 for location) in Lake Sherwood, 16 August 2023.

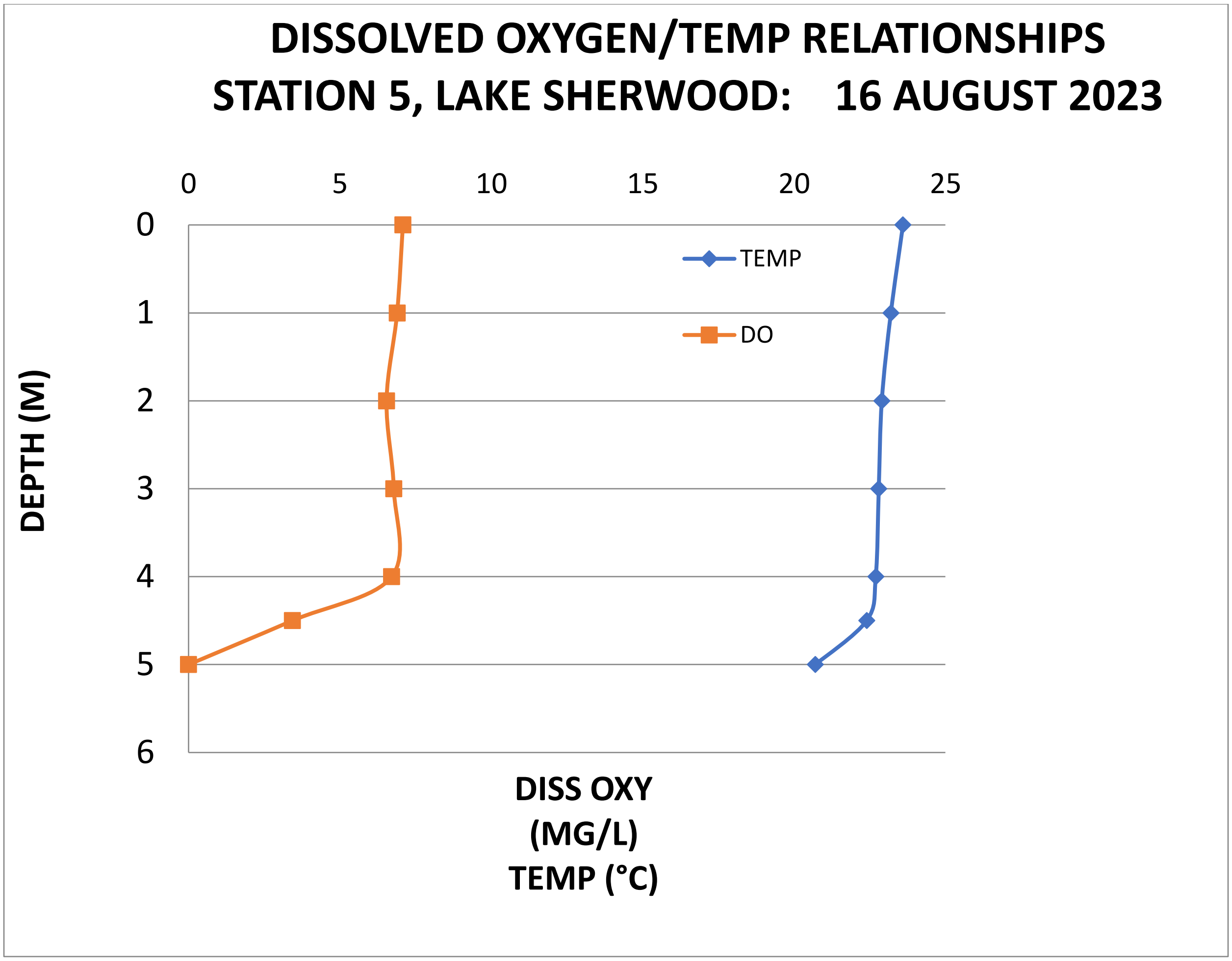


Figure 10. Dissolved oxygen-temperature profile for station 5 (east side – See Fig. 6 for location) in Lake Sherwood, 16 August 2023.

CHEMICAL PARAMETERS

Conductivity

Fusilier (2011) found mean conductivity from stations 1-3 in Lake Sherwood during spring 1994-2010 was 481, while during summer it was 503 uS/cm (or micro Siemens/cm or just uS). The 2011 equivalents were 445 uS/cm during spring and 462 uS/cm during summer (Freshwater Physicians 2010), which are somewhat lower. In the canals (stations 4, 5, 6), Fusilier found the mean spring and summer conductivities averaged over 1994-2010 were respectively 503 and 517 uS/cm, while comparable means for 2011 were: spring 482 uS/cm and summer 494 uS/cm. The 2011 data are similar but slightly lower than the 1994-2010 means. Fusilier noted a trend over the period of the canals having higher readings than the lake and that the Wildwood Canal (near station 4) was highest among the three areas. Our station 7 data from near the Wildwood River inlet on the north side during 2011 had the highest conductivity, reflecting the probable higher concentrations of solutes in the water coming in from the watershed it drains.

During September 2020, conductivity was higher than previous studies averaging 646 uS (Table 3 and Freshwater Physicians 2021) indicating increased accumulation of negative ions in the lake. Chlorides were slightly higher during 2020 than 2011, but not enough to account for the increase. The inlet from the Wildwood River (station 7) had the highest reading of 774 uS, which is indicative of high concentrations of anions in the water.

Our work during 2023 at seven stations showed that mean conductivity was 613 uS with a range of 581-716 uS (Table 4); the highest value was at station 5 surface rather than at station 7, which had the highest values in the past. There was no trend with depth at the two stations with depth data (station 1 and 5). Trends over time showed means of 481-503 uS during 1994-2010, 482-494 uS during 2011, 646 uS during 2020 (Table 3), and 613 uS during 2023 (Table 4).

Table 3. Water chemistry data for Lake Sherwood, 16 September 2020. Cond =conductivity (uSiemens), Cl=chlorides, NO_3=nitrates, NH_3-ammonia, SRP= Soluble reactive phosphorus, TP=total phosphorus, values (except pH) in mg/L. See Table 1 and Fig. 6 for station location.

STATION	PH	COND	CL	NO_3	NH_3	SRP	TP
1-S	8.35	650	53	0.10	0.03	<0.005	0.035
1-M	8.33	656					
1-B	8.20	656	53	0.11	<0.01	0.008	0.029
2	8.22	644	53	0.09	0.02	<0.005	
3	8.20	644	54	0.09	<0.01	<0.005	
4	8.16	480	54	0.04	0.21	<0.005	
5	8.16	644	67	0.02	0.03	<0.005	
6	8.28	653	67	0.02	0.03	<0.005	
7	8.06	774	59	0.10	0.02	<0.005	

Table 4. Water chemistry data for Lake Sherwood, 16 August 2023. Cond =conductivity (uSiemens), Cl=chlorides, NO_3=nitrates, NH_3-ammonia, SRP= Soluble reactive phosphorus, TP=total phosphorus, values (except pH) in mg/L. Secchi=Secchi disk reading in m. See Table 1 and Fig. 6 for station locations.

STATION	PH	COND	CL	NO3	NH3	SRP	TP	SECCHI
1-SUR	8.88	613	58	0.07	<0.01	<0.005	0.024	1.2 M
1-MID	8.91	592	59	0.04	<0.01	<0.005		
1-BOT	8.98	600	58	0.05	<0.01	<0.005	0.026	

2-SUR	8.99	604	56	0.10	<0.01	<0.005		1.2 M
3-SUR	8.96	601	59	0.05	<0.01	<0.005		1.2 M
4-SUR	8.87	586	58	0.11	0.03	<0.005		1.4 M
5-SUR	8.44	726	70	0.10	0.06	<0.005	0.025	1.4 M
5-MID 3M	8.50	576	71	0.05	0.06	<0.005		
5-BOT 5 M	8.00	642	71	0.10	0.86	<0.005	0.062	
6-SUR	8.74	581	69	0.10	0.07	<0.005		1.6 M
7-SUR	8.74	624	51	0.12	0.06	<0.005		1.1 M

pH

The pH from the previous study by Fusilier (2010) noted that pH varied from 7.1 to 8.9, which is an unusually large range. Some of the variation was attributed to water coming in from the inlet streams which may have lower pH values. On 16 September 2020, pH varied from 8.06 to 8.35 (Table 3). Interestingly, the lowest pH was from station 7, the inlet stream in the north. As expected these pH values are high due to probable algal blooms and an abundance of macrophytes removing carbon dioxide from the water column and increasing the pH. The pH values were also high during 16 August 2023 and ranged from 8 to 8.98 (Table 4).

Chlorides

The long-term changes in chlorides are instructive of the forces of development and destruction of the natural order around Lake Sherwood. Although not toxic at the levels we usually measure, chlorides are bellwethers of ecosystem integrity. They enter lakes through runoff from road salting, and they occur naturally in soils. Pristine water bodies usually have chlorides in the 4-10 mg/L range. Another characteristic of chlorides is they are not modified by chemical or biological processes. Hence, once in the lake they stay there and can only be modified or diluted by inputs of lower concentrations of chlorides, rainwater, or evaporation. Therefore, the concentrations of chlorides reveal something about the history of runoff, road-salting activities, or other changes to the landscape that may affect chloride concentrations. In addition, if chlorides are high, other deleterious substances may also accompany them, so serve the purpose of warning us of ongoing pollution. Chlorides during spring 2011 (Freshwater Physicians 2012) ranged from 35 to 87 mg/L with highest values found at station 6 in the east canals. During 14 August 2011, chlorides were somewhat lower, ranging from 43 to 78 mg/L with station 6 once again having the highest concentrations of chlorides. There must be some input of chlorides at that station, which is adjacent to Winewood Lane. These values are moderate and do indicate input of chlorides from the watershed and with the input from two inlet streams and the large area surrounding the lakes with the many roads, road salt may be a problem. The data from 2020 showed chlorides ranging from 53 to 67 mg/L (Table 3) and once again the stations on the east especially station 6 had the highest chloride levels confirming some kind of pattern of increased input of chlorides at this station. During summer 2023, chlorides ranged 56 to 71 mg/L with station 5 having the highest values contrary to previous data, where station 7 had the highest chlorides. These are modest concentrations and they do not seem to be increasing, a positive feature.

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 and possibly where it is generated or originates. Soluble reactive phosphorus (SRP) measures only that P which is dissolved in the water, which is the form that is readily available for algal and plant growth. Total P would be all the P in the water, dissolved and that tied up in algae or other detritus.

Fusilier (2010) measured TP in Lake Sherwood and found values that ranged 0.014-0.098 with a mean of 0.025 mg/L. The available criteria for trophic status of lakes are: oligotrophic <0.010 mg/L TP, mesotrophic 0.010-0.020 mg/L, and eutrophic > 0.020 mg/L making Lake Sherwood a eutrophic lake. Some substantial values (0.200 and 0.214 mg/L) were measured in the inlet streams; these are very high values.

During 2020, TP at station 1 in Lake Sherwood had values of 0.035 mg/L at the surface and 0.029 mg/L on the bottom (Table 3). These values are comparable to the average (0.025 mg/L) from the Fusilier study. Note too that the surface concentration (more algae?) was higher than the bottom value. Since these values are >0.020 mg/L, the lake would be termed eutrophic. During 2023, TP at station 1, the main lake, was 0.024 mg/L at the surface and 0.026 mg/L on the bottom – eutrophic values (Table 4). At station 5, which had some anoxia compared with station 1 which had none, TP values were similar at the surface (0.025 mg/L), but much elevated concentrations on the bottom (0.062 mg/L). This is an example of internal loading which normally contributes nutrients to the lake in spring and fall overturn.

The other form of phosphorus is SRP, which was only measured in our studies. Concentrations of SRP during September 2020, the soluble phosphorus at station 1 available for plant growth was uniformly low (<0.005 mg/L) in the surface waters of all seven stations; concentrations on the bottom of station 1 were slightly higher at 0.008 mg/L (Table 3). The low SRP values in surface water is expected with plant uptake a predominant uptake mechanism. The similar value on the bottom is an indication that the water column was not stratified, and concentrations were similar from top to bottom, something we saw with other parameters and dissolved oxygen. During August 2023, SRP was also a uniform <0.005 mg/L at all stations and depths sampled (Table 4). Again, this shows that the lake is very productive and is taking up all the available SRP in the water column.

Nitrates

Nitrates are an important nutrient for plants and besides P we are quite concerned about the concentrations in lakes. Fusilier (2010) found nitrates in Lake Sherwood ranged from 0.01 to 0.62 mg/L with most concentrations less than 0.20 mg/L. Fusilier thought that the lake was N limited in both spring and summer, which means plant production would cease until more N entered the lake. Hence his and our recommendation to follow some of the recommendations provided in Appendix 1 regarding planting green belts, no lawn fertilization (including nitrate fertilizer), or burning of leaves in the watershed. The lake's fate resides in the behavior of people whose interests are best served through conservative lawn fertilization practices in the watershed.

Nitrates during spring 2011 were variable ranging from trace concentrations to 0.86 mg/L. The highest value from station 3 is much higher than common values (<0.20 mg/L) found in the Fusilier study. It is an indication that large quantities of nitrates are somehow getting into the lake in the area of station 3, which is near the area of discharge of station 7, the outlet Wildwood River from Teeple Lake. This inlet stream may be an important source of nitrates for the lake. Moderate concentrations (0.27-0.28 mg/L) were found at stations 1 and 6; remaining stations had only trace concentrations. During summer 2011, concentrations as expected, were uniformly at trace concentrations at all stations, except at station 7 where 0.41 mg/L was measured. It appears that nitrates were taken up by the algae and macrophytes to such a degree that concentrations were very low and are probably limiting in Lake Sherwood at this time, which was noted by Fusilier in his studies. Hence, any nitrates that enter the lake will be quickly taken up and lead to increased plant growth. Again, this is evidence that this outlet water at station 7 (Wildwood River) contains high concentrations of nitrates that will eventually enter Lake Sherwood and promote plant growth.

During 16 September 2020, nitrates ranged from 0.02 to 0.11 mg/L, which are low values (Table 3). Station 7 had low concentrations as well (0.10 mg/L), which was not in line with the pattern observed with the 2011 data, which showed much higher concentrations at this station. During summer 2023, nitrates averaged 0.08 mg/L; station 7 again had the highest value, 0.12 mg/L (Table 4). These values are low compared with previous data sets.

Ammonia

We focus on how much ammonia is generated on the bottom of a lake, since those that become anoxic in the summer can generate large amounts of ammonia from sediment decomposition under reduced conditions (no oxygen), which then get converted to nitrates and contribute to the nitrate-enrichment problem in Lake Sherwood. Since ammonia is toxic to fish and a nutrient which is re – distributed into the lake during fall and spring turnover to fuel plants, we use the presence of amounts of ammonia as an indicator of how enriched the lake is and as a symbol of ecosystem health in the lake. The 2011 data (Freshwater Physicians 2012) collected during spring showed the expected: similar and low concentrations (trace – 0.16 mg/L) in the water column. All but the 0.16 mg/L value observed at station 4 were in the 0.02 mg/L range. The summer data showed low concentrations as well with a range from trace to 0.08 mg/L. As we discussed earlier, the lake does not stratify very often and apparently is quickly mixed by wind and boat traffic. The data for ammonia give some credence to what we are concerned about: buildup of nutrients, including ammonia, during periods when the lake does stratify. The value of 0.08 mg/L, although low, is still evidence of increased decomposition on the bottom during periods of stratification.

During summer 2020 (Table 3) ammonia concentrations were uniformly low (trace – 0.03 mg/L), except for station 4, where the ammonia value was 0.21 mg/L. This is an unusually high value for lakes in summer, since usually ammonia is quickly converted to nitrates and taken up by algae and plants. Station 4 is near the inlet from Cranberry Lake. Interestingly, the highest concentration found in spring 2011 was also at station 4. This station is near the Wildwood Canal and may be contributing ammonia and other substances to Lake Sherwood. These values are still way below what we find in a routine eutrophic lake study, where ammonia values on the bottom under anoxic conditions can measure up to 1.5 mg/L.

BIOLOGICAL PARAMETERS

Algae

Chlorophyll a

Chlorophyll a is an indicator of algae in the water column. Values that are <2.2 ug/L classify the lake as oligotrophic, values 2.2-6 ug/L are mesotrophic, while values >6 ug/L are termed eutrophic. Chl a values in Lake Sherwood during 1994-2008 varied from 0.4 to 12.4 ug/L (Fusilier 2010) and the author reported that there was an algal bloom ongoing each time they sampled. Summer chlorophylls were generally higher than spring chlorophylls, and the east canals generally had higher chlorophylls than values measured in the lake during summer. The Wildwood Canal (near station 4) generally had the highest chlorophylls, ranging from 6.8 to 31.0 ug/L. Note this is the station that had elevated ammonia concentrations as well. From these data we concluded that there are large quantities of algae proliferating in Lake Sherwood and that it would clearly be designated as eutrophic based on Chl a.

Algae composition and abundance

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 sampling station in main part of Lake Sherwood in August 2023 (Table 5) included:

Cyanobacteria—the blue-green algae are actually 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 have the ability to 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 *Microcystis* in Lake Erie caused the shut down of the Toledo water supply in 2015). Cyanobacteria made up over 60% of Lake Sherwood's Station 1, algal biomass in August 2023 (Fig. 10). The deep station cyanobacteria community was comprised of many small-celled, non-nuisance forms (e.g. *Aphanocapsa* and *Chroococcus*), but several species of concern were noted in abundance in Lake Sherwood (*Anabaena/Dolichospermum, Microcystis, Aphanizomenon*).

Table 5. Predominant (>5% of total algal biovolume, μm^3/mL) algal species or genera in Lake Sherwood, 16 August 2023. Abbreviations of algal groups: CY = cyanobacteria, BA = diatoms, GR = greens, DI = dinoflagellates, CH = chrysophytes, CR = cryptomonads, EU = euglenoids.

Lake Sherwood	**Dominant algae**
August 2023	*Anabaena/Dolichospermum* (CY), *Chroococcus limnetica* (CY), *Aphanocapsa* (CY), *Microcystis* (CY), *Aphanizomenon* (CY), *Aulacoseira ambigua* (BA), little cyclotelloids (BA), benthic diatoms (BA), *Dinobryon* colonies (CH), *Ceratium* (DI), *Nephrocytium* (GR), and the desmids *Staurastrum* and *Closterium* (GR).

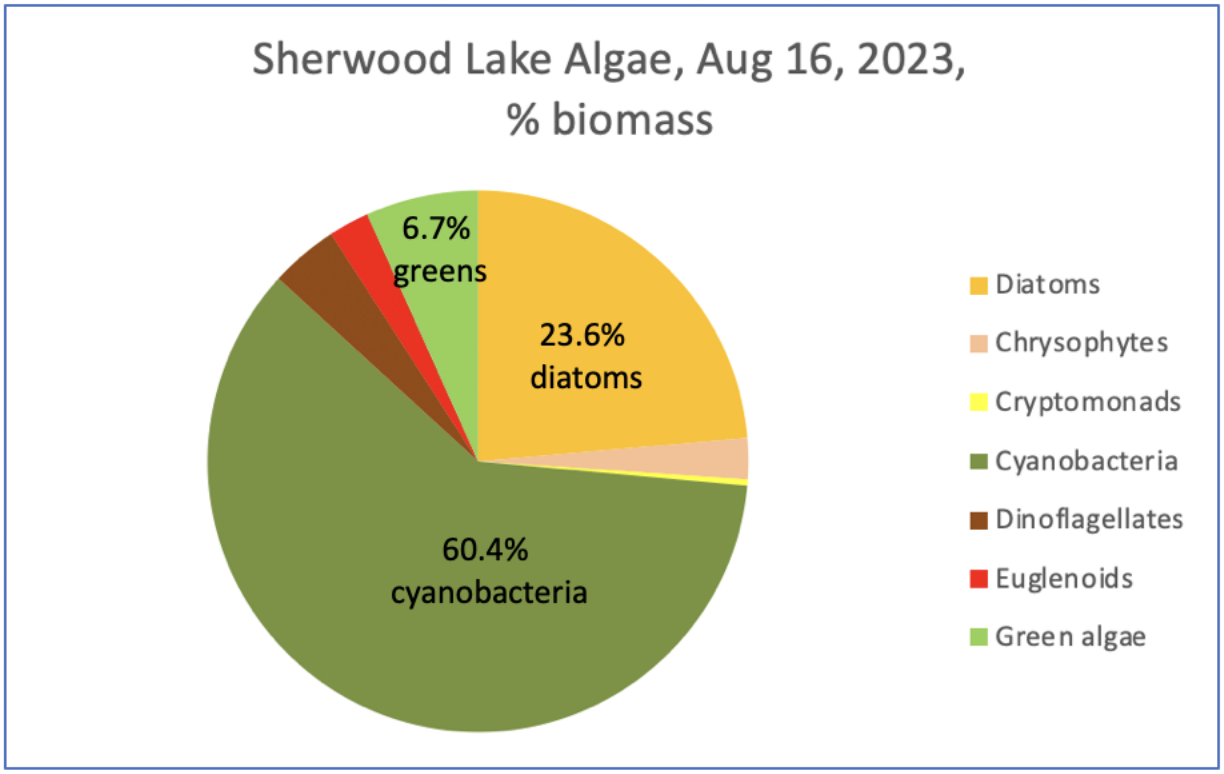


Fig. 10. Proportion of algal biovolume or biomass by algal group for Lake Sherwood, Station 1, 16 August 2023.

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 Sherwood, single-celled and colonial forms that are suspended in the open water can be common; in Sherwood, low levels of single cells of *Staurastrum*, *Closterium* and the colonial forms *Nephrocytium, Pediastrum, Coelastrum,* and *Oocystis* made up 6.7% of the algal biomass at Station 1.

Dinophyceae—the dinoflagellates are a group of large-celled algae where most species surround themselves with an organic shell composed of cellulose plates (called a theca). The dinoflagellates are able to move/swim with flagella and can be very common in some lakes under the ice or in the summer. The dinoflagellates are probably best known for producing red tides in nearshore marine settings; fortunately, this phenomenon does not happen in the freshwater species. In Lake Sherwood, the genus *Ceratium*, because of its large size, contributed 4.1% of biomass in the August 2023 sample (Fig.11).

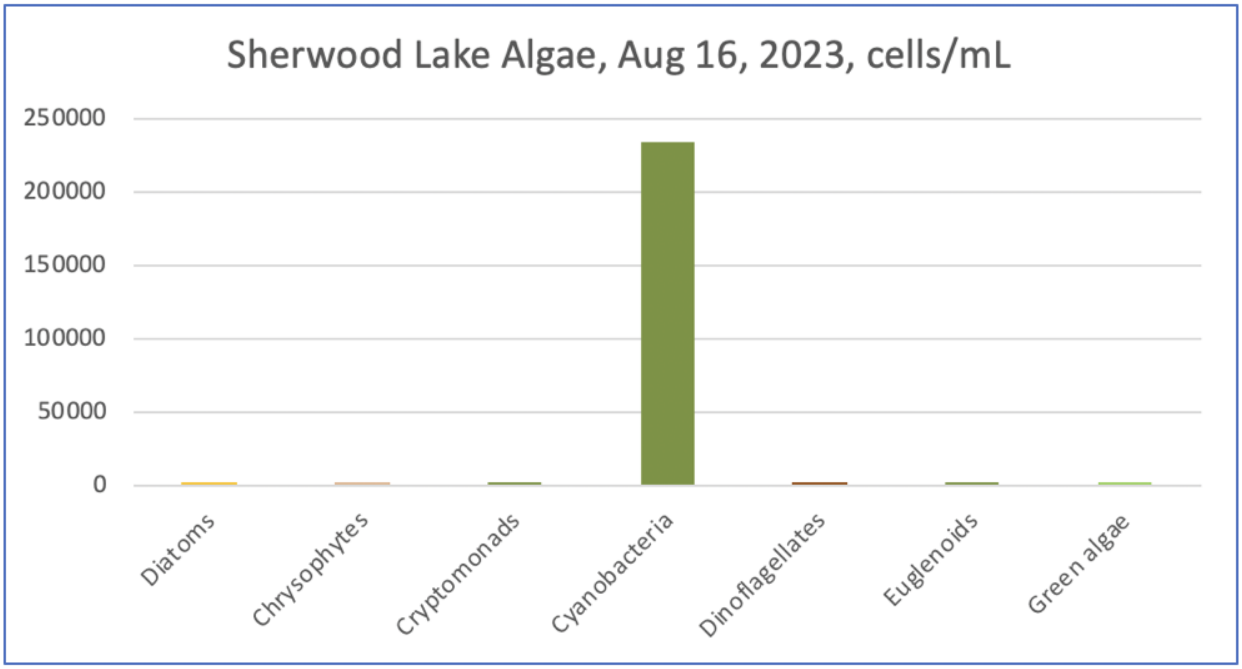
Diatoms or Bacillariophyta—the diatoms are characterized by having a cell wall made of opaline silica or biologically produced glass. The size, shape, and ornamentation of the cell wall provide clues for species identification. Diatoms are generally found in two major ecological groups. The planktonic forms are either round (small *Cyclotella* or *Lindavia* found in Lake Sherwood) or long and spindle-shaped (one *Ulnaria* species) 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 common at Station 1 in Sherwood in August 2023 making up 23.6% of the algal biomass and were primarily represented by mostly *Aulacoseira*, small centrics, and a few benthic diatoms (Fig. 10).

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. The chrysophytes made up 2.5% of Lake Sherwood's algal biovolume in August 2023 and were primarily represented by the genus *Dinobryon*.

Euglenophytes—the euglenoids are more closely related to animals than plants and are well adapted to living in high nutrient (especially N) habitats. These large-celled algae are mostly motile by a single flagellum that pulls them through the water. In Lake Sherwood, euglenoids composed 2.4% of the algal biovolume from cells of *Trachelomonas* and *Phacus*.

Summary--The late summer algal flora of Lake Sherwood (sampled 16 August 2023) was dominated by cyanobacteria and secondarily by diatoms and green algae (Table 5, Fig. 10, 12). With its eutrophic nutrient condition (>0.025 mg/L total phosphorus), we expect high algal biomass, and under mixed summer conditions, we also expect cyanobacteria to be abundant and dominant in a lake. Algal biomass in August 2023 was about one million μm^3/mL at Station 1 (Fig. 10), which included nearly 235,000 cells per ml of mostly cyanobacteria at Station 1 (Fig. 12). The dominant cyanobacteria were small-celled forms of *Aphanocapsa* and *Chroococcus*; however, larger colonial forms of *Microcystis*, *Aphanizomenon*, and *Anabaena/Dolichospermum* were also present in high abundance. *Aphanocapsa* and *Chroococcus* are not commonly associated with cyanotoxin production; however, the other colonial taxa can become cyanotoxin producers under certain conditions. Many of the most notorious producers of cyanotoxins were found in Lake Sherwood (e.g., *Microcystis*, *Dolichospermum/Anabaena*, *Aphanizomenon*). 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. When in doubt, stay out. They may experience skin sensitivity, should avoid ingesting any water, and should not allow pets in the water. The diatoms *Aulacoseira*, small cyclotelloids, and some benthic forms are also expected in nutrient-rich and mixed lakes like Sherwood. The green algae were also common in the late summer algae of Lake Sherwood and included colonial forms such as *Pediastrum*, *Nephrocytium*, and large single cells of *Closterium* and *Staurastrum*.

Fig. 12. Abundance of algae (cells/mL) by algal group for Lake Sherwood, Station 1, August 16, 2023.



Zooplankton

During 2020, we sampled zooplankton at station 1, the master station, and found no *Daphnia*, but other closely related groups (*Bosmina*, *Eubosmina*: crustaceans) made up 36% of the zooplankton community; the rest of the community was composed of copepods (see Picture 3 and 4) (Table 6). Absence of *Daphnia* is usually an indication of severe fish predation (large numbers of stunted bluegills, YOY yellow perch, or other planktivores). Our 2022 fish study (Freshwater Physicians 2022) showed that four species (bluegill, black crappie, largemouth bass, and yellow perch) were eating zooplankton, but no *Daphnia* were found in stomachs; however, digestion can make identifications difficult. We did find *Chydorus* a bottom-dwelling zooplankter and some copepods. The only other reason for no *Daphnia* is usually because of inedible, blue-green algae in the lake. This could certainly be true for some periods, but we believe both fish predation and the preponderance of inedible blue-green algae, which made up over 60% of the biomass of algae in the lake during 2023 may both be factors reducing abundance. The high water clarity, dominance by blue-green algae, and no refuge (anoxia or macrophytes) in the lake all may be factors reducing *Daphnia* in the lake. Often we have also documented *Daphnia* doing vertical diel migrations under anoxic conditions remaining in the hypolimnion where fish cannot go and then rising to the surface at night to feed on algae and avoid fish predation. That option is not available to them in Lake Sherwood over a long enough period of time to protect them.

Table 6. A listing of the abundance (% composition based on counting a random sample of at least 100 organisms) of zooplankton groups (see Picture 3-4) collected with a vertical tow from station 1 (master deep station) in Lake Sherwood, 16 September 2020 (see Fig. 6 for exact station location).

DATE: 10 SEPTEMBER 2020 LAKE: SHERWOOD STATION 1		
SPECIES	**COUNT**	**PERCENT**
Bosmina spp.	5	1.6
Cyclops ♀	5	1.6
Cyclops spp. ♂	2	0.6
Cyclops Imm.	14	4.5
Diaphanosoma spp.	91	29.5
Diaptomus Imm.	38	12.3
Diaptomus ♀	24	7.8
Diaptomus ♂	14	4.5
Eubosmina	106	34.4
Leptodora kindtii	9	2.9

Picture 3. A copepod (zooplankter).

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

DISCUSSION

Lake Sherwood is a shallow, 256-acre, dammed, eutrophic lake surrounded by extensive development and houses (ca. 320 riparians). There are two major inlets, one outlet, a high flushing rate, many smaller storm drains, and the lake has an extremely high shoreline development index, meaning it has many bays, channels, and bayous where additional housing has been built, which results in additional impact on the lake's ecological integrity. Unlike most eutrophic lakes, Lake Sherwood is somewhat different since its deepest basin is around 20 ft; it does not always stratify in summer, but does when conditions (calm weather and low boating activity) allow. This has implications: some good and some bad. When anoxia forms during stratification on occasion, two detrimental things happen. First, there is a nutrient pump that is activated, wherein phosphorus and ammonia (among other substances) are released from the decomposition of bottom sediments (termed internal loading). Second, fish are prevented from that area on the bottom that is devoid of dissolved oxygen. This is detrimental to the lake ecology since during summer, it is common for phosphorus and sometimes nitrogen to become limiting (in low supply) such that algal and macrophyte growth is stopped until more nutrients enter the lake. This mechanism just discussed does just that: it provides a surge of nutrients during summer during a time when the plants may have ceased growth because there is no longer enough nutrients to supply growth. This is also the reason why we make a strong recommendation that lawns are not fertilized, since all fertilizers now are supposed to be P-free, but as we have seen, sometimes N is limiting too, so any new sources of nutrients, such as from lawn fertilization and runoff from lawns with no greenbelts into the lake can also provide the nutrients algae and macrophytes need. The positive aspect of this situation is that there is generally dissolved oxygen from the surface to the bottom from wind fetch and boat activity that mixes the lake, puts oxygen on the bottom, thereby allowing fish access to food items and it prevents nutrient regeneration from bottom sediments. This is not the usual scenario in most eutrophic lakes, where some large quantities of nutrients are generated on the bottom (large internal loading), which then get released into the lake in the fall and spring turnover events, fueling plants the next season. In addition, motorized watercraft activity will stir up sediments and re suspend nutrients into the water column. One way to diminish this effect is for boats to stay in the deeper parts of the lake and some lakes have a rule that motorized boats must stay 200 ft from the shoreline for this and safety reasons, a regulation we recommend for Lake Sherwood.

We drew on four previous studies: 1994-2010: (Fusilier 2010, 2011), 2011 and 2021 (Freshwater Physicians 2012, 2021), and included the information we generated from this study (2023) to provide an overall assessment of limnological conditions in Lake Sherwood. The sediments are composed of a large quantity of clay, with some organic material. The water transparency is good, with the readings from 1980-1990s mostly mesotrophic readings, which is very good. However, the overall trend starting from 1992 declined from values of 10-14 ft down to around 5 ft during 2000; the readings then increased up to a maximum of around 15 ft during 2005, but began to decline again. Our 6.1 ft reading on 6 September 2020 is close to the lowest Secchi disk reading for the whole period and shows that water transparency at least during September 2020 was declining. The September 2023 data (4.2 ft) turned out to be the lowest reading of all. That is a large jump from 15 ft to 4.2 ft and it appeared to be due to algae blooms that were ongoing while we were there. Obviously, a year-long data series would provide more reliability and detail to track changes, especially if related to plant treatments. We are worried that the lake is on its way to shifting from a macrophyte-dominated lake to one dominated by algae. This is a momentous shift and often it is difficult to get back to a situation when macrophytes dominate. Extreme care needs to be taken next year to ensure that macrophytes are given a chance to grow and out compete the algae early on.

There were ten dissolved oxygen-temperature profiles performed from 1994 to 2008 (Fusilier 2010) during summer; six of them showed no stratification and no dissolved oxygen (anoxia) on the bottom. A similar finding (no anoxia) was found during the 2011 (Freshwater Physicians 2012, 2021) and this study. The four times when anoxia was found, the lake was stratified and dissolved oxygen was zero at 17-19 ft at Station 1. As we discussed in detail above, this situation is typical in Michigan eutrophic lakes, since once they stratify in summer they do not mix again until fall. Destratification of the water column in Lake Sherwood is probably caused by boats and strong winds. During the times when there is anoxia, this condition can cause detrimental effects, since anoxia provides nutrients to the system during summer when N and P may be in very low supply. Conductivity was in a moderate range for Lake Sherwood: means were 445-481 uS for spring and 503-462 uS in summer of 1994 to 2011. The overall trend increased over time based on the 2020 mean conductivity of 646 uS, while during 2023 mean conductivity was 613 uS, a slight decline (Table 4). The buildup noted recently did not continue during 2023, which is good news. The Wildwood Canal area showed some of the highest conductivity readings. Chlorides were moderately high ranging 35-87 mg/L during 2011, while they ranged 53-67 mg/L during 2020. Station 6 near the Wildwood River had the highest readings during 2020. Chlorides during 2023 averaged 62 with a range of 51-71 mg/L (Table 4). Fusilier (2010) measured TP in Lake Sherwood and found values that ranged 0.014-0.098 with a mean of 0.025 mg/L making Lake Sherwood a eutrophic lake (>0.020 mg/L). Some very high values (0.200 and 0.214 mg/L) were measured in the inlet stream (Wildwood River) from Teeple Lake. During 2020, TP at station 1 in Lake Sherwood had values of 0.035 mg/L at the surface and 0.029 mg/L on the bottom. These values are comparable to the average (0.025 mg/L) from the Fusilier study. During 2023, TP was 0.024 mg/L at the surface and 0.026 mg/L on the bottom at deep Station 1 (both eutrophic) , while at station 5, TP was 0.025 mg/L at the surface and much higher, 0.062 mg/L on the bottom where anoxia was also noted.

The other form of phosphorus is SRP: that P form most available for plant growth. Concentrations of SRP during September 2020 at station 1 were uniformly low (<0.005 mg/L) in the surface waters of all seven stations; concentrations on the bottom of station 1 were slightly higher at 0.008 mg/L (Table 3). A similar pattern, low SRP values, was documented at all stations during 2023 (Table 4). The low SRP values in surface water is expected with plant uptake a predominant uptake mechanism. The similar value on the bottom is an indication that the water column was not stratified, and concentrations were similar from top to bottom, something we saw with other parameters and dissolved oxygen.

Ammonia is usually at trace concentrations because it quickly gets converted to nitrates which are taken up by plants. Spring 2011 data showed mostly low concentrations (trace – 0.16 mg/L). The high values came from station 4 near the Cranberry Lake inlet. Summer data were low as well (trace to 0.08 mg/L). During summer 2020 ammonia concentrations were uniformly low (trace – 0.03 mg/L), except for Station 4 (0.21 mg/L). This is an unusually high value for lakes, and it was found in spring and summer. This station receives discharge from Cranberry Lake and may be contributing ammonia and other substances to Lake Sherwood. During 2023, ammonia at station 5 on the bottom was a very high 0.86 mg/L (Table 4).

Chlorophyll a values (algae surrogate) during 1994-2008 varied from 0.4 to 12.4 ug/L (Fusilier 2010) and the author reported that there was an algal bloom ongoing each time they sampled. Summer chlorophylls were generally higher than spring chlorophylls, and the east canals generally had higher chlorophylls than values measured in the lake during summer. The Wildwood Canal (near station 4) generally had the highest chlorophylls and is the station that had elevated ammonia concentrations as well.

Lake Sherwood's "vital signs" showed a mixed result (Table 7). Water transparency appears to be reasonable with values reaching up to 14 ft in the past, but the long-term trend is for a decline as the 2020 reading was 6 ft, while the 2023 value was 4.3 ft, the lowest reading we have observed in the lake. We discuss this in more detail below, but believe that zebra mussels were probably responsible for the peak clarity in the past, while the declines noted recently are related to algae - created turbidity, as zebra mussels populations have probably declined (noted in many other adjacent lakes) and we think it may also be related to the aggressive treatment of macrophytes to reduce their densities. The depth of the lake is a drawback, since it is shallow with one deep basin around 20 ft. A deeper lake would more easily be able to absorb chemical insults to the ecosystem. Bottom sediments were mostly clay with some organic material buildup. The pH values are within normal ranges. The lake is unusual as we explained above, because it temporarily stratifies on occasion during summer, but is usually de-stratified due to wind fetch and boat traffic. This situation is a double-bladed sword: under anoxic conditions it results in regeneration of nutrients (P and ammonia) which after a subsequent wind event are mixed into the lake during a time when nutrients are limited and fuel more plant growth. However, most of the time the lake is mixed, and the bottom is oxygenated preventing nutrients from regenerating and providing optimal habitat for some fishes. Chlorides are moderate with a few places with high concentrations. Nitrates were low to moderate at station 7 (Wildwood River) indicating this source is bringing in large quantities of fertilizer. Since summer concentrations of both N and P are usually at very low levels, any additional input of nitrates (e.g., lawn fertilization runoff) will stimulate growth of algae and macrophytes. Ammonia, as expected was at trace levels at most stations, but at unusually high concentrations at one specific station (4 - near Cranberry inlet) in spring and summer. This station may be contributing ammonia and other substances to Lake Sherwood. Total phosphorus during 1994-2010 in Lake Sherwood ranged 0.014-0.098 with a mean of 0.025 mg/L making Lake Sherwood a eutrophic lake. Some very high values (0.200 and 0.214 mg/L) were measured in the inlet stream Wildwood River that originates far upstream at Teeple Lake. During 2020, TP at Station 1 in Lake Sherwood had values of 0.035 mg/L at the surface and 0.029 mg/L on the bottom. These values are comparable to the average (0.025 mg/L) from the Fusilier study. Algae and macrophytes are the manifestation of the cause of the problem: too many nutrients. These plants need to be observed closely as manifestations of some of the elevated nutrient concentrations we and others found. The exotic Eurasian milfoil and starry stonewort are present in the lake and need to be controlled while not harming native species, which are critical habitat for insects, fishes, and they thwart wave action which destratifies the lake and stirs up sediments that release nutrients. There has been a macrophyte and algae control program ongoing in Lake Sherwood to address excess growth in specific areas of the lake. Algae and macrophytes need to be observed closely as manifestations of some of the elevated nutrient concentrations we found. It needs to be understood that there are probably three major types of algae that can form in the lake: phytoplankton, filamentous, and bottom-dwelling forms. Phytoplankton are the microscopic forms that can sometimes be seen floating on the surface like green paint (blue-greens) or that turn the water green in the spring (diatoms). Filamentous forms are the green sometimes almost yellow stringy, almost cloth-like mats on the shoreline (usually in spring) or accumulating on the tops of macrophytes. We discourage treatment of algae (phytoplankton) using copper sulfate and prefer manual methods (raking) to make suitable clearing of beaches for recreational use, if the algae are *Chara* or *Cladophora*. Starry stonewort (see Picture 2) is the invasive species that looks a lot like *Chara*; this must be targeted and destroyed using copper sulfate where found. In addition, keep in mind, copper must be used judiciously, it accumulates in the sediments killing snails and other benthic organisms and once algae are killed it decomposes and recycles N and P which can then result in another algal bloom. There were no *Daphnia* in our summer 2020 zooplankton sample, but there were some closely related groups that composed 36% of the community. The remining community was composed of copepods, which are not as efficient at removing algae and more difficult for fishes to catch. We believe fish predation and inedible blue-green algae may be part of the reason for lack of *Daphnia*.

Table 7. A compilation of the various physical, chemical, and biological measures for Lake Sherwood during 2023 and a qualitative assessment (good, bad, no problem) in general. + = positive, 0 = as expected, - = negative. "See guidelines" refers to Appendix 1 – guidelines for lake residents to reduce nutrient input into the lake. DO=dissolved oxygen.

Condition Documented	Qualitative assessment	Problem Potential	Action to Take
Physical			
Water Clarity	-	Water clarity lowest in 2023	Reduce nutrients
Water Depth	-	Shallow, Sediment buildup	Dredge,Drawdown,Reduce nutrients
Water Temp.	0	Warms up in summer, affects fish	None now
Sediments	-	Black organic muck/clay	riparians-see Appendix 1
Chemical			
pH	0	None	None
Dissolved oxygen	-/0	Anoxia at times	Reduce nutrients
Chlorides	0	Moderate	Reduce salting
Nitrates	0	Concerning-Monitor	See Guidelines; reduce lawn fertilizer
Ammonia	-	Excessive in places-Monitor	See Guidelines
SRPhosphorus/TP	0	Monitor	See Guidelines/reduce P
Hydrogen sulfide	0	Monitor	Monitor
Runoff	-	High nutrients, contaminants,CL	lawn fertilization;monitor drains
Biological			
Algae	-	High	Use mechanical means; Cu for starry stonewort
Macrophytes	+/-	High	Control invasives; preserve natives

Zooplankton	-	*Daphnia* absent	Monitor, fish study

Positive and Negative Attributes of Lake Sherwood

It may be useful to list the positive and negative conditions of Lake Sherwood to focus our attention on what needs to be done (Table 7, above discussion). First, it should be realized that Lake Sherwood is a unique lake for several reasons. It provides aesthetically pleasing views, moderately good fishing, an area for water skiing and boating, canals for kayaking, and islands for parties and picnicking. It would be classified as a eutrophic lake based on water quality measures and high productivity. Here are positive attributes:

Positive attributes:

1. Presence of one deep basin, which can absorb more chemical insults than a shallower lake
2. Presence of native macrophytes in many areas of the lake; good for insects and fish spawning, but this has changed in recent years with algae coming to dominate the lakes plant community
3. The lake stratifies only occasionally during summer, which keeps the bottom oxygenated resulting in low quantities of nutrients released from decomposing sediments
4. Moderately good fishing
5. Water clarity is sometimes good
6. Aesthetically pleasing views
7. Drawdown each fall allowing sediments to dry and residents cleanup opportunities
8. High flushing rate

Negative attributes:

1. Anoxia (dead zone) on the bottom of the lake during summer on some occasions leads to exclusion of fish from the hypolimnion and release of phosphorus and other deleterious substances (e.g., ammonia, nitrates, hydrogen sulfide, carbon dioxide) from the sediments after destratification due to wind or motorized watercraft
2. Total phosphorus, nitrates, and ammonia concentrations are high in some parts of the lake, especially the Wildwood River, which originates from Teeple Lake

3. Excessive macrophyte growth of invasive species and algae requires herbicide and copper sulfate treatments. These treatments have been aggressive and may have shifted the lake toward algal dominance from one dominated by macrophytes

4. Riparians: People can have negative (or positive) effects on lake condition through their behavior in developing their property (paving roads, putting in tennis courts, cutting down trees and vegetation), fertilizing their lawns, burning or letting leaves decompose on their property in the watershed, and not planting greenbelts to retard nutrient flow into the lake (see Appendix 1)

5. At times, excessive motorized watercraft can endanger other enthusiasts on the lake and de-stratify the lake, leading to release of nutrients from the bottom area at the deep station and shallow areas nearshore

6. Three invasive species in the lake: Eurasian milfoil, starry stonewort, and zebra mussels

7. Long-term decline in water transparency probably related to algal blooms

8. At least two major inlets plus many other drains enter the lake carrying nutrients and probably other toxic substances

9. No *Daphnia* found in samples from late summer 2020

10. Lake Sherwood is a reservoir with a large watershed bringing in excess nutrients

11. Blue-green algae blooms (60% of biomass) dominate summer; species include those that can bloom excessively and produce toxins that could be detrimental to pets and keep humans out of the water when obvious scums develop in the lake

Issues to address:

1. Zebra mussels

There are long-term datasets on water clarity contributed by Fusilier, Dan Devine, and Freshwater Physicians (see above for data – Fig. 7 for trends). These data show that water clarity started at around 12-14 ft in the early 1980s (oligotrophic would have been 15 ft or greater, so very good readings), then bounced around, then declined to 4.8 ft during 2000. Water clarity then increased to 14.8 ft during 2005, but has declined ever since to the lowest values documented in this series of 4.2 ft during our 2023 studies. There is a NOAA database on first occurrences of zebra mussels in lakes and rivers of the USA which we consulted for data on when they were first observed in Oakland County lakes. Cass and Walled lakes were the first lakes colonized during 1993 with some 22 other lakes having first occurrences of zebra mussels from 1994 through 2000. There were no data on Lake Sherwood, but Dan Devine speculates it must have been around 1998, which would be a good estimate based on the NOAA data set. Examination of the data (Fig. 7) shows that the peak water clarity was 14.8 ft during 2005 but it started to decline the next year and reached an all time low during 2023 at 4.2 ft. The peak occurred after around 7 years from zebra mussel estimated first entry into Lake Sherwood. A second data point is provided by our fish study done in 2021 (Freshwater Physicians 2022). No zebra mussels were found in the stomachs of pumpkinseeds (well known mollusk eaters), bluegills, or yellow perch suggesting by 2021 they were extirpated or at very low levels. Considering we have no exact data on when they arrived or how fast they may have attained peak abundance, we think it is reasonable to assume that the peak water clarity seen during 2005 was probably related to the zebra mussel infestation. However, it needs to be pointed out that during 1980, water clarity was also at 14 ft, which was at least 8-10 years prior to the arrival of zebra mussels in North American which occurred in 1988 in the St. Clair River. So, the lake at that time had high water clarity without any influence of zebra mussels. Zebra mussels may have declined because of their interaction with the dynamics of macrophyte control. As we will discuss below, we believe that the macrophytes have been over controlled, resulting in algae becoming dominant in the lake. Most of these algae are blue-green (60%) and some filamentous algae, both of which zebra mussels cannot eat. In addition, the occasional anoxia that develops in Lake Sherwood during summer would kill most zebra mussels in the dead zone around Station 1. Thus, it may have been these processes that resulted in the absence of, or low densities of zebra mussels recently.

Zebra mussels create their water clarity impacts by filtering the water of their preferred prey – algae, and they prefer diatoms, one of the major groups of algae that are usually abundant in spring and have a high fat content. There were plenty around from our algae data set in August, so there would be a reliable food supply for them and zooplankton too. One mussel can filter up to 1 liter of water per mussel per day and remove all the algae in the water they filter. They require a substrate to stick to with their basal threads, such as debris, sticks, rocks, and logs, macrophytes, docks, and any hard substrate in the water, including each other (called druses). Also, they require dissolved oxygen in adequate levels as noted above, so if at any time during the year in the deep water sites, dissolved oxygen would decline below zero for a few days, it would kill all the zebra mussels in the area affected. What people do not realize is that zebra mussels are removing the base of the food chain (algae) that feed zooplankton that are critical food for small fishes and some juveniles and adults as well. For example, after zebra mussels and quagga mussels (a closely related species) entered Lake Michigan, the water clarity in Lake Michigan was greater than in Lake Superior! Hence, besides their water-clearing activity, they also degrade the food web and divert all that energy that would have gone into the fish food web into zebra mussel biomass, which then sit on the bottom and eventually die (an ecological dead end), since few native species (yellow perch, white suckers, some pumpkinseeds and bluegills) will eat them. The pattern in inland lakes we have sampled, including work we did on the Great Lakes, shows that they eventually hit limits to their growth and their populations decline. Two other effects of zebra mussels that should be noted is that because of the increased water clarity, macrophytes grow thicker and become more abundant. Second, there is what we like to call the "thistle: effect. When cows eat grass they eschew thistles, and as a result it fosters their growth. In lakes, this same selective removal of preferred algae (diatoms) can result in more nutrients for blue-green algae and they can bloom as a result. We certainly have seen more blue-green algae blooms in our recent visits to Lake Sherwood. We think that happened in Lake Sherwood, where we believe the effects of zebra mussels have been sharply reduced from their peaks in 2005, reducing their impact on the ecosystem and making the dynamics of algae and macrophytes much more important, a subject we take up in the next paragraph.

2. Interactions between algae and macrophytes

One of the principles governing aquatic and for that matter land-based ecosystems is called carrying capacity. On land this is best illustrated by bushels of corn/acre, while in aquatic ecosystems, the concept is the same, pounds of plants per acre. The carrying capacity is governed by the amount of nutrients (N and P) available to the plants. A further extension of this concept is called limiting nutrients. Usually, the limiting nutrient in lakes is nitrogen or phosphorus and the analogy we think that is useful in understanding how this works is making a car. As we have seen during the pandemic, chips were a problem, the limiting factor, that was necessary to complete the car. No cars left the factory until the chips came in. It is the same with nutrients N and P, either or both can be limiting, which is often the case during early spring and summer when plant growth is at a maximum. Thus, no plants can grow when there is no N or P around. The first point from this is that any introduction of N or P into Lake Sherwood during summer when nutrients are limiting, can foster excessive growth of plants. Nutrients can come from lawn fertilization that runs off during rains into the lake, lack of green belts to retard runoff, burning leaves in the watershed, input from the two major inlet sources to Lake Sherwood (Wildwood River and drains that come into the lake), internal loading during times when the lake goes anoxic on the bottom, intense boat activity that re-suspends nutrient-laden sediment, and washing cars or boats in the street with high phosphate detergents. These problems and suggestions to ameliorate them are summarized in Appendix 1.

The second problem with this whole scenario is that as noted above the lake has a set capacity to grow plants. Those plants can be macrophytes or they can be algae, or a combination of both; the best management option is to maintain the macrophytes as dominants in the lake since they are easier to control and are preferred for several reasons: fish habitat, spawning substrate, macrophyte beds act as a barrier retarding wind- and large-boat generated waves from impacting the shoreline, they provide substrate for insects for fish food, and they help maintain balance in the ecosystem. Thus, control should be directed only at invasives (Eurasian milfoil, curly-leaf pondweed, starry stonewort) and leave the natives alone. However, sometimes people are so intent on utilizing the lake, not as it is, but as they would prefer it to be, that there is intense pressure to kill as many plants as possible to provide for less macrophytes getting on their props, or the macrophytes provide a less than optimal surface for swimming or skiing. This can lead to a complete shift in the dominance of plants in the lake from macrophyte dominated to algae dominated. We have seen this happen in at least three lakes we have worked on recently and it looks suspiciously that Lake Sherwood may have joined this group. Great care should be exercised during 2024 to foster native plants and keep the nutrients tied up in macrophytes, not in algae!

3. Wave and large boat concerns

In this section we review one of our reports which is pertinent to this issue (Freshwater Physicians 2021b). Recent trends in Michigan and other lake-blessed states have seen a rise in the number, size, power outputs, and especially the proliferation of Wave Boats. We did some research on the effect of boating activity on Elizabeth Lake (Oakland County) water quality and water clarity with our initial sampling day (control) during 26 May (prior to Memorial Day) 1988 and we sampled on Memorial Day (treatment date: 29 May 1988) (Freshwater Physicians 1989). We examined a number of water quality parameters prior to and after Memorial Day activities. The Secchi disk readings averaged 7 m on the control day and ranged from 2.1-5.5 m on Memorial Day, a substantial increase in turbidity that we attributed to the intense boat activity. There were no significant differences in any of the other water quality parameters; however, nitrates almost doubled going from a mean of 0.09 to 0.17 mg/L. Both of these findings suggest that boating activity can re-suspend sediments that diminish water clarity and that more nitrates are introduced into the water column that will fuel plant growth during a time in summer when nitrates and phosphates are limiting in the water column.

The second study documented occurred on Pine Lake, Oakland County. We sampled the water quality during the pandemic period in spring when the governor banned boats from lakes (control: with start date: 24 March 2020) and we ended it on 29 April 2 days after Memorial Day long after boats were allowed on the lakes again (Freshwater Physicians 2021). We measured nine water quality parameters and Secchi depth at 10 stations throughout the lake at a site in 3 m of water. We ran t-tests to determine if there were statistical differences between the pre and post sampling periods and none, except chlorides, were significant. In retrospect, the study should have been more short term similar to the Elizabeth Lake one focusing on a holiday with samples taken before the holiday and maybe at the end of the holiday. In addition, stations should have been closer to shore where maximal effects of the boat activity would be expected.

The third part of this report reviewed the literature on effects of waves and boats on lake ecosystems. Sizes of boats have increased: over 40% of the registered boats in Minnesota were between 16 and 39 feet long in 1997-98 compared with just 18% in 1968-69. Boats also have increasingly larger engines. There have been explosions in new types of watercraft, especially personal watercraft and most recently “wave boats”. The smaller, more powerful craft, like skidoos, have unique issues, due to their maneuverability and accessibility to shallow and remote areas. Increased development of lakes has led to increased boat activity, especially in areas that have traditionally not been used for recreation. Boats may interact with the aquatic environment by a variety of mechanisms, including emissions and exhaust, propeller contact, turbulence from the propulsion system, waves produced by movement, noise, and movement itself. In turn, each of these impacting mechanisms may have multiple effects on the aquatic ecosystem. Sediment resuspension leading to nutrient distribution in shallow water, water pollution, disturbance of fish and wildlife, destruction of aquatic plants, and shoreline erosion are the major areas of concern. Yousef and others (1980) is the most-often cited publication on motor boat impacts. Turbidity, phosphorus, and chlorophyll *a* were measured on control and intentionally mixed sites on three shallow Florida lakes (all less than 6 m or 18 ft deep), both before and after a set level of motor boat activity. On the two shallowest lakes, significant increases were seen in these parameters on the mixed sites, but not at the control sites. Average increases in phosphorus ranged from 28 to 55%. Maximum increases in turbidity and phosphorus occurred within the first 2 hours of boating activity. Turbidity declined at a slower rate after boating ceased, taking more than 24 hours to return to initial levels.

Johnson (1994) investigated the role of recreational boat traffic on shoreline erosion and turbidity generation in the Mississippi River. Turbidity was monitored at several depths and distances from shore during weekends of heavy boating activity. Turbidity increased the most near the bottom of the river but did not vary with distance from shore. Peak turbidity corresponded with peak boating activity, but only in sites with high-boating activity.

U. S. Army Corps of Engineers (1994) investigated the relationship between boat traffic and sediment resuspension on the Fox River Chain O’ Lakes in northeastern Illinois. Samples were collected in channels connecting the lakes so that boats could be counted with some accuracy. There was a direct correlation between the number of boat passes and the amount of suspended solids in the water column. However, the amount of resuspension varied with water depth and sediment type. In silt substrate, the highest amounts were seen in water depths of 3 ft (1 m), about half as much at 6 ft, and none at 8 ft. In marl substrate, effects were seen at 3 ft, but not 6 or 8 ft. The authors also determined that sediment resuspension by boats at 3 ft was equivalent to the amount of disturbance generated by a 20-mph wind, but the frequency of boat passes was much higher than the frequency of winds of that magnitude.

Asplund (1996) investigated the effects of motor boats on sediment resuspension and concurrent effects on nutrient regeneration and algal stimulation in several Wisconsin lakes. Weekend and weekday water quality was measured on 10 lakes over three summer holiday weekends and an additional weekend in August. Motor boat use increased on holiday weekends compared with weekdays (200-350% increase). Water clarity usually decreased, associated with increases in turbidity, particularly in near-shore sites. Chl *a* showed no consistent trends. Phosphorus (TP) often increased in mid-lake sites, while ammonia generally decreased in both areas. Shallower lakes tended to experience greater changes in turbidity and TP than deeper lakes. Water clarity and boat activity were measured on an additional 20 lakes during every summer weekend. Motor boat use increased consistently on weekends for most of the lakes in the study. Water clarity did not show a consistent increasing or decreasing trend for any individual lake on weekends. However, weekend Secchi disk readings were 10% lower than weekday readings on average for the entire data set. Clear water lakes tended to show slightly larger drops in clarity than turbid lakes (as was found on Elizabeth Lake), and had more weekends with decreased clarity. The magnitude of change in water clarity was small compared with seasonal changes and differences among lakes.

The upshot of all of these studies is clear: There are a number of adverse effects generated by boat activity documented in these studies. There were disturbances to wildlife and fishes, destruction of macrophyte beds, riprap, and erosion of shorelines, increases in turbidity, and re-suspension of sediments and the associated nutrients that were released. Effects were directly related to the number of boats involved, their sizes, and how close to shore they went, since effects were most obvious in the nearshore zone. Studies recommended that:

1. Large boats, especially Wave Boats stay away from the shoreline and in deep water with distances from shore being 200-500 ft.
2. Wave Boats should be banned in shallow lakes with no deep zones.

It should be noted that some of these and other recommendations are currently being considered by the Michigan State Legislature to be put into law. Lake Sherwood has a no-wake rule for the canals, which is great and will help maintain stable conditions in the shallowest areas of the lake. However, in the main lake, it is our opinion that Wave Boats should be banned. They belong in the Great Lakes or other large lakes and Lake Sherwood is too shallow to withstand the currents generated by the intense boat activity on the lake. The large boats currently in use (assuming the Wave Boats are banned) will still be too intense to change the problems that their waves generate when they go too close to shore, so they too need to stay offshore away from shore as far as possible.

4. Efficacy of the RIGERO, muck-eater devices

RIGERO was hired to put Bio-health pods into Lake Sherwood. During the day we did our sampling I was taken to a spot where one of these devices was deployed. It was under a dock in one of the shallow bays of Lake Sherwood and I could just see a small area where bubbles were breaking the surface. The residents had applied for a permit to dredge the area, which is a project and activity I support, and they wanted to do other things to improve the water quality of Lake Sherwood until the permit was approved. From what I understand these devices are expensive, but claim to remove large quantities of sediment from filled-in areas with the use of a small aerator and some specially designed bacteria that will break down organic matter. The species of bacteria of course cannot be revealed as they have a patent pending. I could not find any published literature, the scientific evidence I would need to view this as acceptable. Because of my scientific doubt as to whether this device does what it says, no published literature evaluating it, only testimonials to advertise it that are not verifiable, and experiences we had here on my lake (they were terminated after 2 years when no changes were noted), I am strongly against their use until evidence of their viability is proven. Do you really believe that pellets can reduce muck by 15 inches in 1 year or that humans can do a better job of providing the bacteria to break down sediments than Mother Nature? For my edification, I consulted the article on "what works" a manual of scientifically proven and accepted techniques for improving lakes and I consulted experts for their opinions.

The four experts I consulted for their opinions came from Michigan (three) and Minnesota (one). The first person I have worked with during many lake management projects in Michigan and he too, like me, has dealt with similar requests by not only RIGERO, but other macrophyte-treatment companies, that advocate using some variation of this technique. We both advised the lake association we were working for to forgo the offer to put in enzymes or bacteria that would "eat" muck. His comment to me was that it was "foolishness" and that after spending thousands of dollars over 3 years, lake associations realized that the treatments did nothing to reduce sediments in the treatment area. This was exactly the experience I had on the lake I live on in Brighton, MI.

The second person in Michigan noted that they were very skeptical of bacterial muck reduction systems and that they like me, have never seen any scientific evidence of their efficacy. These plant control companies advocate these treatments based on riparian's fear of chemicals, muck, and weeds. In addition, they pointed out that they are against introducing new "beneficial bacteria" into lakes. Have we not learned the lesson of introducing new species to solve old problems and the problems that has created? Don't you think that the native bacterial community would be adequate to break down the organic material? The final comment was that these treatments at best seem like band aids and worst like scams that may damage the ecosystem.

The third person I talked with is a fellow member of the faculty of the School of Environment and Sustainability at the University of Michigan. He is an expert in forest systems and ecology and the breakdown of organic matter by the bacterial biome. I asked him my question whether there could be bacteria that could break down organic matter better than the native bacterial communities already present in the muck. His response was that there are millions of bacteria per gram of muck - there is no way adding pods can establish a new community of better-adapted organisms. He further noted that this technique that claims to oxidize 15 inches of muck in a year is biologically not feasible.

Since I am a native Minnesotan, I consulted Dick Osgood, a certified lake manager, who has a company called Lake Advocates in Duluth and who wrote the article (What Works) I noted above. It is in a peer-reviewed journal LakeLine, a publication of the North American Lake Management Society of which I am a member. In that issue (35(1):8-16.), he has an article: Do You Want Something That Works? (I can provide that article should you desire to read it). He evaluates many of the techniques used in lake management including dredging, harvesting, alum treatment, drawdowns, etc. He discusses their reliability, applicability, provides a rating, and cites their duration and maintenance requirements. One technique is “Microbes and Enzymes”. He states that microbes and bacterial concoctions sometimes augmented with enzymes promise to facilitate algae control or nutrient manipulation. (Note: I asked Dr. Osgood in an email whether this applied to muck removal and he said yes). He further stated that there is no objective documentation of positive outcomes. Successes have “claimed” to have been achieved, but testimonials are touted by the vendor and not third-party reviewers. No controls are used. When asked about what bacteria or enzymes are in the “concoction”, vendors often cite proprietary information or that a patent is pending. His final evaluation was that the treatments are untested, that applicability is low, and that its rating was: not recommended. He noted that the RIGERO treatment would be illegal in Minnesota. I should also note he wrote a book: Lake Management Best Practices: Managing Algae Problems by D. Osgood and H. Gibbons, 60 pp. I asked his opinion of the claimed 15 in of muck that was removed in my lake. He stated that he had observed similar claims and results in the past (although not with RIGERO). In situations like this, he observed the aerator caused some local sediment displacement, giving the appearance of removal. Simply, the physical disruption of the sediments washed them elsewhere nearby. I completely understand the intent of riparians to try to do something to help improve the water quality of their lake. However, I would rather that money be used to buy green belt plants to plant along the water lawn interface to reduce the flow of fertilizers into Lake Sherwood. Consult the Michigan Shoreline Protection Website for guidance and pictures of lawns transformed into beautiful environments with luscious plants and fruits that are great food for insects, wildlife, and birds, all need our help from the relentless use of herbicides and pesticides, so reviled in Rachel Carson's Silent Spring.

MANAGEMENT RECOMMENDATIONS

Lake Sherwood is a eutrophic lake which "occasionally" develops anoxia (no dissolved oxygen) on the bottom during summer stratification, which leads to two potential problems: 1. It stresses cool-water fish like northern pike and walleyes, which are forced to survive in a thin layer of optimal water, and 2. It promotes P and ammonia release from bottom sediments after de-stratification due to wind/boat traffic. Eutrophic lakes are very productive and generate large quantities of macrophytes and algal blooms, which degrade aesthetics and recreational activities. In addition, Lake Sherwood has two large inlets, several smaller storm drains, and runoff from riparian lawns, which pollute the lake with nutrients and toxic substances. There has been a long-term decline in water transparency, with recent Secchi disk readings at only 4.3 ft. There were several areas of notable concentrations of chlorides, nitrates, ammonia, and phosphorus.

Studies like the one we did in late summer 2020 and summer 2023 are short-term snapshots of the chemical environment and biological community of Lake Sherwood designed to flag any potential problems and provide data to identify these problems and warn of future threats to the ecological integrity of the lake ecosystem. Lake Sherwood has a rich history of prior studies from Fusilier (2010) and Freshwater Physicians (2012, 2021, 2022a, and 2023), on which we relied and have leaned heavily on to ascertain detrimental long-term changes, inform us of potential problems, and elaborate on the history of the lake, so we can identify any trends that may be different from long-standing conditions. Our study is certainly limited by not having seasonal data and little information on the chemical content of the inlets and stormwater drains which enter the lake. With these caveats, we will proceed to document some of the changes and concerns we identified with our studies.

This study was initiated because of a concern for some of the changes in Lake Sherwood, including water clarity changes, algal blooms, and extensive treatment of macrophytes in an effort to understand better the chemical conditions and food webs of Lake Sherwood. To address concerns it would be best to have a nutrient budget so we could focus on the sources that were the most serious to the ecological integrity of the lake. Such a study would be very costly, so the best we can do is hypothesize, based on previous and present studies, what these sources might be. Usually internal loading (nutrients released from decomposing sediments) is the leading source of nutrients, and although it may be important during periods of quiescence and hot days when anoxia may develop on the bottom, we do not think it is the major source. The incoming creeks, drains, and ditches that deliver water to Lake Sherwood are probably the leading source of nutrients, suggesting work to be done for the major inputs to identify areas of concern and methods to curtail nutrient input. This could be constructed wetlands, planting of greenbelts, identifying sources of nutrients and ways to curtail them, and contacting entities in these areas that can assist in implementing methods to limit their entry to Lake Sherwood. Riparians also are implicated in this budget, since their activities are contributing to the degradation of the lake. Riparians need to think more about reducing their boot prints on the lake by reducing as much lawn as possible and replacing it with fruit trees, greenbelts, and water gardens. They need to eliminate fertilization, not just by using nitrogen-based fertilizers, but none at all. Think of all the money that would be saved, the pollution that would be foregone from not using climate-change-generating chemicals derived from gasoline-powered lawn mowers, the insects that would NOT be killed by the use of toxic chemicals for insect and weed control, and the birds that would not suffer an unneeded death. The example of Flaco, the city owl, is a classic example of how poisoned rats eaten by this bird probably contributed to his death. The other classic is the book Silent Spring which showed how pesticides (DDT) used to kill insects led to the death of robins at MSU and elsewhere. Birds and insects are showing great signs of decline (how many monarch butterflies have you seen?). The canary in the mine is speaking. Riparians can also reduce their impact by reducing their contribution to impervious surfaces by installing cobble driveways, and foregoing a swimming pool or tennis court. There are also the other usual suggestions for reducing nutrient input to the lake summarized in Appendix 1: no washing of vehicles or boats with high phosphate detergents, no burning of leaves by the lake, disposal of leaves outside the water shed, cleanup of pet waste, and directing drains into water gardens. There are other sources of nutrients that we cannot do much about: nutrients come from the air as wet and dry deposition (support legislation to curb power plant emissions), they can come in from ground water, and they can be generated from boat traffic, which we discussed, re suspending sediments. Everyone needs to do their part: do not let Lake Sherwood become a "Tragedy of the Commons".

To address these issues, we initiated studies in summer 2011 (Freshwater Physicians 2012), 2020 (Freshwater Physicians 2021a), and 2023. One of our first observations was lack of anoxia on the bottom of the lake, which is unusual for eutrophic lakes and a positive feature of the lake. However, other datasets showed that the lake does stratify and can resulted in anoxia which produced high concentrations of SRP and TP along with nitrates in bottom waters. Nutrients also enter the lake through the two inlets streams, numerous storm drains, and runoff from riparian lawn fertilization activities, where we observed few greenbelts or water gardens to retard runoff. The other important consideration is manifestations of nutrient enrichment: aquatic plants (macrophytes) and algae. As we noted, there are large expansive macrophyte beds noted in the past and extensive algal blooms have been present often. There are two invasive aquatic plants, Eurasian milfoil and starry stonewort (an alga), in the lake. These problem species have been treated in the past with herbicides and copper sulfate and should be only "spot treated" in the future to maintain control before they expand their presence in the lake and present an even more serious problem, since the habitat in Lake Sherwood is optimal for these two species: organic sediments and high nutrients. Emphasis needs to be focused on removing only invasive species and preserving native species.

More extensive discussion will follow each item.

Problem Areas:

1. NO DISSOLVED OXYGEN (ANOXIA)/DRAMATIC INCREASES IN SRP, TP, AND AMMONIA ON THE BOTTOM

There is anoxia periodically on the bottom of Lake Sherwood in the deep basin (Station 1) we sampled. Anoxia prevents fish access during summer and promotes nutrient (phosphorus and ammonia) release from decomposition of bottom sediments termed internal loading. Since the basin where this is occurring is small and most of the time wind and boat activity de-stratify the lake, they may not be large contributions of nutrients to Lake Sherwood, but we think they could be substantial and contribute nutrients at a time when most P and N are limiting. There are several actions that will help maintain or reverse the current increasing eutrophication of the lake.

Recommendation 1: Internal loading could be a source of nutrients to the lake when nutrients are in low supply or limiting. Very high concentrations of phosphorus and ammonia are sometimes produced because of anoxia and then mixed into the lake. Alum or Phoslock treatments, which would tie up P on the bottom for many years, is an option to consider. Another option to consider, if this condition worsens in the future, is to set up a siphon by the dam and discharge hypolimnetic water which is high in nutrients, rather than epilimnetic water, which has low nutrients.

2. DECREASE IN WATER CLARITY, ALGAL BLOOMS, EXCESSIVE MACROPHYTE GROWTH

Recommendation 2: A water drawdown of about 18 inches is done on the lake each October to 1 April. This is another good technique to consolidate the near shore sediments and reduce their ability to be re suspended as well as killing exotic aquatic plants.

Recommendation 3: There are about 630 residences (320 riparians) on Lake Sherwood, which are possible contributors to potential nutrient pollution. One pound of phosphorus can produce 500 pounds of algae and aquatic plants. Most lawns do not need any phosphorus at all. NO fertilization is best. At times both phosphorus and nitrogen can cause additional blooms since both can be limiting. Figure 4 shows examples of Lake Sherwood houses showing extensive lawns, which are green presumably from fertilization and weed free, due to herbicides, and extend all the way to the lake. No greenbelts are visible for most. We did observe many places where there were extensive plant growths, which will aid in retarding runoff of nutrient-laden water into the lake. A transformation recognizing the importance of every riparian home owner to reduce or eliminate fertilizer applications to lawns and plant greenbelts (see: Michigan Shoreline Partnership for guidelines and plants to use) needs to happen. Riparians must help in reducing nutrient input to the lake by following recommendations in Appendix 1. Chief among these are: no lawn fertilization, planting of greenbelts and water gardens near the lake and in runoff areas, and no burning of leaves in the watershed. Put these recommendations into the newsletter and herald at annual meetings to garner support.

Recommendation 4: Motorized watercraft traffic (especially the recent Wave Boats) can produce large waves, which tend to re suspend sediments in nearshore areas, putting more nutrients into the water column and probably de-stratifying the lake, releasing nutrients into the water column fueling plant growth. First, Lake Sherwood is not large or deep enough to support the wave-generating ability of Wave Boats and their ability to damage macrophytes, shorelines, and release nutrients into the lake; they should be banned. A bill is being considered in the Michigan Legislature that may do exactly that for shallow lakes. Rules may need to be instituted for other boats as well (e.g., no skiing or large motorized watercraft within 200 ft or more of shore) to reduce this effect.

Recommendation 5: From discussions and reading of prior studies, it is apparent that there are two major inlets to Lake Sherwood (Wildwood River and the inlet from Cranberry Lake) and several storm drains that run into Lake Sherwood, especially in the canals. We did not see any of these storm drains (we did sample the Wildwood River at its entrance to Lake Sherwood), but they can be important sources of nutrients, sediment input, and other deleterious material. Some idea of the discharge and nutrient inputs from these sources would help understand if they are important sources of nutrient input to the lake and canals. An effort should be made to identify these input sources, determine if there are actions that might mitigate the incoming nutrients (wetland construction, green belts, nutrient reduction, cooperation with other entities who share similar goals). Are there mitigation procedures that can lessen the impact of these drains?

Recommendation 6: Wet and dry deposition: This is input from the sky that mostly originates from power plants and the material that comes down includes acid rain, mercury that has contaminated our fish and resulted in fish contaminant advisories for most large fish in Michigan's inland lakes, and also includes nutrients. Little can be done about this except support for rules/legislation to clean up coal-burning power plants and other industries that pollute the air.

Recommendation 7. Geese, swans, ducks: Although a minor part of the nutrient budget of a lake, efforts should be continued to reduce the populations of these waterfowl, as they bring in nutrients to the lake. Do not encourage them through feeding!

3. MACROPHYTES AND ALGAE

Our observations during summer 2023 showed that there were very few massive beds of macrophytes like we have seen in the past and saw during our fish survey. The lake was dominated by algae, very turbid (lowest Secchi of 4.3 ft in the dataset), and we saw thick accumulations of probably blue-green algae in pockets and areas where the wind had concentrated them. As we discussed in detail above, macrophytes appear to have been decimated through herbicide controls, prompting release of large quantities of nutrients and rebound by algae leading to the current situation of an algae-dominated lake. Whether this situation continues during 2024 will remain to be seen, but much care should be taken to ensure that macrophytes can grow early in the absence of algae and dominate the lake. This will require vigilance and constant monitoring of the macrophytes to ensure they are growing well before any herbicide treatments are allowed.

Recommendation 1: Continue to control Eurasian milfoil and starry stonewort; do not treat native plants: they are important fish habitat, produce fish food, are spawning sites, will preserve the dominance of macrophytes over algae, and can retard motorized water craft impacts on stirring up sediments. Herbicides are justified to control these species, but treatment should not be on a whole lake basis but focused on known and identified beds of invasive species; be careful to avoid killing native plants. Use a rake to clear beach areas of algae to gain access if necessary.

Recommendation 2: Zebra mussels filter specific algae (diatoms, some green algae) from water, which can increase water clarity, but can detrimentally modify the algal community favoring blue-green algae, which can produce toxins and large blooms. We have seen zebra mussels declining in most Michigan lakes where they were introduced, and it appears that may be the case for Lake Sherwood. However, vigilance needs to be maintained, to ensure that this mussel remains in low abundance. Monitor this species to make sure it does not proliferate.

4. Invasive species

Recommendation 1: Lake Sherwood has only four known invasive species: Eurasian milfoil, possibly curly-leaf pondweed, starry stonewort (which is an alga), common carp, and zebra mussels. They need to be closely monitored and the exotic plants controlled so they do not dominate the native macrophytes in Lake Sherwood, which are invaluable for many reasons. There was also a common carp die-off in the lake which was attributed to a virus. Viral Hemorrhagic Septicemia was recently blamed for a fish kill in Lake Macatawa, so this virus is still active in Michigan. Non-indigenous species enter lakes with a boat, watercraft, contaminated gear, or dumping of minnow buckets from another lake contaminated with these species, which is how they got into the lake in the first place. Therefore, riparian contribution to this problem is a valid concern. We cannot warn residents enough about the threat of additional species entering the lake, including quagga mussels (relative of zebras but much more impactful), Viral Hemorrhagic Septicemia (have we not heard enough about viruses?), the red swamp crayfish, and recently a virus that has killed largemouth bass in southern Michigan lakes. A common carp virus already killed many of these fish in your lake, but spared sport fishes. VHS will not. Live bait from outside the lake, should be discouraged or banned as well. Quagga mussels have recently been found in the first inland lake in Michigan recently. Any stocking of fish by individuals should be banned for this very reason. Warnings should be communicated to lake association members to ensure contaminated watercraft or gear (clean, dry, or add bleach to ballast water) do not bring in parasites, viruses, and diseases or non – indigenous species, that could have a devastating effect on the ecology and fish community of Lake Sherwood.

SUMMARY OF RECOMMENDATIONS

Problem areas are summarized, and recommendations are given more concisely below:

No Dissolved Oxygen (Anoxia)/Dramatic Increases in SRP, TP, and Ammonia on the Bottom

Internal loading: Treat deep basin with alum or Phoslock

Dredging sediments from impacted areas

Decrease in Water Clarity, Algal Blooms, Excessive Macrophyte Growth

Drawdown

Riparians: no lawn fertilization, green belts, no leaf burning, dispose of leaves out of watershed (see Appendix 1)

Ban Wave boats and regulate large motorized watercraft away from shallow areas to reduce sediment re-suspension and nutrient re-distribution

Monitor inlet streams (Wildwood River, Cranberry inlet, etc.) and other storm drains; identify areas where green belts/rock dams could be deployed to restrict incoming water; work with entities in these areas to reduce nutrients and install devices to slow water flow.

Support laws reducing power plant emissions to curtail aerial deposition of nutrients and mercury

Discourage ducks, swans, and geese from staying in the lake/watershed- no feeding

Algae and Macrophytes

Continue to spot-treat the exotic Eurasian milfoil and starry stonewort. Preserve native plants. Rake beaches of algae where needed.

A concerted effort needs to be made to ensure that macrophytes are not over treated in 2024 by doing a careful on-site survey of macrophyte beds to document that they are growing well before any treatment begins. That treatment then must be directed carefully at invasive plants.

Residents must be aware of the threat of blue-green algae in Sherwood which composed 60% of the biomass of the algae; these species included some that are known bloom and toxin producers. Lake users need to be careful not to let pets drink the water or swim in it when the lake is turbid or a "green paint scum" (algae) is noted in the water.

Invasive Species

Educate lake association members to rid incoming watercraft/gear from outside lakes of clinging vegetation/treat ballast water with chlorine or dry out items; the reverse is also true: people with boats leaving Lake Sherwood should be careful NOT to transport invasives to other lakes they visit.

Ban or discourage use of live bait (minnows, crayfish) from outside lake sources.

No unauthorized fish stocking.

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I want to thank Dan Devine for his help in coordinating the study, for providing a vessel and guidance on the lake, and providing me with answers for a constant request for information. This report is more accurate and informative because of his inputs. Jason Jude provided help with some of the figures and some lost text restoration. Lake Sherwood residents should be appreciative of the efforts of some of its residents who care about the ecological integrity of the lake. We ask that they share in the care of the lake by taking heed of the measures we suggest that will help maintain or reverse some of the degrading influences on the water quality of the lake.

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APPENDIX 1

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

1. DROP THE USE OF "HIGH PHOSPHATE' DETERGENTS. Use low or no 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 if you must. 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. Dispose of leaves outside the watershed.

4. STOP USING PERSISTENT HERBICIDES AND 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. We are experiencing silent spring all over again in recent losses of frogs, birds, and insects, critical components of our ecosystem. Don't contribute to this continuing loss.

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 AND YOUR LAWN IN ITS NATURAL STATE; PLANT GREEN BELTS. Do not fertilize lawns down to the water's edge – it is now the law. The natural vegetation will help to prevent erosion, remove some nutrients from runoff, and be less expensive to maintain. Greenbelts and water gardens should be put in to retard runoff directly to the lake. Consult the Michigan Shoreline Partnership for guidance and examples of native plants for green belts.

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 OR OTHER WATERFOWL. Goose droppings are rich in nutrients and bacteria.

13. IF YOU HAVE A LARGE BOAT; STAY AWAY FROM THE SHORELINE.

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