FRONTESPIECE: Spotted gar ***LEPISOSTEUS OCULATUS***

THE LIMNOLOGY AND FISH COMMUNITY OF LAKE TEMPLENE, ST. JOSEPH COUNTY, MICHIGAN, 2022

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INTRODUCTION

We were contacted by the Templene Lake Improvement Board and asked to conduct a limnological and fishery study of the lake, which we did on 14-16 July 2022. We collected an algae and two zooplankton samples which were sent to the laboratory for analysis. We collected limnological data from three in lake-sites (two deep basins and one shallow in the lake), at the entrance of Prairie Creek into the lake, and a well sample was analyzed to determine if ground water was contaminated with septic tank effluent or agricultural practices. Secchi disk measurements of water clarity were taken at the two deep basins and at one other site. We measured water clarity, nutrients, pH, conductivity and chlorides. We also collected fishes to assess the fish community status, growth, diet, and spawning successes and algae and zooplankton to assess the food web.

We drew on Gunderman (2014) for much of the following information which characterizes the environment and conditions that are pertinent to understanding the data we collected and how it is integrated with the other information about Lake Templene. Lake Templene is an 870-acre reservoir formed in 1970 from damming Prairie Creek which is near Centreville, Mi. It inundated three existing lakes and the surrounding wetlands. It has two deep basins around 35 ft. Water residence time is short (26 days). Sand and Fish Lake both feed into Templene Lake when water levels rise, so we assume this water is probably epilimnion (surface) water which would be low in nutrients during summer. This is not so for Prairie Creek which drains a 180-square mile watershed which is 67% agriculture, followed by wetlands (13%), and forests (11%). Most land immediately adjacent to Lake Templene has been modified for residential or vacation home development. A MDNR 2013 habitat survey revealed a dwelling density of 18.1 dwellings/mile, which is near the 25% percentile for lakes in southwest Michigan. Approximately 42% of the shoreline is armored with seawalls or riprap, which made finding sites to seine difficult. There is a boat launch on the west side of Nottawa Road. Surficial materials in the watershed are primarily glacial outwash sand and gravel overlaid by loamy sands. These materials are porous and allow rapid infiltration of precipitation. All residents are on septic systems, have extensive lawns with little or no green belts, and probably fertilize those lawns. Since the soils are sandy we expect that runoff from lawns and septic tank nutrients are contaminating Templene Lake through seepage into the groundwater then into the lake. In Lake Templene, the ratio of total nitrogen to total phosphorus was 67:1. Thus, phosphorus is the limiting nutrient in this system. In the past, the total phosphorus concentration was 0.016-0.025 mg/L (oligotrophic to mesotrophic). The chlorophyll a concentration, which provides an index of algal biomass, was 3.1 ug/L (mesotrophic). The Secchi disk depth (a measure of water transparency) was 11 ft making it mesotrophic (between 7.5 and 15 ft). Alkalinity was 186 mg/L making Templene Lake a hardwater lake. Based on these water quality parameters, Lake Templene is considered a mesotrophic or moderately productive lake.

HISTORY

As we noted above, Lake Templene is an 870-acre reservoir formed in 1970 from damming Prairie Creek, a tributary of the St. Joseph River, which is near Centreville, Mi. It inundated three existing lakes and the surrounding wetlands. Because it is a reservoir with its main influent stream Prairie Creek, a creek that drains a 180-square mile watershed which is 67% agriculture, we expect a considerable input of nutrients to enter the lake from this source, especially during spring rain events. Second, the riparian areas adjacent to Lake Templene have been severely modified for residential or vacation home development and shorelines hard armored with sheet piling and other deleterious structures, degrading fish habitat. Third, the homes are on septic tanks, which are known polluters of lakes, especially when the soils are sandy. Fourth, we observed extensive, weed-free, green lawns down to the shoreline with no green belts to retard runoff from fertilization practices by land owners. From what we have measured so far, the lake has degraded based on prior comparisons (to be discussed later) so it is time to pay attention to common sense recommendations to curtail nutrient entry to the lake before it shifts from one of macrophytes to one dominated by algae, which we have been seeing with increased regularity in Michigan lakes.

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 obtained for Manistee Lake from Progressive AE. This map will assist us in identifying stations and in assessing 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.

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).

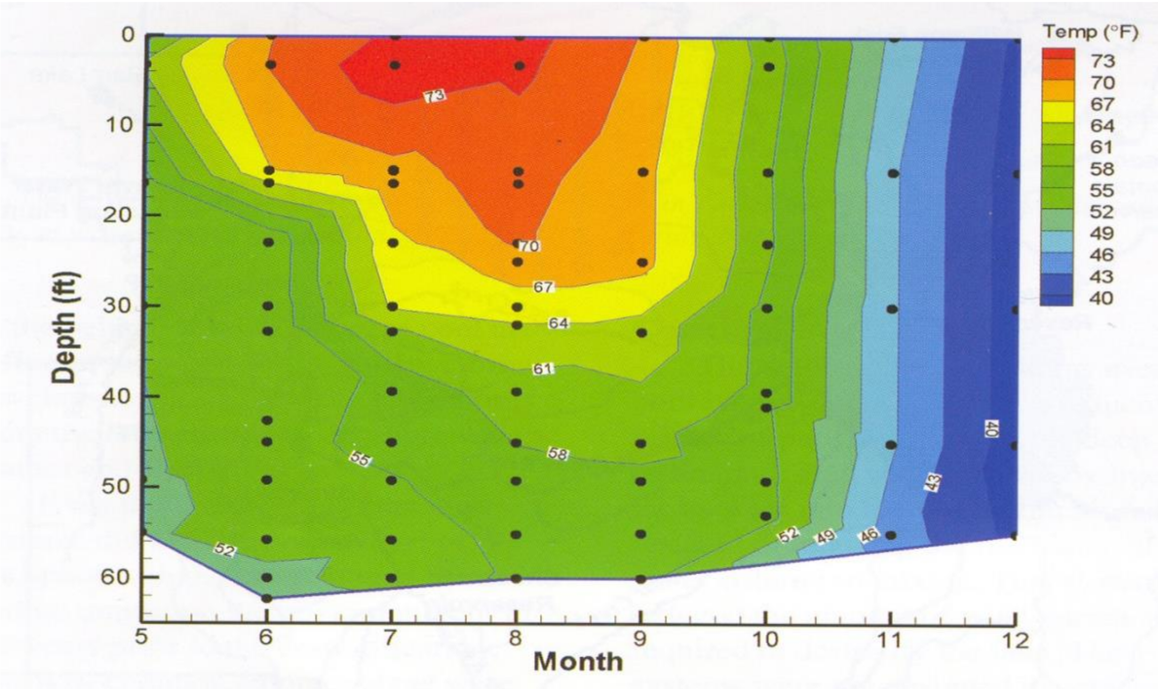

Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red, yellow, and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during 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 yearly cycle. This represents a typical cycle, and many variations can exist, depending on the lake shape, size, depth, and location. Summer stratification is usually the most critical period in the cycle, since the hypolimnion may go anoxic (without oxygen--discussed next). We always try to schedule our sampling during this period of the year. Another critical time exists during late winter as oxygen can be depleted from the entire water column in certain lakes under conditions of prolonged snow cover.

Dissolved Oxygen

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

A series of dissolved oxygen determinations can tell us a great deal about a lake, especially in summer. In many lakes in this area of Michigan, a summer stratification or stagnation period occurs (See previous thermal stratification discussion). This layering causes isolation of three water masses because of temperature-density relationships already discussed (see Fig. 2 for demonstration of this process).

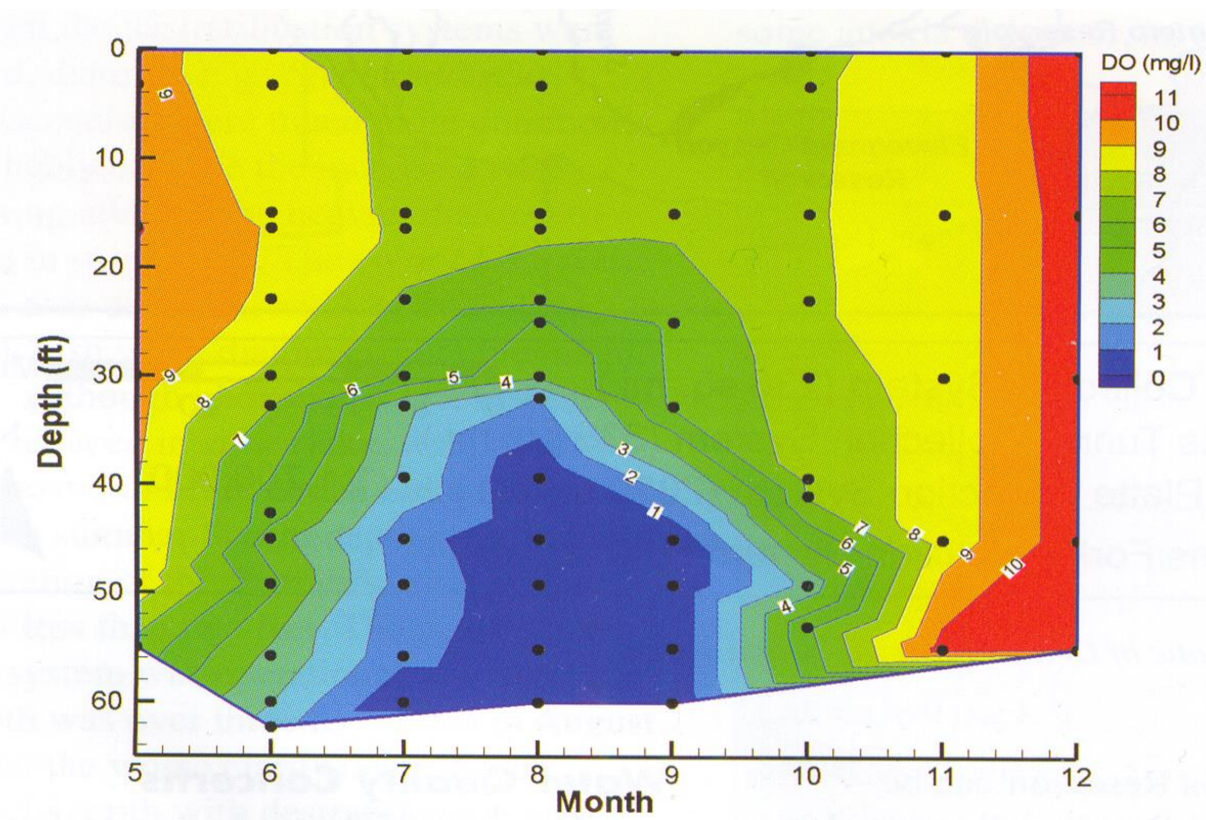

Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when the dissolved oxygen is the same from top to bottom. Adapted from NALMS.

In the spring turnover period, dissolved oxygen concentrations are at saturation values from top to bottom (see red area, which is the same in the spring – Fig. 2). However, in these lakes by July or August some or all of the dissolved oxygen in the bottom layer is lost (used up by bacteria) to the decomposition process occurring in the bottom sediments (blue area in Fig. 2). The richer the lake, the more sediment produced, and the more oxygen consumed. Since there is no way for oxygen to get down to these layers (there is not enough light for algae to photosynthesize), the hypolimnion becomes devoid of oxygen in rich lakes. In non-fertile (Oligotrophic) lakes, there is very little decomposition, and therefore little or no dissolved oxygen depletion. Lack of oxygen in the lower waters (hypolimnion) prevents fish from living there and changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic).

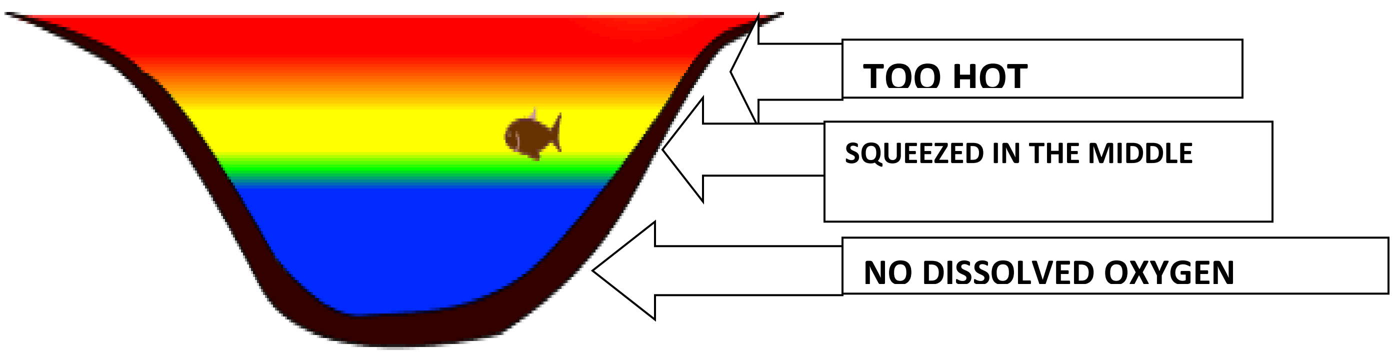

Figure 3. Depiction of the dissolved oxygen concentrations in a stratified lake during summer, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, 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 and motor boat activity during open water periods. Some lakes or reservoirs have large flow-through so stratification never is established.

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

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

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 29-hour cycle. During the day in summer, plants photosynthesize and produce oxygen, while at night they join the animals in respiring (creating CO2) and using up oxygen. This creates a diel cycle of high dissolved oxygen levels during the day and low levels at night. These dissolved oxygen sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

pH

The pH of most lakes in this area ranges from about 6 to 9. The pH value (measure of the acid or alkaline nature of water) is governed by the concentration of H (hydrogen) ions, which are affected by the carbonate-bicarbonate buffer system and the dissociation of carbonic acid (H2CO3) into H + ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO2 from the carbonate-bicarbonate system. The pH will rise as a result. During evening hours, the pH will drop due to respiratory demands (production of carbon dioxide, which is acidic). This cycle is similar to the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO2 during the day in photosynthesis there is a drop in CO2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO2), thus causing a rise in CO2 concentration and a concomitant decrease in pH toward a more acidic condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution, which would cause deviations from expected values. 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, providing a history of past inputs of this substance. Chlorides (Cl-) are transported into lakes from septic tank effluents and urban run-off from road salting and other sources. Chlorides are detected by titration using mercuric nitrate and an indicator. Results are expressed as mg/L as chloride. The effluent from septic tanks is high in chlorides. Dwellings around a lake having septic tanks contribute to the chloride content of the lake. Depending upon flow-through, chlorides may accumulate in concentrations considerably higher than in natural ground water. Likewise, urban run-off can transport chlorides from road salting operations and bring in nutrients. The chloride "tag" is a simple way to detect possible nutrient additions and septic tank contamination. Ground water in this area averages 10-20 mg/L chlorides. Values above this are indicative of possible pollution.

Phosphorus

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

Nitrogen

There are various forms of the plant nutrient nitrogen, which are measured in the laboratory using complicated methods. The most reduced form of nitrogen, ammonia (NH_3), is usually formed in the sediments in the absence of dissolved oxygen and from the breakdown of proteins (organic matter). Thus, high concentrations are sometimes found on or near the bottom under stratified, anoxic conditions. Ammonia is reported as mg/L as N and is toxic in high concentrations to fish and other sensitive invertebrates, particularly under high pHs. With turnover in the spring most ammonia is converted to nitrates (NO_3=) when exposed to the oxidizing effects of oxygen. Nitrite (NO_2-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured. Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. Nitrates, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about succession of algae species, which usually proceeds from diatoms, to green algae, to blue-green algae. Blue-green algae (some are 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 are able to fix their own and become dominant in late summer.

The types of algae found in a lake serve as good indicators of the water quality of the lake. The algae are usually microscopic, free-floating single and multicellular organisms, which are responsible many times for the green or brownish color of water in which they are blooming. The filamentous forms, such as *Spirogyra* and *Cladophora* are usually associated with aquatic macrophytes, but often occur in huge mats by themselves. The last type, *Chara*, a green alga, looks like an aquatic macrophyte (we collected *Chara* in our benthos samples from 2 ft) and grows on the bottom in the littoral zone, sometimes in massive beds. Starry stonewort *Nitellopsis obtusa* (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 lakes. 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 management plans.

Samples during 2022 were collected at station A using a 2-m long, 25-mm diameter, PVC pipe that integrates the water from the surface to 2 m on 14 July. Algae samples were preserved with gluteraldehyde, kept from light and in the refrigerator until delivered to Dr. Edlund for analyses. Measured subsamples of preserved algae (120 mL) were allowed to settle for a minimum of 1 week, and the algae concentrated to a volume of 15-20 mL for microscopical analysis. Well-mixed subsamples of 0.1 mL were distributed in a Palmer counting chamber and analyzed with an Olympus BX50 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 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 was accomplished using 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 by algal group (e.g., cyanobacteria, diatoms, green algae), and a table (see Table 4 in Algae section below) 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 from both 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 ethanol and then examined microscopically in the laboratory. One sample was collected from near bottom to the surface at station A (30-ft (9 m)deep station) and a shallow station B (10 ft). Samples were preserved with alcohol. Qualitative estimates of abundance are usually given.

Benthos

The group of organisms in the bottom sediments or associated with the bottom is termed benthos. These organisms are invertebrates (lacking a backbone) and are composed of such animals as aquatic insect larvae and adults, amphipods (fairy shrimp), oligochaetes (aquatic worms), snails, and clams. The importance of this group for fish food and as intermediates in the food chain should be emphasized. Because of the tremendous variety of animals in each group and their respective tolerances for different environmental conditions, this group is a very important indicator of environmental quality. One of those organisms is called *Hexagenia*, the large mayfly that hatches in late July and precipitates much trout fishing in our local trout streams. This organism has a 2-yr life cycle; the larval form (naiad) lives in thick organic muds making a U-shaped burrow, so it can take in algae and detritus on which it feeds. It always requires high dissolved oxygen and good water quality to survive, so when present it indicates excellent water quality is present. We examine samples from deep-water stations for the presence of organisms, as certain types live in low to no dissolved oxygen conditions, whereas other kinds can only exist when their high dissolved oxygen needs are satisfied.

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

Fish

The top carnivores in most aquatic ecosystems, excluding man, are the fish. They are integrators of a vast number and variety of ever-changing conditions in a body of water. They, unlike the zooplankton and benthos, which can reflect short-term changes, are indicative of the long-range, cumulative influences of the lake or stream on their behavior and growth. The kind of fish, salmon or sunfish, can tell us much about how oligotrophic (low productivity) or eutrophic (high productivity) a lake is. We collect fish with seines, gill nets, trap nets, and from lucky anglers on the lake. The seine used in this study was a 50-ft long seine with a 10-ft wide bag in the middle. Most hauls were about 50-70 ft, except for station 3 (wetlands) where the hauls was about 40 ft. We used an experimental, 125-ft gillnet with various mesh sizes set over night to catch predators. Most fish are weighed, measured, sexed, and their stomach contents removed and identified. Fish are aged using scales, and breeding condition is observed and recorded. The catches from our nets and age information on the fish will tell us how your length-at-age data compare with state averages and whether fish growth is good. Another problem, "stunting", can be detected using these sources of information.

Stomach contents of fish document whether good sources of food are present and help confirm age and growth conclusions. Imbalances in predator-prey relationships are a closely related problem, which we can usually ascertain by examining the data and through discussions with local anglers. From studying the water chemistry data and supportive biological data, we can make recommendations, such as habitat improvement, stocking of more predators, and chemical renovation. We can also predict for example, the effects of destroying macrophytes through chemical control. All elements of the ecosystem are intimately interrelated and must be examined to predict or solve problems in a lake or help us explain perplexing problems discovered in the lake ecosystem.

RESULTS

WATERSHED

Prairie Creek, which was dammed to form Lake Templene (Fig. 4, 5) drains a 180-square mile watershed, which is predominately agricultural (65% - Gunderman 2013).

STATION LOCATION

We established a set of stations throughout the lake for water chemistry (stations A, C, and D), Prairie Creek inlet (station E), a well sample, zooplankton (stations A and B) and algae samples (station A), and fish sampling stations (G = gill net, T = trap net, and S = 50-ft seine) (Fig. 4-5, Tables 1-2). The first number after G is the site and the second number is the first (1), second (2), or third (3) time the net is reset at the same location.

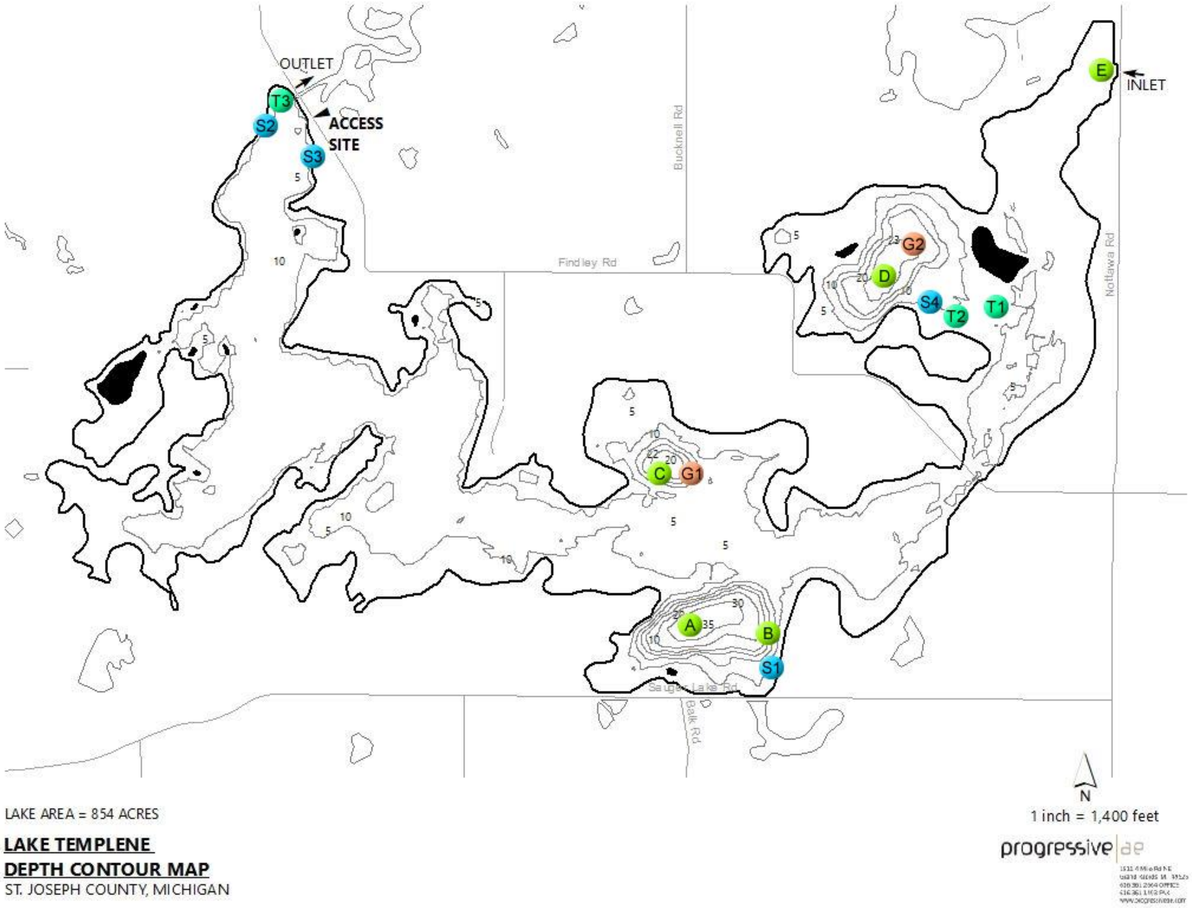

Figure 4. Map of Lake Templene showing water quality sampling stations (A, C, D, E - green), zooplankton sampling stations (A, B), seining stations (S1-S4 -blue), gill net stations (G1-G2 – orange), and trap net stations (T1-T3). Adapted from Progressive AE.

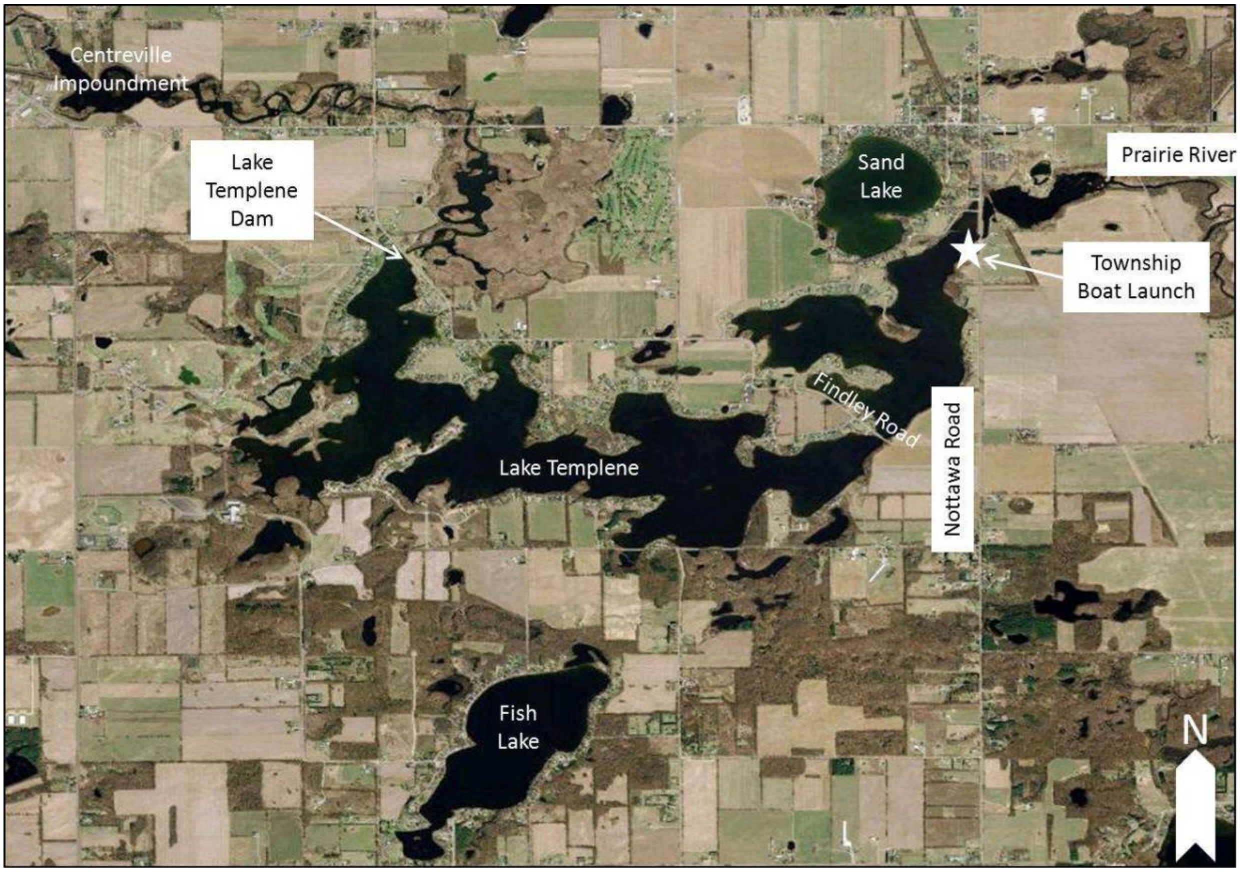

Figure 5. Aerial view of Lake Templene and the surrounding area. Image from www.bing.com/maps.

Table 1. Listing of stations (STA), gear and sample type, starting time of net deployment, ending time of gear deployment, and approximate number of fish present. See Table 5, 6 for definition of fish codes. YOY=young-of-the-year).

STA	GEAR	TIME START	TIME END	FISH PRESENT
A	WQ, ZOOP/ALGAE TOW	1233 14 JUL		NA
B	SHALLOW ZOOP TOW	1445 14 JUL		NA
C	SURFACE WQ SAMPLE	1421 14 JUL		NA
D	DO,TEMP SAMPLE	1400 15 JUL		NA
E	WQ-PRARIE CREEK INLET	1548 15 JUL	1610 15 JUL	NA
G1-1	GILL NET	1314 14 JUL	1702 14 JUL	8BG, 2BC, 2YP
G1-2	GILL NET	1710 14 JUL	1103 15 JUL	1BC
G1-3	GILL NET	1108 15 JUL	1032 16 JUL	2YB,BC,2BG
G2-1	GILL NET	1420 14 JUL	1725 14 JUL	9YP,SPGAR,1CP,2LB,25BG
G2-2	GILL NET	1745 14 JUL	1037 15 JUL	5BG,1YB,2YP
T1	TRAPNET	1553 14 JUL	1145 16 JUL	2BC,29BG,1YB

T2	TRAPNET	1600 14 JUL	1140 16 JUL	6BG,1BN
T3	TRAPNET	1622 14 JUL	1052 16 JUL	1BC,3LB YOY
S1	SEINE	1138 15 JUL	1150 15 JUL	PS,LP,GL,JD,BM,LB,YP,BG,BC
S2	SEINE	1215 15 JUL	1250 15 JUL	SH,SV,JD,BM,PS,LP,LB,BG,YP
S3	SEINE	1253 15 JUL	1310 15 JUL	BM,JD,LP,PS,SV,YP,BG,LB
S4	SEINE	1330 15 JUL	1350 15 JUL	LP,LB,BM,YP,BG
WELL	TAP WATER	15-Jul		NA

Table 2. Station locations (see Table 1 and Fig. 4) and their corresponding GPS parameters.

STATION	GEAR	GPS 1	GPS 2
A	WQ, ZOOP/ALGAE TOW	N41 53.579	W-85 27.974
B	SHALLOW ZOOP TOW	N41.911488	W-85.448588
C	SURFACE WQ SAMPLE	N41 54.359	W-85 27.548
D	DO,TEMP SAMPLE	N41.904636	W-85.458993
E	WQ-PRARIE CREEK INLET	N41.911488	W-85.44858
G1-1	GILL NET	N41 53.891	W-85 28.141
G1-2	GILL NET	N41 53.891	W-85 28.141
G1-3	GILL NET	N41 53.891	W-85 28.141
G2-1	GILL NET	N41 54.359	W-85 27.548
G2-2	GILL NET	N41 54.359	W-85 27.548
T1	TRAPNET	N41.904409	W-85.457310
T2	TRAPNET	N41 54.14	W-85 27.27
T3	TRAPNET	N41.91048	W-85.48622
S1	SEINE	N41.892041	W-85.463651
S2	SEINE	N41.910528	W-85.486945
S3	SEINE	N41.908997	W-85.485330
S4	SEINE	N41 54.16	W-85 27.44
WELL	TAP WATER	RIPARIAN	

PHYSICAL PARAMETERS

Depth

Templene Lake has three major basins, one of 35 ft in mid lake on the eastern shore (station A), one just opposite of that one on the western side (22 ft) (station C), and one in the northern half on the western side (23 ft – station D) (Fig. 4). The remainder of the lake is shallow and productive with considerable amounts of woody debris from damming up three lakes and subsequent covering with water all the wetlands and forests present. From our seining experiences, it seemed to be considerably more mucky in the northern parts than near the dam in the south which was mostly sand.

Acreage

The lake is 870 acres (Gunderman 2013).

Temperature/Dissolved Oxygen

The dissolved oxygen – temperature relationships in a lake are key parameters to understand whether cool water species, such as northern pike and walleyes, will survive and grow well. Our data from 15 July 2022 at stations A (south half) and D (north half) (Figs. 6, 7) and that of Gunderman (2014) all show that the lake stratified during summer, and that dissolved oxygen levels were too low for survival of most warm water fish species (they need a minimum of 3 mg/L) from around 20 ft (5-6 m) to the bottom; this is also where the cool temperatures required by cool water species is optimal, which will prevent them from residing there, causing stress and low or no growth. We expect that anoxia (no dissolved oxygen on the bottom) probably develops later in summer and this will switch the internal phosphorus pump on which generates ammonia and phosphorus from the decomposition of the sediments under anoxic conditions (internal loading- discussed below). These nutrients are then mixed into the water column during the fall overturn.

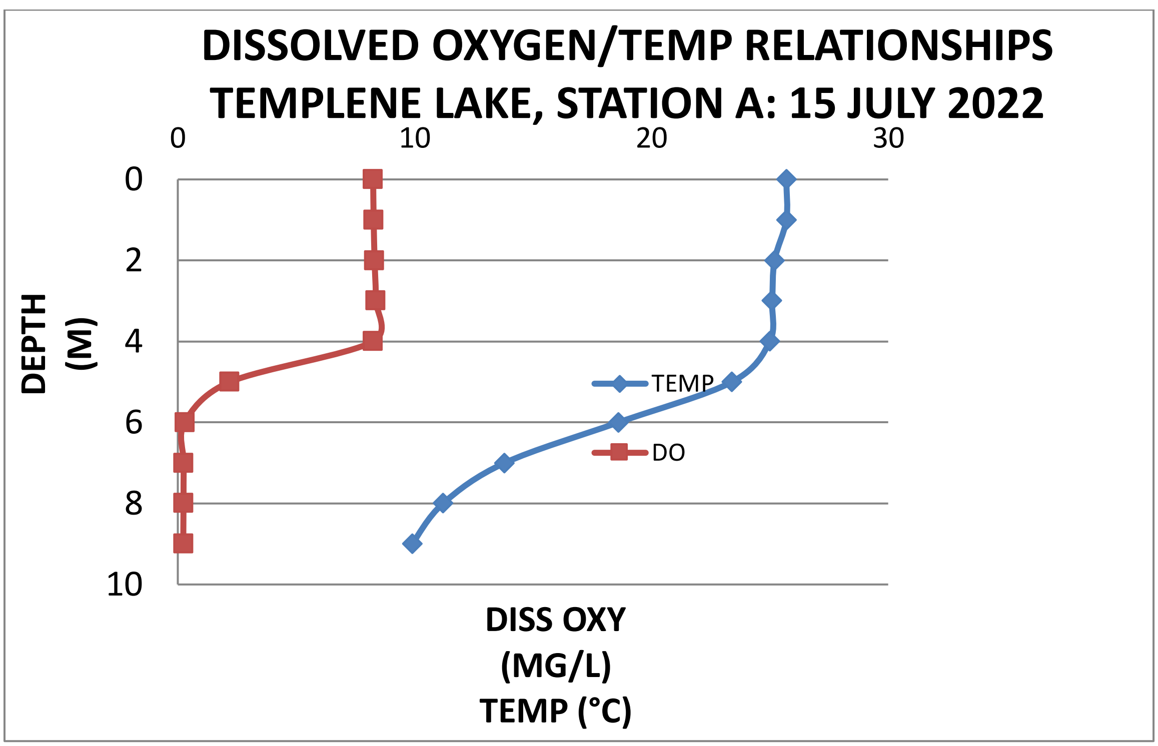

Figure 6. Dissolved oxygen-temperature profile for Lake Templene, 15 July 2022 at station A (see Fig. 4).

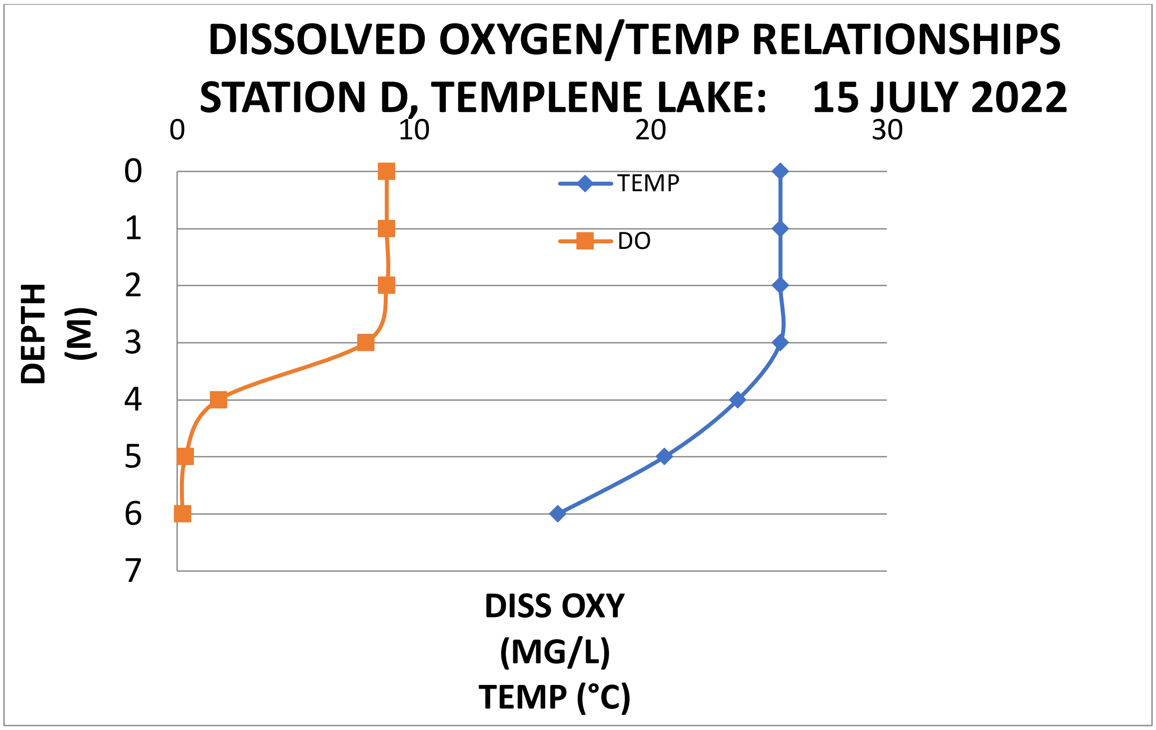

Figure 7. Dissolved oxygen-temperature profile for Lake Templene, 15 July 2022 at station D (see Fig. 4).

Light penetration

Our Secchi disk readings were around 2 m (1.8-2 m) or 6.6 ft, a considerably lower reading than most reported by Gunderman (2013), which varied from median values of 7.3 ft in 1983-1984 to 5.5 ft in 1999 and 11.5 ft in 2009-2011. Except for the 1999 measurements, our readings were the lowest recorded in the past years since 1983. The lake was somewhat turbid, and this was also reflected in our turbidity measurements (1.3 NTU- nephelometric turbidity units), but chlorophyll a concentrations, which are a surrogate for algae, were high and ranged from 13.9 to 16.3 ug/L (Table 3). Values > 6 ug/L Chlor a are indicative of a eutrophic lake. Gunderman (2013) reported median chlorophyll a concentrations were 2.5 ug/L in 1999 and 1.3 mg/L in 2009-2011, which suggests that conditions have gotten worse in the intervening years since 2011. We also measured phycocyanin which is a surrogate for blue-green algae (measures protein pigments in blue-green algae); values ranged from 3.2 to 3.9 ug/L. These are low values, but indicate there are some blue-green algae in the lake.

Table 3. Water quality characteristics at stations A and C, at the Prairie Creek inlet, and at a riparian well along the eastern side of mid-lake, Templene Lake (see Fig. 4), 14-15 July 2022. Shown is depth (m), pH, conductivity (uS), along with chlorides, nitrates, ammonia, SRP (soluble reactive phosphorus), and TP (total phosphorus) which are all in mg/L. PHY = phycocyanin and CLOR A = chlorophyll a (in ug/L), while TURB = turbidity in NTU.

DEPTH	PH	COND	CL	NO3	NH3	SRP	TP	PHY	CLOR A	TURB
				STATION A						
0	8.29	701	17	0.94	0.05	<0.005	0.014	3.9	16.3	1.3
4.5	8.3	731	14	0.80	0.08	<0.005				
8.5	7.61	797	20	0.29	1.41	<0.005	0.026			
				STATION C						
0	8.61	667	17	0.76	0.07	<0.005	0.024	3.2	13.9	1.3
				PRAIRIE CREEK						
0	8.07	832	17	1.41	<0.01	<0.005				
				WELL						
0	7.7	597	6	<0.01	0.03	<0.005				

CHEMICAL PARAMETERS

pH

The pH values were as expected, high in surface waters at station A (8.3) and much lower (7.61) in bottom waters, where more decomposition and carbon dioxide production is ongoing (Table 3). The pH was even higher in surface waters at station C (8.61). Incoming Prairie Creek water had a pH value of 8.07. The well sample was within normal limits at 7.7, which is characteristic of ground water.

Conductivity

Conductivity (measure of the capacity of water to conduct electricity) at station A surface was 701, then declined to 731 at mid depth, and hit its peak on the bottom (where material decomposing accumulates) at 797 uS at the deep basin stations with the highest values from bottom samples where decomposition creates negative ions that conduct electricity (Table 3). The surface conductivity at station C was 667 uS, somewhat lower than other values at station A. The Prairie Creek sample was even higher at 832 uS. These are moderately high values. The well sample was 597 uS, which was below conductivity levels in the lake proper.

Chlorides

Chlorides are indicators of road salting contamination of water samples and septic tank effluent contains high quantities of sodium chloride. Chlorides in all our samples were surprisingly low (6-20 mg/L – Table 3), which is an excellent finding, suggesting little contamination of the lake or the ground water to date. Perhaps the large volume of water that runs through the reservoirs and its high turnover time (26 days, less than a month – Gunderman, 2013) dilutes the chlorides that enter the lake during periods of runoff and seepage from septic tanks. At station A, chlorides were slightly stratified, with14-17 mg/L in surface waters and 20 mg/L on the bottom. Surface chlorides were similar at station C and the inlet at Prairie Creek. The lowest concentrations were found in the well sample (6 mg/L) a clear indication that at least at this site, there did not appear to be any blatant indicators of contamination of the ground water. This value is very low and indicates pristine conditions in the immediate watershed.

Phosphorus

We are concerned about nutrients, especially phosphorus, since it is usually a key nutrient in a lake ecosystem and can be the limiting nutrient, curtailing growth of aquatic plants. The reason for this concern is our experience in managing lakes that recently have demonstrated how important the concept of eutrophication, especially cultural eutrophication (man-induced nutrient enrichment) can be in the natural and accelerated aging of our precious lakes. We have worked on several lakes recently that were reservoirs with huge watersheds dominated by agriculture, had aggressive macrophyte control programs that destroyed large quantities of plants to accede to the demands of riparians with large boats, including wave boats, had extensive development in the riparian zone with little attention to not using fertilizer on lawns and had few green belts to retard runoff, were on septic systems they refused to upgrade to sewers, and then were dismayed when the lake either slowly in some cases but rapidly in others (since 2017) have switched from a macrophyte-dominated to one dominated by blue-green algae, some of which can be toxic. Once that happened it becomes very difficult to reverse this scenario and return the system back to one dominated by macrophytes. We will have more to say about this scenario in our Conclusions and Recommendations.

There are two phosphorus compounds we measure: SRP (the reactive form of P available for growth in plants) and TP (all the P in various forms including SRP in a given volume of water). SRP is usually at trace concentrations (as it was in Lake Templene and the well sample – Table 3). There was no excess production of SRP on the bottom of station A where decomposition might have produced some, which is a great finding. It may change later in summer if the bottom waters go anoxic. TP was measured at three sites: stations A and C. The TP at the surface of station A was 0.014 mg/L, which is a very good reading in the mesotrophic range. The criteria for trophic status are: <0.010 mg/L – oligotrophic (think Lake Superior), mesotrophic 0.010-0.020 mg/L, and eutrophic <0.020 mg/L. At the bottom of station A, TP was higher at 0.026 mg/L and the surface at station C was also elevated at 0.024 mg/L. These are eutrophic values, but barely over the level of 0.020 mg/L, so are certainly acceptable, but care must be taken to ensure these values do not increase later in summer or in the future.

Nitrates

Nitrogen is the second nutrient of concern. It takes the form of ammonia (see below) in anoxic (no dissolved oxygen) bottom waters and nitrate in oxygenated waters and when ammonia is mixed into the water column in the fall and spring overturn period (see explanation above in Methods) it is converted mostly to nitrate. There were nitrates throughout the water column at station A and in unusually high concentrations for typical Michigan inland lakes with 0.94-0.80 in surface waters and 0.29 mg/L in bottom waters (Table 3). They were also high at station C (surface) where 0.76 mg/L was measured. In addition, the inlet creek E had very high concentrations – 1.41 mg/L. This is unusual to have such high levels of nitrates throughout the lake and it certainly appears that the inlet creek may be a substantial source of nitrates that emanates throughout the entire lake. The fact that there is so much apparently un-utilized nitrates in the water column, suggests that P is limiting the uptake of nitrogen and is a limiting factor in the further growth of algae and macrophytes in Lake Templene. Gunderman (2013) also demonstrated that P was limiting in the lake. This is a dangerous situation, since any input of P into the lake will result in a huge growth surge among the plants. Lastly, nitrates were negligible in the well sample, a good sign that nitrates are not contaminating the ground water resources, at least in that area of the lake.

Ammonia

As indicated above, we key in on the concentrations of ammonia, since they are one of the products of anoxic conditions on the bottom of deep basins. At station A, ammonia was as expected at trace concentrations in surface waters (0.05-0.08 mg/L – Table 3), but it was elevated on the bottom at 1.41 mg/L, a very high concentration that will kill organisms, especially fish, and eventually result in the dissipation of this substance into the entire lake at fall turnover, when it would be converted to nitrates. The fact that there are high levels of nitrates in surface waters at station A (0.94 mg/L) and high concentrations of ammonia on the bottom (1.41 mg/L station A) is unusual and suggests that the low dissolved oxygen there did provide some ability of the decompositional processes to produce both species of nitrogen. This is one of the few characteristics that portend dire consequences for water quality now and in the future for Lake Templene.

BIOLOGICAL PARAMETERS

Algae

While sampling the lake we noted the presence of algae and macrophytes. First, we measured phycocyanin, which is a surrogate for blue-green algae and there was an indication that some is present in the lake. We also found starry stonewort (Picture 2), an invasive algal species similar to *Chara* in our gill net at the north end of the lake and we also found the alga bladderwort *Utricularia*. It is native and actually captures insects it uses for a nitrogen and phosphorus source. Starry stonewort is a dangerous invasive species, known for growing into huge tumbleweed-like, dense algal mats that can smother important spawning substrate and cover over native macrophytes. They need to be controlled and we make the case that a drawdown could be the most environmentally safe way to do this, as copper sulfate can accumulate in sediments and kills snails and harvesting is only temporally effective.

Picture 2. Starry stonewort *Nitellopsis obtusa*.

The major groups of algae that we encountered at station A (see Fig. 5) in Lake Templene in July 2022 (Table 4) included:

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 the clues for species identification. Diatoms are generally found in two major ecological groups. The planktonic forms are either round (*Aulacoseira ambigua* in Lake Templene) or long and spindle-shaped (the species *Fragilaria crotonensis* in Lake Templene) and are especially common during spring and fall turnover. 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 the most abundant group in Templene in Jul 2022 making up 65% of the algal biomass (Fig. 8, 9).

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 in Lake Erie caused the shut down of the Toledo water supply in 2015). Cyanobacteria made up about 13% of Templene's algal biomass in Jul 2022. The cyanobacterial community comprised mostly small-celled non-nuisance forms (e.g., *Aphanocapsa, Aphanothece, Chroococcus, Snowella*, Fig. 8), with the latter two taxa each contributing about 5% of the total algal biomass. There were no species of concern, i.e., potential bloom or toxin producers.

Dinophyceae—the dinoflagellates are a group of large-celled algae where most species surround themselves with a 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 that does not happen in the freshwater species. In Lake Templene, the genus *Peridinium* contributed 2.6% of biomass in the Jul 2022 samples.

Chrysophytes—the golden-brown algae or chrysophytes live in small motile colonies or as single cells. Many of the forms have small silica scales that cover their cells (*Synura, Mallomonas*) or live in organic vase-shaped structures (*Dinobryon*). The chrysophytes are typically common in cooler months of the year but can be found in the summer as they are motile in the open water. The few very large cells of *Mallomonas* and colonies of *Dinobryon* that were found in Lake Templene made up 17% of the algal biomass in Jul 2022.

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 Templene, single-celled and small colonial forms that are suspended in the open water such as *Scenedesmus, Ankistrodesmus,* and *Crucigenia* were less than 2% of the July 2022 algal biomass.

Table 4. Predominant (>5% of total algal biovolume, μm^3/mL) algal species or genera in Lake Templene, 14 July 2022. Abbreviations of algal groups: CY = cyanobacteria, BA = diatoms, GR = greens, DI = dinoflagellates, CH = chrysophytes, CR = cryptomonads, EU = euglenoids.

Lake Templene	**Dominant algae**
July 2022	*Fragilaria crotonensis, Aulacoseira ambigua* (BA), *Mallomonas* (CH), *Chroococcus limnetica, Snowella* (CY), minor (<5% biomass) but common species or genera also included small-celled *Aphanocapsa* colonies (CY).

The mid-summer algal flora of Lake Templene (sampled 14 July 2022) was dominated by diatoms and secondarily by chrysophytes, cyanobacteria, dinoflagellates, and chlorophytes (Fig. 9). Algal biomass in July 2022 was about 1.6 million μm^3/mL comprising over 750 diatom cells/mL and over 4,000 cyanobacteria cells/mL. The summer algal community in Lake Templene is not overly abundant nor does it have toxic or nuisance forms. Rather the greatest biomasses are composed of large-celled diatoms (*Fragilaria crotonensis* and *Aulacoseira ambigua*) and the chrysophyte *Mallomonas*. For comparison, really nasty lakes often have 2-5 million μm^3/mL biomass of algae and are predominantly cyanobacteria. Finally, high numbers of the zooplankton *Daphnia* in Lake Templene will reduce algae abundance by their feeding.

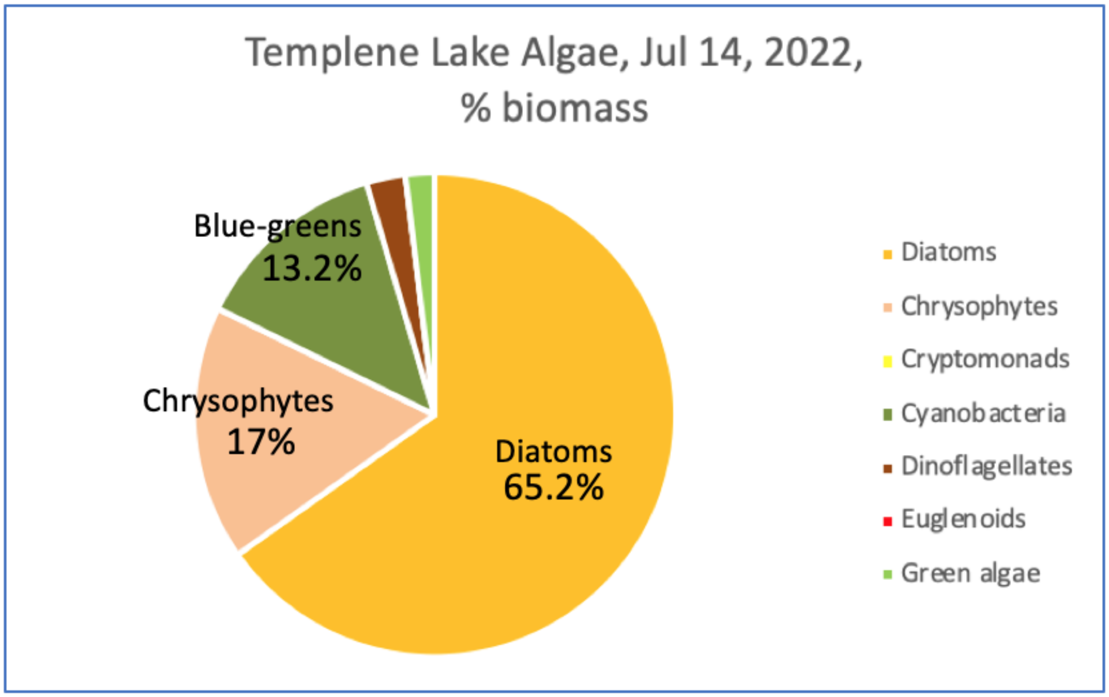

Figure 8. Proportion of algal biovolume or biomass by algal group for Lake Templene, July 14, 2022.

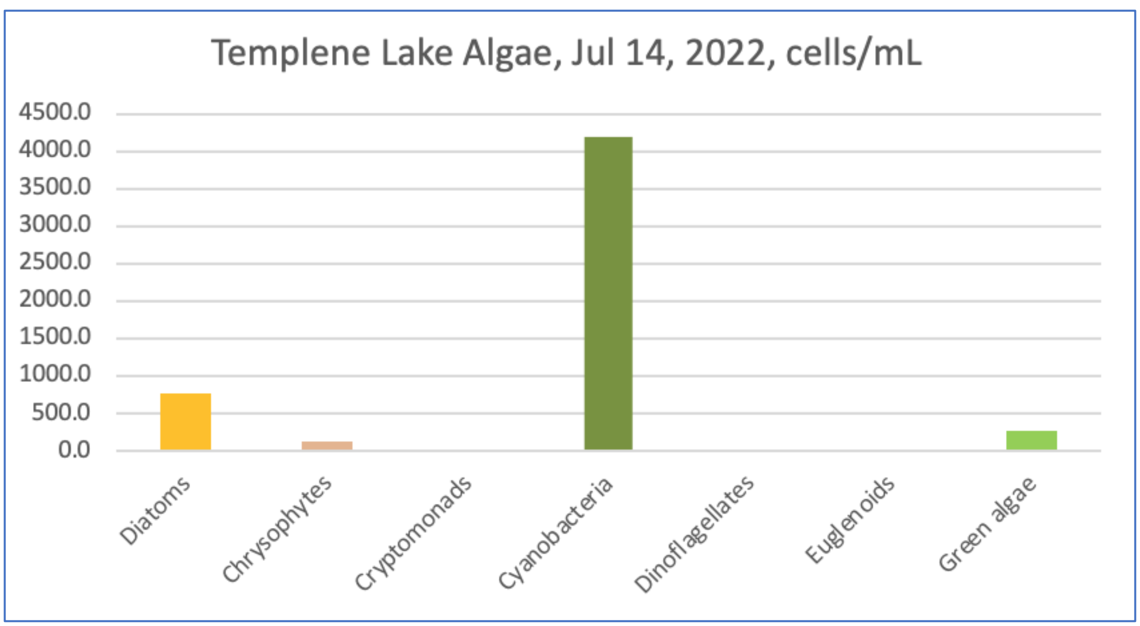

Figure. 9. Abundance of algae (cells/mL) by algal group for Lake Templene, July 14, 2022.

Macrophytes

We found the following macrophytes: Eurasian milfoil and *Potamogeton crispus* curly leaf pondweed (invasive species in low to medium abundance), and the following natives: *Najas* spp. and *Ceratophyllum demersum* coontail. There were lily pads *Nymphaea* and cattails *Typha* at our seining station 2 (Fig. 4). Interestingly, we also found an unusual species that we sent pictures to an expert and found out it is a rare species and can be a detriment to the ecosystem. It turned out to be *Najas marina* (Picture 4) and it was reported to a national database.

Picture 3. Spiny water nymph *Najas marina*, an exotic macrophyte found in Lake Templene. It occurs in mesotrophic water over deep peat or mud.

Zooplankton

We collected a sample of zooplankton from station A (deep water) and station B (shallow water) using a vertical tow of a plankton net (Picture 4). Zooplankton of the class Crustacea is comprised of three major groups: Rotifera (rotifers), Copepoda (copepods), and Cladocera (cladocerans). Rotifers are usually smaller than most other zooplankters and pass through the net mesh. Copepoda (Picture 5) is comprised of three suborders or subgroups: Calanoida (calanoids), Cyclopoida (cyclopoids), and Harpacticoida (harpacticoids). Organisms from the Copepoda group are usually faster and smaller than cladocerans; hence they are preyed on less than the cladocerans by fish, while on the other hand they are not as efficient feeders on algae as are the cladocerans. If cladocerans are eating diatoms and green algae, they provide a more nutritious food source for fish. Cladocerans are characterized by three genera: *Daphnia* (Picture 6), *Eubosmina*, and *Bosmina*. These three groups, especially *Daphnia*, are large prey items for fish and are more efficient at eating algae. *Leptodora*, which we sometimes captured, are the largest and are predators on zooplankton, and because of their large size and slow swimming behavior are usually targeted by fishes and therefore rare. This information has two implications. First, fish will feed on the largest zooplankton prey available and examination of a sample of zooplankton can indicate if there is severe fish predation (e.g., stunted bluegills) or undesirable algae food supplies (blue-green algae), if one finds few or no *Daphnia* collected in a sample during summer. Second, *Daphnia* can be very important in controlling algae and therefore increasing water clarity in a lake. *Daphnia* at around 20/L can filter the algae from an entire lake volume more than once per day if temperatures are moderate. Fish can change the zooplankton size-distribution from large to small sizes (e.g., small cladocerans, a few-fast moving copepods, and a lot of tiny rotifers). Copepods have low algae predation potential and cannot do much to reduce algae. Aquatic plants and low dissolved oxygen in deep basins can provide shelter for *Daphnia* during the day, allowing them to flourish and feed at night; however, high lake turbidity and fertility diminishes their survival.

We sampled zooplankton at two sites on Lake Templene – stations A and B (Fig. 4) and found a surprising result- *Daphnia* composed 85% of the zooplankton community at both station A and B (Table 5). This is the highest percentage composition we ever recorded in the lakes we have sampled. This has several good implications for Lake Templene. First, because

Table 5. Zooplankton collected with a 153-micron mesh net at two stations (A- deep, B-shallow) and a random collection of several samples pooled together from fish stomachs. *Qualitative sample only.

	Station A		Station B		Fish Stomachs	
Group	Numbers	%	Numbers	%	*Numbers	%
Daphnia spp.	327	84.5	244	85.3	27	4.3
Cyclops immature	30	7.8	17	5.9		0.0
Cyclops male	10	2.6	0	0.0		0.0
Cyclops female	13	3.4	5	1.7	1	0.2
Bosmina	2	0.5	4	1.4	325	51.2
Eubosmina	0	0.0	0	0.0	280	44.1
Diaptomus Immature	5	1.3	9	3.1		0.0
Diaptomus male	0	0	2	0.7	2	0.3
Diaptomus female	0	0	3	1.0		0
Leptodora	0	0	2	0.7		0
Totals	387	100	286	100	635	100

Picture 4. An example zooplankton sample.

Picture 5. A copepod (zooplankter).

Picture 6. *Daphnia*, a large zooplankter, adept at eating algae (note green in intestine).

this high density, they will (and have) provide an excellent food resource for fishes that depend on large zooplankton or regularly feed on them when other prey are unavailable, which includes black crappies, bluegills, yellow perch, and pumpkinseeds (discussed in the Fish Diet section below). Second, as we noted, *Daphnia* eat algae and therefore can have a positive effect on the entire Lake Templene ecosystem by removing large quantities and therefore improving water clarity in the lake. They may even be preventing algal blooms by shifting nutrients from algae to zooplankton. The increased water clarity is also important for visual predators such as northern pike, yellow perch, and black crappies which will help to keep the prey fish in balance.

There are two other considerations to note. First, we sampled at a shallow station and a deep station to determine if there was a difference in % composition between the two sites that could be related to fish predation, hypothesizing that with more small planktivorous fishes nearshore that there would be fewer *Daphnia* there. Obviously that was not the case, indicating that predation pressure was similar at shallow and deep sites. Perhaps if we had sampled a very shallow depth (the shallow site was about 10 ft) we might have documented such an effect. Second, we found zooplankton in the diets of many different species (see Fish Diet section below), so they are eating zooplankton, but not the most abundant species collected in our net tows (*Daphnia*) but *Eubosmina* and *Bosmina*, smaller-sized species (and some *Daphnia)*, that were not collected in our net tows. We have no explanation for this finding, with the exception that perhaps these two species were deeper in the water column or distributed closer to shore than our net tows sampled.

We should also note that part of the reason for the success of *Daphnia* in Lake Templene, besides optimal algae (diatoms) present, is the low dissolved oxygen (hypoxia) in the deep parts of the deep basins in the lake. Fish are restrained from going there because of the low dissolved oxygen and *Daphnia* performs a diel (24-hr) vertical migration, migrating to the surface at night and going back down into bottom waters during the day to avoid fish predation.

Lastly, to confirm our identification of zooplankton in the stomachs of fishes in the fish diet section of the report, we randomly selected a number of fish stomachs and pooled the zooplankton they had eaten. Interestingly, *Bosmina* and *Eubosmina*, closely related but smaller members of the same group *Daphnia* is in (Crustaceans) were the dominant zooplankton eaten with only 4% of the zooplankters selected being *Daphnia*. One *Leptodora* was found and as we noted, since they are so big are susceptible to fish predation (several were eaten by fishes). No *Bosmina* or *Eubosmina* were found in our net-collected zooplankton samples, which is unusual, but apparently they are confined to the nearshore area or bottom depths where most of the zooplankton consumption occurred. These zooplankton species, like *Daphnia*, are very efficient consumers of algae and will act like *Daphnia* in removing algae from the water column, albeit at lower rates since they are smaller organisms than *Daphnia*.

Fish community

Fish Diversity

We collected 16 species of fishes during our netting activities over 3 days in July 2022 on Lake Templene (Table 5). One species we caught that was not caught by Gunderman (2013) was logperch and they were common to abundant depending on where sampling occurred on the lake. Gunderman (2013) found 29 species plus hybrid sunfish. Fishes he captured but we did not included: warmouth, striped shiner, blackchin shiner, lake chubsucker, channel catfish, northern pike, redear sunfish, walleye, rainbow darter, bowfin, white sucker, golden redhorse, greater redhorse, rock bass, and green sunfish. He deployed four gear types including electro shocking over 4 days 29 April-2 May 2013. The counts we made and size ranges (Table 6) represent only those fish sampled for length, diet, and age determinations. Most fish were released; those fish that succumbed to netting and not required as samples were kept and counted.

Table 5. List of fishes collected from Lake Templene on 14-16 July 2022. Also given is their perceived abundance in the lake based on netting results and knowledge gained on site and from discussions with residents and fishers.

FISH CODE	COMMON NAME	SPECIES	ABUNDANCE
BC	BLACK CRAPPIE	*Pomoxis nigromaculata*	COMMON
BG	BLUEGILL	*Lepomis macrochirus*	ABUNDANT
BM	BLUNTOSE MINNOW	*Pimephales notatus*	UNCOMMON
BN	BROWN BULLHEAD	*Ameiurus nebulosus*	RARE
CP	COMMON CARP	*Cyprinus carpio*	UNCOMMON
GL	GOLDEN SHINER	*Notemigonus crysoleocas*	RARE
JD	JOHNNY DARTER	*Etheostoma nigrum*	UNCOMMON
LB	LARGEMOUTH BASS	*Micropterus salmoides*	COMMON
LP	LOGPERCH	*Percina caprodes*	ABUNDANT
PS	PUMPKINSEED	*Lepomis gibbosus*	UNCOMMON
SG	SPOTTED GAR	*Lepisosteus oculatus*	RARE
SH	SAND SHINER	*Notropis stramineus*	RARE
SV	BROOK SILVERSIDES	*Labidesthes sicculus*	UNCOMMON
XX	UNKNOWN FISH	*To decomposed to identify*	RARE
YB	YELLOW BULLHEAD	*Ameiurus natalis*	RARE
YP	YELLOW PERCH	*Perca flavescens*	COMMON

Table 6. The species, size ranges, number saved for analyses, and % composition based on the total no. saved for Templene Lake, 14-16 July 2022.

FISH CODE	COMMON NAME	RANGE (IN)	NO.	%
BC	BLACK CRAPPIE	1.7-11.5	27	8.4
BG	BLUEGILL	2.3-7.3	73	22.7
BM	BLUNTOSE MINNOW	1.1-2.4	35	10.9
BN	BROWN BULLHEAD	12.1-12.8	2	0.6
CP	COMMON CARP	23.6	1	0.3
GL	GOLDEN SHINER	2-2.1	2	0.6
JD	JOHNNY DARTER	1.5-2.5	18	5.6
LB	LARGEMOUTH BASS	1.5-16.0	36	10.9
LP	LOGPERCH	2.0-4.7	39	12.1
PS	PUMPKINSEED	3.1-6.1	9	2.8

SG	SPOTTED GAR	21	1	0.3
SH	SAND SHINER	2.0-2.1	2	0.6
SV	BROOK SILVERSIDES	1.5-2.2	9	2.8
XX	UNKNOWN FISH			
YB	YELLOW BULLHEAD	11.6-12.9	3	0.9
YP	YELLOW PERCH	1.8-8.5	65	20.2
TOT			321	100

Fish Diets

Bluegills, as was found by Gunderman (2013), were the most-abundant species (22.7% - Table 6) collected in our gear and ranged from 2.3 to 7.3 inches, a good range of sizes. Young fish were abundant in our seine hauls and bigger fish were caught in offshore gill nets. Several of the adult fish were still gravid. It appeared that spawning was very successful, since we observed large numbers of small (presumably YOY fishes) in our seine net samples. Certainly, there were areas of optimal sand substrate for successful spawning outcomes. Most of the fish were eating zooplankton (they were difficult to identify because of digestion but appeared to be *Bosmina, Eubosmina*, *Daphnia,* and *Leptodora*) (Table 7). Some larger adults were eating naiads of the large mayfly *Hexagenia*. The presence of *Hexagenia*, which we observed as exuviae on the surface from recent hatches and in the diets of fishes like bluegill, is an excellent sign of high water quality in the lake and a very nutritious food as both naiads and adults for many species of fishes. This also includes birds.

Black crappies ranged from 1.7 to 11.5 inches (8% of catch), with a similar pattern: large numbers of small YOY were found in near shore seines, while larger adults appeared in our offshore gill nets (Table 5, 6). Certainly, the large size of this species and its successful spawning based on YOY abundance in the near shore, should bode well as a dominant sport fish in Lake Templene under current conditions. Black crappies <4 inches were eating zooplankton, while large specimens were eating fish (mostly unidentifiable but one ate a largemouth bass YOY) and some *Hexagenia* (Table 7). We have seen large black crappies act as effective predators on YOY bluegills in other lakes and assume that some of the unidentified fish eaten were bluegills.

Bluntnose minnows were rated as uncommon (10% of catch though – Table 5, 6), but appeared in many of our seine hauls; they were mostly small with some large adults and ranged from 1.1 to 2.4 inches. They should, along with other prey species (bluegills, black crappies, yellow perch, Johnny darters, logperch, golden and sand shiners), provide a substantial source of forage for the predators in the lake. There were several other minnows identified by Gunderman (striped shiner, and blackchin shiner) that if still present, should also contribute to the forage base. Our diet analyses of predators often showed that they were eating fish, but it was difficult to identify them to species because they were digested beyond recognition. However, we did identify Johnny darters, bluegills, and largemouth bass in the stomachs of several fishes.

We caught two large brown bullheads, which are well known for their piscivory; they ranged from 12.1 to 12.8 inches (Table 5, 6). One ate a green beetle while the other ate a large bluegill, which was probably in the trap net with it, but does demonstrate their ability to feed on large prey probably at night (Table 7).

We observed many common carp splashing and jumping in the area but only caught one fish 23.6 inches long, the longest fish captured. It had plant debris and detritus in its stomach. These species are destructive, stirring up bottom sediments and increasing turbidity in lakes and a concerted effort should be encouraged to remove as many of them as possible, through sport fishing and bow fishers.

We sampled 18 Johnny darters (ca. 6% of catch – Table 6) that ranged from 1.5 to 2.5 in. They were insectivores, eating chironomids and mayflies. They too will provide forage for predators and we did find them in predator stomachs. Johnny darters were eating insect larvae as expected, including mayflies and chironomids (Table 7). The presence of yet other smaller species of mayflies in stomachs, is further demonstration of the good water quality that must exist in places where these species flourish.

We saved 36 largemouth bass for diet and age determinations that ranged from 1.5 to 16.0 inches; they composed 11% of the catch (Table 5, 6). There was good reproduction based on the abundance of YOY in our seine hauls, but we did not catch many larger largemouth bass and no very large specimens, despite this lake being well known for its sport fishery and bass tournaments. We observed many bass boats on the lake during our study. We normally do not catch many large largemouth bass with the gear we use, since they are notorious for avoiding gill nets and trap nets as they did in this study. Three fish (14, 15, and 16 in) were provided by our host David Young. The smaller fish we did catch were eating insects and zooplankton, while larger individuals were eating unknown fish, Johnny darters, logperch, and YOY largemouth bass (Table 7). This is a diverse forage base and should result in good largemouth bass growth. The lack of larger fish in our study was similar to findings by Gunderman (2013) who only collected six fish in the 14-16 in category. We always advocate that bass fishers return their catches to the lake (catch and release) because it takes many years to grow a fish to that size and maturity, so they can reproduce, for future fishers to enjoy, and because a large number of those large largemouth bass are contaminated with mercury (See MDNR fish consumption guidelines for recommended amounts to eat). We are also aware that most largemouth bass fishers follow this protocol and are to be commended for this behavior. However, the lack of many large largemouth bass (at least based on our and past studies) could be the well known propensity for large largemouth bass to avoid sampling gear or some other problem.

We collected large numbers of logperch (diminutive member of the perch family) in our seines (12% of saved fish) and saved 35 for length and diet analyses; fish ranged from 2.0 to 4.7 inches (Table 5, 6). They were exclusively feeding on amphipods, insects, and zooplankton (Table 7). As noted this species was not collected by Gunderman during 2013 so since then it entered the lake and has flourished. It is common in that southern area of the state (Bailey et al. 2004). They are not usually found in many inland lakes in other areas of the state and it usually requires high water quality to attain high populations levels, as it apparently has in Lake Templene. It will provide an excellent forage base (as seen here) for most predators in the lake.

We only collected nine pumpkinseeds (3.1-6.1 in) (Table 5, 6) and this species is known to eat mollusks, which was born out in our data, since they were eating zebra mussels *Dreissena polymorpha*, and aquatic insects, including chironomids and *Hexagenia* (Table 7).

We also collected some brook silversides (9) in our seine samples; fishes were somewhat smaller than what we usually see in lakes, ranging from 1.5 to 2.2 inches. This is a member of the silversides family which prefers clear water with vegetation. They are often seen at the surface of lakes feeding on terrestrial insects and jump out of the water when disturbed, usually by a predator. They are an excellent addition to the food base of Lake Templene.

We also collected two golden and two sand shiners. They will also contribute to the forage base for Lake Templene, as will two species (striped and backchin shiners) that Gunderman collected if they are still present.

There were three yellow bullheads in our nets; they ranged from 11.6 to 12.9 inches (Table 6). They were eating black crappies, bluegills, and crayfish (Table 7). They will be another predator helping to control the sunfish populations.

Another common species we encountered was yellow perch; they ranged in size from 1.8 in to 8.5 inches and composed 20% of our catch (Table 5, 6). Gunderman found larger yellow perch than we did including large numbers of 9 and a few in the 10-inch range. We have often found a truncated population of yellow perch in lakes with a large population of northern pike, but there are few in Lake Templene, based on one collected by Gunderman and none in any of our nets. There are considerable numbers of spotted gar present, which could also be effective predators on yellow perch, since they too prefer vegetated habitat as well as yellow perch. There appeared to be good reproduction based on many YOY in our seines (Table 7), but as noted, there did not seem to be many large individuals in the population, since our gill nets are very efficient at catching them because of their bony structures. We did see a newspaper report of a large northern pike specimen caught in the lake recently which apparently was released. The high turbidity will impede predation and warm temperatures with little optimal thermal habitat with adequate dissolved oxygen based on our and Gunderman's dissolved oxygen curves suggest that northern pike (and walleye) will not flourish in Lake Templene (and therefore should not be stocked). There are other predators that could prey on yellow perch including channel catfish (rare apparently), spotted gar, bowfin, and to a small degree largemouth bass. Smaller yellow perch were eating zooplankton, chironomids, and amphipods, while stomachs of larger individuals were mostly empty, but some were eating Johnny darters, *Hexagenia*, and one had a worm (fishing lure) and another a rock in its stomach (Table 7).

We caught one spotted gar (see Picture 1), which are rare in most of Michigan, confined to the southern part of the state, but appeared to be common in Lake Templene based on

Gunderman's data. However, he reported that most of the gar they caught were caught in one spot in the lake. The one we collected was 21 inches long and had eaten one large bluegill.

Table 6. Listing of the species captured, total length (inches), weight (ounces), sex (M=male, F=female, I=immature, and condition noted as 1=poorly developed, 2=moderately developed, 3=ripe, 4=ripe running, and 5=spent), and diet. MT=empty, XX=unknown fish. See Table 5 for definition of fish codes and Table 2 for definition of gear codes.

GEAR	SPECIES	TL-IN	WT-OZ	SEX	DIET
		BLACK CRAPPIE			
S1	BC	1.7	0.02	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S1	BC	1.7	0.03	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S1	BC	1.7	0.03	II	ZOOPLANKTON BOSMINA AND EUBOSMINA PLUS SOME COPEPODS
S1	BC	1.8	0.03	II	ZOOPLANKTON BOSMINA AND EUBOSMINA, DAPHNIA
S1	BC	1.8	0.03	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S1	BC	1.9	0.04	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S1	BC	1.9	0.04	II	ZOOPLANKTON
S1	BC	1.9	0.04	II	ZOOPLANKTON DAPHNIA
S1	BC	2.0	0.04	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S1	BC	3.5	0.3	CC	MT
S1	BC	3.6	0.3	CC	ZOOPLANKTON
S1	BC	3.7	0.3	CC	MT
S1	BC	3.9	0.4	CC	XX FISH
S1	BC	4.0	0.4	CC	XX FISH
S1	BC	4.1	0.5	CC	XX FISH, CHIRONOMIDS
S1	BC	4.4	0.6	CC	XX FISH
S1	BC	4.9	0.9	CC	ZOOPLANKTON
S1	BC	5.2	1.0	F1	XX FISH
G1-3	BC	5.3			
S1	BC	6.0	1.6	CC	200 CHIRONOMIDAE PUPAE
S1	BC	8.0		M1	ZOOP
G1-3	BC	8.3		f2	LB 63 mm
T1-1	BC	9.5		F1	ZOOPLANKTON
G1-2	BC	9.6	7.2	M1	HEXAGENIA
G1	BC	11.1		F2	ZOOP
T3-1	BC	11.1		m1	4 HEXAGENIA
T1-1	BC	11.5		M1	XX FISH
		BLUEGILL			
S1	BG	2.3	0.1	II	ZOOPLANKTON

S1	BG	2.4	0.1	II	ZOOPLANKTON
S1	BG	2.4	0.1	II	ZOOPLANKTON
S1	BG	2.4	0.1	II	ZOOPLANKTON
S1	BG	2.7	0.2	II	CHIRONOMIDS
S1	BG	2.7	0.1	II	ZOOPLANKTON
S1	BG	2.8	0.2	II	INSECT PARTS
T2-1	BG	2.8	0.2	F2	ZOOPLANKTON DAPHNIA
S2	BG	3.2	0.3	II	CADDISFLIES, CHIRONOMIDAE
S1	BG	3.4	0.3	II	ZOOPLANKTON
S1	BG	3.5	0.3	II	ZOOPLANKTON
S1	BG	3.6	0.4	II	CHIRONOMIDS
S1	BG	3.7	0.4	II	CHIRONOMIDS, INSECT PARTS
S1	BG	3.9	0.5	CC	MT
S1	BG	4.0	0.6	CC	INSECT PARTS
S2	BG	4.1	0.5	F1	ZOOPLANKTON BOSMINA AND EUBOSMINA AND DAPHNIA
S2	BG	4.1	0.8	M1	ZOOPLANKTON BOSMINA AND EUBOSMINA
T2-1	BG	4.1	0.7	F1	ZOOPLANKTON DAPHNIA
G1-1	BG	4.2	0.7	F1	MT
G2-1	BG	4.2	0.7	F1	HEXAGENIA
S1	BG	4.3	0.6	F1	MT
S1	BG	4.3	0.6	CC	MT
S3	BG	4.3		M1	ANTS
G2-1	BG	4.5	0.8	M1	MT
T1-1	BG	4.6	0.9	F2	MT
T1-1	BG	4.6	0.9	CC	ZOOPLANKTON DAPHNIA
T2-1	BG	4.6	1.0	F1	ZOOPLANKTON DAPHNIA
T1-1	BG	4.7			
T1-1	BG	4.8			
T1-1	BG	4.8			
T1-1	BG	4.8			
T1-1	BG	4.9			
T2-1	BG	4.9	1.2	CC	ZOOPLANKTON DAPHNIA
T1-1	BG	4.9	1.1	CC	ZOOPLANKTON BOSMINA, DAPHNIA
T1-1	BG	4.9			
T1-1	BG	4.9			
T1-1	BG	5.0			
T1-1	BG	5.0			
T1-1	BG	5.0			
T1-1	BG	5.0			
T1-1	BG	5.1			
T1-1	BG	5.1			
T1-1	BG	5.2			
T1-1	BG	5.2			

T2-1	BG	5.2	1.3	M1	ZOOPLANKTON DAPHNIA
T1-1	BG	5.3			
T1-1	BG	5.4	1.5	F2	SMALL ZOOPLANKTON
S4	BG	5.5	1.5	F2	ANTS, CADDISFLY, CHIRONOMIDAE
T1-1	BG	5.5	1.7	CC	ZOOPLANKTON, LEPTODORA,CHIRONOMIDS, SNAIL
T2-1	BG	5.6	1.7	F2	ZOOPLANKTON DAPHNIA
S4	BG	5.6	1.7	M1	MT
T1-1	BG	5.6	1.7	F2	ZOOPLANKTON, SEDIMENTS
G1-1	BG	5.7	2.2	F1	ZOOPLANKTON BOSMINA AND EUBOSMINA
T1-1	BG	5.8	2.0	F1	ZOOPLANKTON ABUNDANT
G2-2	BG	5.8	2.0	M1	MT
T1-1	BG	5.8	2.1	F1	OSTRACODS, FILMENTOUS ALGAE, LEPTODRA?, HEXAGENIA
G1-1	BG	5.9	2.2	F2	ZOOPLANKTON BOSMINA AND EUBOSMINA
G2-1	BG	6.0	2.4	F1	ZOOPLANKTON
S4	BG	6.1	2.0	F1	BEETLE
G2-1	BG	6.2	2.7	F3	ZOOPLANKTON DAPHNIA
G1-1	BG	6.3	2.6	F1	ZOOPLANKTON BOSMINA AND EUBOSMINA AND DAPHNIA
G1-1	BG	6.4	3.0	F2	ZOOPLANKTON BOSMINA AND EUBOSMINA
G1-1	BG	6.4	3.1	M2	ZOOPLANKTON BOSMINA AND EUBOSMINA
G2-1	BG	6.6	2.9	F3	ZOOPLANKTON
G2-2	BG	6.6	3.0	F5	ZOOPLANKTON BOSMINA AND EUBOSMINA
G2-2	BG	6.8	3.4	M1	MT
G2-2	BG	6.9	3.6	N1	ZOOPLANKTON LEPTODORA
G1-1	BG	6.9	3.3	F3	ZOOPLANKTON BOSMINA AND EUBOSMINA
T1-1	BG	6.9	3.5	M2	2 HEXAGENIA, LEPTODORA, CADDISFLY
G2-1	BG	6.9	3.3	F1	ZOOPLANKTON DAPHNIA
T1-1	BG	7.1	3.6	F2	ZOOPLANKTON DAPHNIA
G2-2	BG	7.1	3.3	F3	ZOOPLANKTON BOSMINA AND EUBOSMINA
T1-1	BG	7.3	4.4	M1	MT

BLUNTNOSE MINNOW

S2	BM	1.1
S1	BM	1.1
S3	BM	1.2
S3	BM	1.2
S1	BM	1.2
S1	BM	1.3
S4	BM	1.3
S1	BM	1.3
S2	BM	1.3
S2	BM	1.4
S4	BM	1.4
S3	BM	1.4

S3	BM	1.4			
S1	BM	1.4			
S2	BM	1.4			
S1	BM	1.5			
S2	BM	1.5			
S1	BM	1.5			
S4	BM	1.5			
S2	BM	1.5			
S3	BM	1.7			
S4	BM	1.9			
S4	BM	1.9			
S3	BM	2.0			
S3	BM	2.1			
S1	BM	2.1			
S2	BM	2.1			
S1	BM	2.1			
S4	BM	2.1			
S3	BM	2.2			
S2	BM	2.2			
S4	BM	2.3			
S4	BM	2.4			
S2	BM	2.4			
S1	BM	2.4			
		<u>BROWN BULLHEAD</u>			
T2-1	BN	12.1		M1	BG 111 mm
G2-2	BN	12.8	14.6	F1	GREEN BEETLE
		<u>COMMON CARP</u>			
G2-1	CP	23.6		F2	DETRITUS
		<u>JOHNNY DARTER</u>			
S3	JD	1.5			
S1	JD	1.6	0.02		
S1	JD	1.6	0.02		
S2	JD	1.6			
S2	JD	1.6			
S2	JD	1.6			
S1	JD	1.7	0.02		
S3	JD	1.7			
S2	JD	1.7			
S3	JD	1.7	0.02	CC	MAYFLIES, CHIRONOMIDAE
S3	JD	1.7			

S3	JD	1.7			
S1	JD	1.8	0.03		
S3	JD	1.7			
S3	JD	1.7			
S1	JD	2.0	0.03		
S2	JD	2.1			
S1	JD	2.5	0.05		CHIRONOMIDAE (MIDGES)
		<u>LARGEMOUTH BASS</u>			
S2	LB	1.5			
S2	LB	1.5			
S1	LB	1.6	0.03	II	HYALELLA AMPHIPOD
S2	LB	1.6			
S2	LB	1.6			
S2	LB	1.7			
S2	LB	1.7			
S3	LB	1.8	0.03	II	CHIRONOMIDAE PUPAE
T3-1	LB	1.8	0.04	II	DAPHNIA, LEPTODORA
S2	LB	1.8			
S2	LB	1.8			
S2	LB	1.9			
S2	LB	1.9			
S2	LB	2.0			
S2	LB	2.0			
S2	LB	2.0			
T3-1	LB	2.0	0.07	II	LEPTODORA
S2	LB	2.0	0.05	II	ZOOPLANKTON
S2	LB	2.0			
T3-1	LB	2.0	0.07	II	DAPHNIA, LEPTODORA
S1	LB	2.1	0.06	II	XX FISH
S1	LB	2.4	0.09	II	XX FISH
S1	LB	2.5	0.09	II	MT
S4	LB	2.7	0.1	II	XX FISH
S1	LB	2.7	0.1	II	XX FISH
S1	LB	2.9	0.2	II	XX FISH
S2	LB	5.1	0.9	M1	XX FISH
S1	LB	6.8	2.5	M1	LB 38 MM
S1	LB	7.6	3.3	F1	MT
S1	LB	8.0	3.9	F1	XX 70 MM ?LP
S1	LB	9.9		M1	BG41mm, XX fish
S1	LB	10.4	8.3	F1	?JD 45 MM
S1	LB	12.8		M1	MT
SF	LB	15.0			

SF	LB	16.0			
		<u>LOGPERCH</u>			
S2	LP	2.0			
S2	LP	2.0			
S2	LP	2.1			
S2	LP	2.1			
S2	LP	2.1			
S2	LP	2.2			
S3	LP	2.2	0.04	CC	CHIRONOMIDAE, 2 MAYFLIES CAENIS
S2	LP	2.2			
S2	LP	2.2			
S2	LP	2.3			
S2	LP	2.3			
S1	LP	2.4	0.05	II	MAYFLIES
S2	LP	2.4			
S2	LP	2.4			
S2	LP	2.5	0.06	CC	ZOOPLANKTON DAPHNIA
S2	LP	2.6			
S2	LP	2.6			
S2	LP	3.5			
S2	LP	3.7			
S3	LP	3.7	0.3	F1	30 MAYFLIES, 1 CHIRONOMIDAE
S2	LP	3.7	0.2	M1	MAYFLY CAENIS
S2	LP	3.8			
S1	LP	3.8	0.3	CC	MAYFLIES, CHIRONOMIDAE
S2	LP	3.8			
S1	LP	3.9	0.3	M1	AMPHIPODS HYALELLA, MAYFLIES CAENIS
S2	LP	3.9			
S2	LP	3.9			
S1	LP	3.9	0.3	CC	MAYFLIES
S2	LP	4.0			
S2	LP	4.1			
S4	LP	4.1	0.3	CC	15 MAYFLIES CAENIS
S1	LP	4.1	0.3	CC	CADDISFLIES, MAYFLIES
S2	LP	4.1			
S3	LP	4.2	0.3	CC	MAYFLIES, SNAIL
S1	LP	4.2	0.3	CC	AMPHIPODS HYALELLA, MAYFLIES CAENIS
S3	LP	4.2	0.3	CC	60 CHIRONOMIDS
S2	LP	4.2			
S2	LP	4.4	0.3	CC	4 HYALELLA, 3 MAYFLIES CAENIS
S2	LP	4.7	0.4	M1	4 HYALELLA

		PUMPKINSEED			
S1	PS	3.1	0.3	F1	HEXAGENIA
S2	PS	4.8	1.2	F2	2 HEXAGENIA, CADDISFLIES
S2	PS	4.9	1.2	F1	20 CHIRONOMIDS
S2	PS	5.0	1.3	M1	ZEBRA MUSSELS, CHIRONOMIDS, SNAIL
S2	PS	5.2	1.7	M1	ZEBRA MUSSELS
S2	PS	5.2	1.5	M1	ZEBRA MUSSELS, CADDISFLIES, CHIRONOMIDS
S2	PS	5.7	2.2	F1	ZEBRA MUSSELS
S2	PS	5.8	2.4	M1	ZEBRA MUSSELS
S3	PS	6.1	3.0	F2	ZEBRA MUSSELS
		SPOTTED GAR			
G2-1	SG	21.0		M5	BG 91 mm
		BROOK SILVERSIDES			
S2	SV	1.5			
S3	SV	1.6			
S2	SV	1.7			
S2	SV	1.7			
S2	SV	1.8			
S2	SV	1.9			
S2	SV	1.9			
S2	SV	2.0			
S2	SV	2.2			
		SAND SHINER			
S4	SH	2.0			
S4	SH	2.1			
		GOLDEN SHINER			
S4	GL	2.0			
S4	GL	2.1			
		YELLOW BULLHEAD			
G1-3	YB	11.6		F1	XX FISH
G1-3	YB	12.5		F5	BC 134 MM,BG 95 MM,BG 75 MM
T1-1	YB	12.9		F5	GREEN BEETLE, CRAYFISH
		YELLOW PERCH			
S2	YP	1.8			
S2	YP	2.0			
S2	YP	2.0			
S2	YP	2.0			

S2	YP	2.0			
S2	YP	2.0			
S2	YP	2.0			
S2	YP	2.0			
S2	YP	2.1			
S2	YP	2.1			
S2	YP	2.1			
S2	YP	2.1			
S2	YP	2.1			
S1	YP	2.2	0.05	II	ZOOPLANKTON
S2	YP	2.2			
S2	YP	2.2			
S2	YP	2.2			
S2	YP	2.2			
S2	YP	2.3			
S2	YP	2.3			
S2	YP	2.3			
S2	YP	2.3			
S2	YP	2.3			
S2	YP	2.4	0.07	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S3	YP	2.4	0.07	II	
S2	YP	2.4	0.07	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S2	YP	2.4	0.07	II	ZOOPLANKTON BOSMINA AND EUBOSMINA
S2	YP	2.4			
S1	YP	2.4	0.08	II	ZOOPLANKTON, MAYFLY SIPHLONURIDAE
S1	YP	2.5	0.09	II	HYALELLA AMPHIPOD
S1	YP	3.6	0.3	II	MT
S1	YP	3.7	0.2	M1	HEXAGENIA, ZOOPLANTON BOSMINA AND EUBOSMINA
S1	YP	3.7	0.3	II	INSECT PARTS
S2	YP	3.8			
S2	YP	4.0			
S2	YP	4.1			
S1	YP	4.1	0.4	II	HYALELLA AMPHIPOD
S2	YP	4.1			
G2-2	YP	4.2	0.4	M1	MT
S2	YP	4.2			
S1	YP	4.3	0.4	F1	MT
S2	YP	4.3			
S2	YP	4.3	0.4	F1	MAYFLIES CAENIS, CHIRONOMIDS
S1	YP	4.4	0.5	F1	JD 40 MM
S2	YP	4.4			
S4	YP	4.4	0.5	F1	MT
G1-1	YP	4.4	0.4	M1	MT

S2	YP	4.5			
S2	YP	4.5			
S1	YP	4.6	0.5	II	MT
S2	YP	4.7	0.5	F1	DETRITUS
G1-1	YP	4.7	0.5	M1	MT
S1	YP	4.9	0.6	F1	HEXAGENIA
G2-2	YP	4.9	0.6	F1	MT
S1	YP	5.2	0.7	F1	XX FISH CA 35 MM
S2	YP	5.2	0.7	F1	30 CHIRONOMIDS, CADDISFLIES, HYALELLA
G2-1	YP	5.2	0.7	F1	MT
S2	YP	5.7	1.1	F1	MT
S3	YP	5.8	1.1	F1	MT
S2	YP	5.9	1.1	F1	MT
S1	YP	6.0	1.2	F1	MT
S1	YP	6.2	0.1	II	MT
G2-1	YP	7.2	2.0	F1	RUBBER WORM
S1	YP	7.3	2.4	F1	ROCK
S2	YP	8.5	3.9	F1	MT

Fish Growth

Bluegills were the most common fish we captured and except for 1-yr old fish were growing at about state average growth rates (Table 8, Fig. 8). The yearlings were growing faster than state averages. This finding contrasts with Gunderman's (2013) results which showed all age groups growing far above state averages. Apparently, there have been changes in the lake that depressed this good growth. It could be related to reduced predator depredations (most likely hypothesis) or reduced food supply (unlikely). Certainly, there were very few fish predators collected in our study compared with the prey species and this was also what Gunderman also espoused – predator sparse and prey profuse. Even the prey fish may be at lower than preferred densities, since the *Daphnia* population appears to have suffered little predation by fish predators.

We did not catch many large largemouth bass; the largest was 16 in, about 6-yr old (Table 8, Fig. 10). Our data showed that the fish we aged were mostly growing at Michigan standards. Gunderman (2013) found largemouth bass abundance was high and that fish 4-yrs old and older were growing faster than state averages.

The largest yellow perch we caught was 8.5 inches and it was 4-yr old and along with the 3-yr olds, was growing above state averages; remaining fish were growing at state standards (Table 8. Fig. 11). Gunderman found yellow perch during 2013 were growing at average state rates.

We caught very few pumpkinseeds but they were all growing at state standard rates (Table 8, Fig. 12), a finding also noted by Gunderman (2013).

Some very large (11-11.5 in) black crappies were captured, and these were 6-8 years old (Table 8, Figure 13). In total, all age groups were growing at state averages and this species should provide some excellent sport fishing opportunities. Gunderman (2013) data showed even better growth than our fish and state averages and the catches were dominated by large individuals. They never caught any of the smaller YOY and yearlings like we did.

Table 8. Growth of selected fishes collected from Lake Templene, St. Joseph Co., 14-16 July 2022. Fish were collected in seines, gill nets, and trap nets, scales removed, aged, and ages compared with Michigan state averages (see Latta 1958). Shown is the age of the fish in inches with the sample size in parentheses for Lake Templene fishes, the mean age reached by fish collected and compiled from MDNR sources, and size-at-age determined from fishes we collected during this study. N=sample size for each species.

MDNR Age (yr)	MDNR Len (in)	TEMPLENE 2022 Len (in)
BLUEGILL		N=38
AGE	MDNR	TEMPLENE-2022
0	2.1	2.5(6)
1	2.9	3.6(7)
2	4.3	4.3(7)
3	5.5	5.7(6)
4	6.5	6.7(10)
5	7.3	7.2(2)
6	7.8	
7	8	
8	8.5	
9	8.5	
10	9.2	
LARGEMOUTH BASS		N=17
AGE	MDNR	TEMPLENE-2022
0	3.3	2.4(9)
1	6.1	
2	8.7	7.4(2)
3	10	10.2(2)
4	12.1	
5	13.7	14(3)
6	15.1	16(1)
7	16.1	

8	17.7	
9	18.8	
10	19.8	
11	20.8	
YELLOW PERCH		N=27
AGE	MDNR	TEMPLENE-2022
0	3.3	2.7(4)
1	4	4.4(14)
2	5.7	5.6(6)
3	6.8	7.3(2)
4	7.8	8.5(1)
5	8.7	
6	9.7	
7	10.5	
8	11.3	
9	11.7	
BLACK CRAPPIE		N=17
AGE	MDNR	TEMPLENE-2022
0	3.6	2.6(7)
1	5.1	4.8(2)
2	5.9	6(1)
3	8	8.1(2)
4	9	
5	9.9	9.6(2)
6	10.7	11.1(1)
7	11.3	11.1(1)
8	11.6	11.5(1)
PUMPKINSEED		N=9
AGE	MDNR	TEMPLENE-2022
0	2	
1	2.9	3.1(1)
2	4.1	
3	4.9	5.0(5)
4	5.7	5.9(3)
5	6.2	
6	6.8	
7	7.3	
8	7.8	

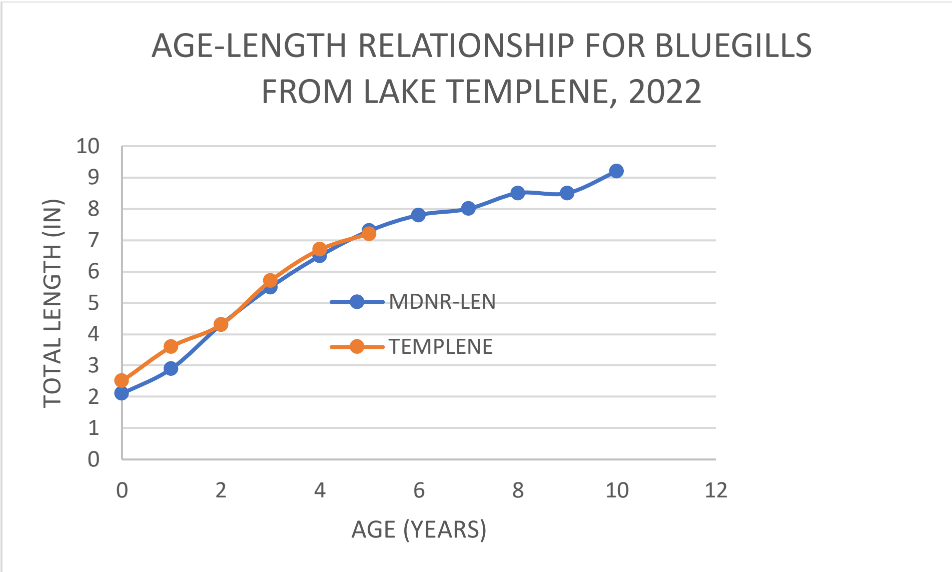

Figure 9. Growth of bluegills in Lake Templene during 14-16 July 2022 (red circles) compared with the Michigan state averages (blue circles) (see Latta 1958). See Table 8 for raw data.

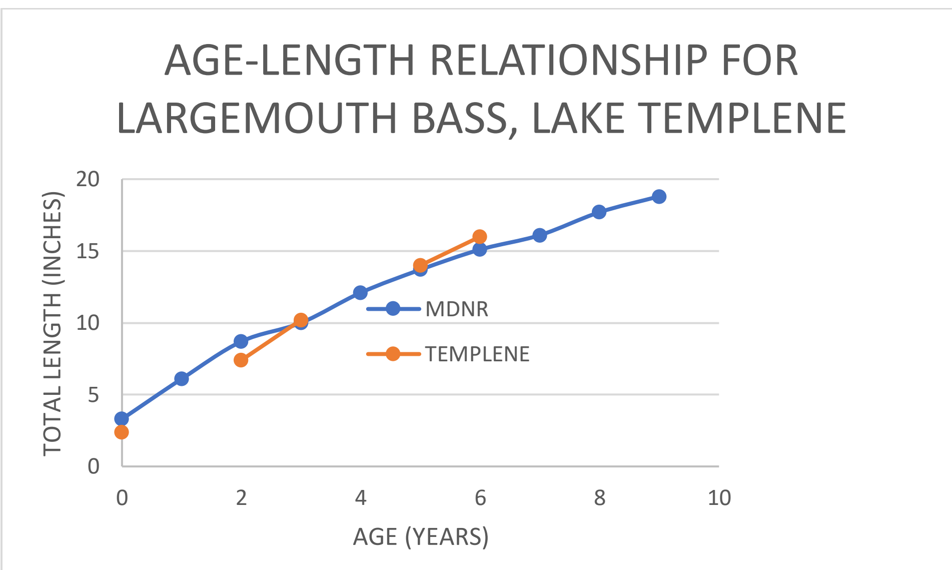

Figure 10. Growth of largemouth bass in Lake Templene during 14-16 July 2022 (red circles) compared with the Michigan state averages (red circles) (see Latta 1958). See Table 8 for raw data.

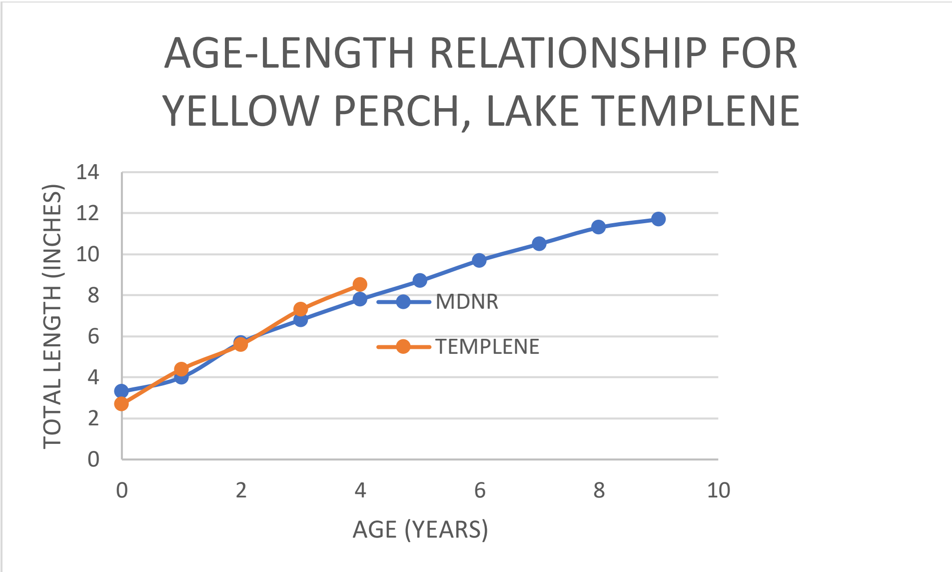

Figure 11. Growth of yellow perch in Lake Templene during 14-16 July 2022 (red circles) compared with the Michigan state averages (blue circles) (see Latta 1958). See Table 8 for raw data.

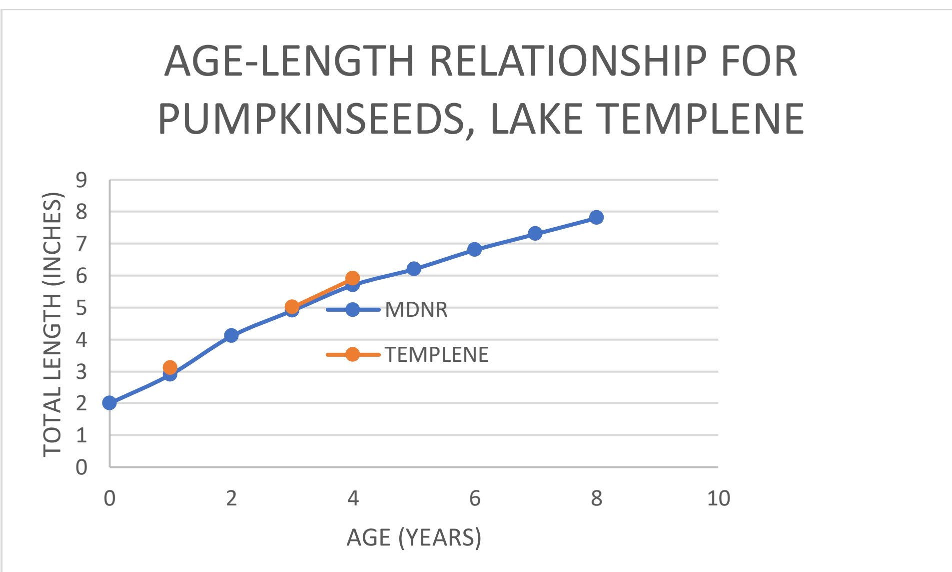

Figure 12. Growth of pumpkinseeds in Lake Templene during 14-16 July 2022 (red circles) compared with the Michigan state averages (blue circles) (see Latta 1958). See Table 8 for raw data.

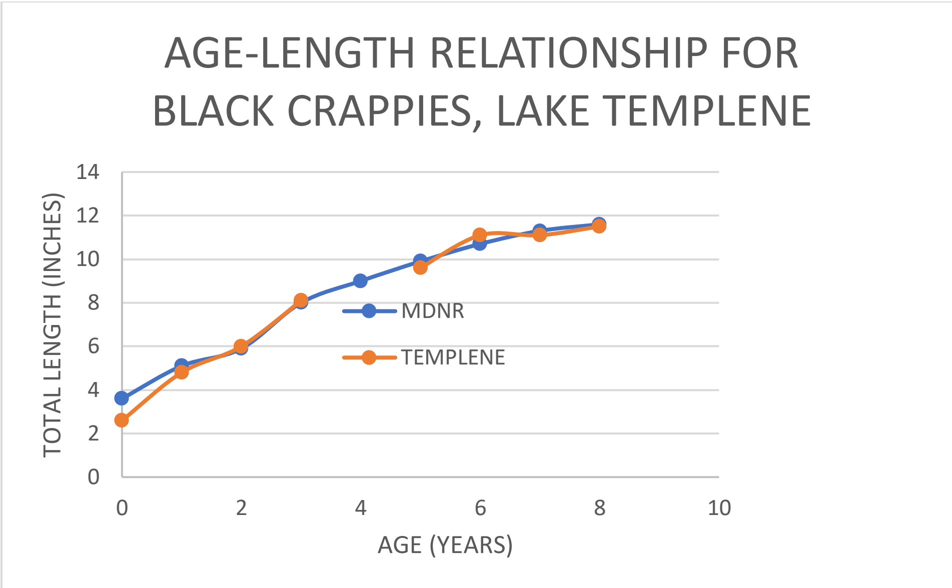

Figure 13. Growth of black crappies in Lake Templene during 14-16 July 2022 (red circles) compared with the Michigan state averages (blue circles) (see Latta 1958). See Table 8 for raw data.

DISCUSSION

Positive Aspects of Lake Templene

There are some good aspects of Lake Templene that need to be highlighted first. The lake is very large, moderately productive, has a high diversity of fish species (at least 29 based on our and Gunderman's studies), provides many recreational opportunities for water enthusiasts and fishers, pleasant spaces for residences, and it has a diverse and important benthic community, including caddis flies and mayflies (at least three species: *Caenis*, *Siphlonuridae*, and *Hexagenia*), and the amphipod *Hyalella*. These species, especially the mayflies and in particular *Hexagenia*, are bellwethers of high water quality. *Hexagenia* have a 1-2 year life cycle, with the larval form (naiad) living in U-shaped burrows in the sediment for up to 2 years filtering water of detritus and algae. They require high water quality and high dissolved oxygen to survive; it is the same for the caddis flies and other smaller mayflies, which usually thrive in cold water streams not inland lakes. Obviously they are very important food for fishes and we found several species eating them in our studies (Table 5). The good growth noted in prior studies is probably related to this nutritious food supply, which also included zooplankton which was also heavily preyed on by several species. Zooplankton species collected included a large proportion of the sample that was *Daphnia*, a group that is among the largest species, is excellent fish food, and filters large amounts of algae, fostering increased water clarity (discussed below). In addition, the algae were in low abundance compared to impaired lakes, had blue-green algae, but they were not abundant and not the toxin-producing kind, and were also dominated by the preferred group: diatoms. Diatoms are fat-rich, and provide excellent food for zooplankton, which is probably why the *Daphnia* were so abundant and flourishing in Lake Templene.

Limnological Considerations

Templene Lake has some basic characteristics that configure its destiny. It is a reservoir with a 180-square mile watershed that is mostly agricultural. Agricultural activities are well known to contribute large quantities of nutrients (phosphorus and nitrogen) to waterways that receive its runoff from rain events and floods. Our water quality data showed that nitrates were unusually high during summer in Prairie Creek the inlet to Lake Templene (1.41 mg/L – during a non-rain event!) and unusually high in some of the strata in the lake proper (station A - 0.29-0.94 mg/L; station C – 0.76 mg/L – suggesting phosphorus is the limiting nutrient, which was also noted by Gunderman). Second, the lake is large (870 acres), well developed, residents are on septic tanks, lawns that extend to the water's edge are probably well fertilized and we saw very few greenbelts to thwart runoff. In addition, the soil is mostly sandy encouraging seepage of septic tank effluent and lawn fertilizer into the ground water (and through runoff on steep sloped banks) and thence into the lake fueling macrophyte growth and algae blooms. We sampled one well in an effort to determine if there was contamination of groundwater with septic tank effluent or agricultural contamination- none was found in this one site. We suggest that additional anonymous sampling be done with more wells to determine if wells may be contaminated in nearshore areas of the lake. Monitoring wells can also be installed in several areas of the lake to further ensure the groundwater is clean and healthy for drinking. The public health department should support this effort and help such a sampling program to protect the quality of drinking water. In our opinion, Prairie Creek and septic tank leakage into the lake may be the two major sources of nutrients to the lake. Solutions are equally obvious: best management agricultural practices (BMPs) in the watershed and sewers plus elimination or severe reduction in fertilization of lawns. Gunderman suggested similar action for BMPs including their cooperation with: MDEQ, MI department of Agriculture and Rural Development, drain commissioners, Friends of the St. Joe River, and local Conservation District staff to restore wetlands and reduce nutrient and sediment transport from the watershed to Lake Templene. These recommendations require a real revolution in thinking. Less lawn is a boon for insects and thus birds and increased pollination of our plants, will help with climate change, will cost residents less, and is ecologically sound. The "no mow during spring" is a recent advocated action state-wide to encourage no lawn mowing to allow flowers to flourish and thereby help insects that pollinate our plants. There are other sources of nutrients of course: e.g., internal loading (nutrients that derive from the decomposition of sediments, but we view these as small, since there are only three basins that compose a small proportion of the total area of the lake). One other way to remove some of these nutrients is to discharge bottom waters (hypolimnetic) through the dam and we found out that is exactly what is being done at the dam. There are also nutrients that come in from the air (wet and dry deposition), waterfowl (there are huge numbers of swans and geese on the lake- these should not be encouraged to stay by feeding and it may be necessary to do some reduction in the population through egg removal if the MDNR will give approval).

Water clarity during 2022 was around 6.6 ft, lower than most values documented by Gunderman (1983-84 – 7.3 ft, 1999 – 5 ft, and 2009-2011 - 11.5 ft). This value makes Lake Templene a eutrophic lake (Secchi disk <7.5 ft). Water clarity is important for fish communities since it can affect predator success if the water is so turbid it inhibits capture of prey fish; abundant macrophytes can cause the same effect. Increased turbidity can be caused by algae and can be affected by boat traffic stirring up flocculant sediments and re-suspending nutrients embedded in those sediments fostering algal blooms. We observed first-hand the high frequency of boat traffic, which appears to be common in this recreationally active lake. Regarding algae, first we note that zebra mussels are present in the lake, and will filter out preferable algae (diatoms, some green algae species) and reject the long filamentous green and blue-green algae, favoring them over the course of the growing season. We do not believe that zebra mussels are abundant in the lake, but we did find large numbers in some fish stomachs (e.g., pumpkinseeds) so there are some in apparently favorable habitats (perhaps dead trees and other hard substrates in the lake). Second, there is another amazing finding we documented: large numbers of *Daphnia* in our offshore zooplankton tows, more than we have seen in any other lakes we studied, which is a great situation for the lake ecosystem. *Daphnia* can filter large quantities of algae of the right kinds from the water column, which they are obviously doing and therefore help with keeping algae from reducing water clarity in the lake. Third, we measured turbidity and found it to be low, while chlorophyll a, which is a surrogate for algae, was very high (13.9 - 16.3 ug/L). Values > 6 ug/L are indicative of a eutrophic lake. Gunderman (2013) reported median chlorophyll a concentrations of 2.5 ug/L in 1999 and 1.3 mg/L in 2009-2011, which suggests that conditions have gotten much worse in the intervening years since 2011. We also measured phycocyanin which is a surrogate for blue-green algae (measures protein pigments in blue-green algae); values ranged from 3.2 to 3.9 ug/L. These are low values, but indicate there are some blue-green algae in the lake. Fourth, the algae data we collected from a surface sample at station A showed exactly what the Pycocyanin predicted: low abundance of blue-green algae, none of which were toxin-producers, low abundance of algae compared with other lakes, and the sample was dominated by diatoms, the most preferred group because they are optimal food for zooplankton, enhancing fish production.

These observations suggest that Lake Templene is in a balancing act with many ecological forces and man-induced ones impinging on its health and integrity. A limnologist who would examine the gross features of this lake might conclude that it would have excessive nutrients entering from Prairie Creek that would foster excessive macrophyte growth and severe algal blooms and would have a degraded fish community because of turbid water and anoxia in bottom waters. Some of these conditions are present in the lake, but others are not. To maintain the present ecological conditions in the lake, one recommendation that would be made is to be VERY careful about how macrophytes are controlled, so as to promote an abundance of macrophytes, focus on enhancing native species, but also try to control and inhibit the two invasive species that were most common in the lake: Eurasian milfoil and starry stonewort. As a cautionary tale, note that we have seen and been asked to help with the management of at least four lakes in Michigan with a history of abundant macrophyte growths, and pressures from riparians advocating excessive “weed” control, switched the lake from one dominated by macrophytes to one now dominated by algae. Reversing this switch is very difficult and has not been done yet in any of those four lakes. You do not want Lake Templene to join this list!

Fish Community Considerations

The fish community has great species diversity (around 29 species -using this study and Gunderman’s list) which is analogous to a diverse stock portfolio: when one species has a poor year class another has a great year and the fish community remains stable. Gunderman (2013) reported that the fish community was predator-poor and forage-fish rich, which we can certainly confirm and should lead to good growth of predators, which Gunderman found during 2013. This conclusion is based on his report and our findings.

First it was strange that we collected a species, logperch, that was common in seine hauls during 2022 (12% of total catch), but it was not collected in the earlier 2013 study. Apparently the most common predator is the largemouth bass and we were unsuccessful in assessing the abundance of the larger individuals (three 14-16 in fish were obtained from fishers – our thanks), but Gunderman found their CPUE (catch-per-unit-effort) data ranked their abundance higher than state averages. Based on previous data (Gunderman caught fish from 2 to 16 in) and the fact that there are many bass tournaments on the lake, it certainly appears that there is a large population of larger largemouth bass that we were unable to catch. Our growth data showed largemouth bass mostly growing at state averages during 2022, while Gunderman found they were growing at state averages through age 4 then declined in growth. We did adequately sample the smaller age groups and found that there was a large group of YOY largemouth bass present in the near shore zone, so successful reproduction certainly occurred during 2022. Smaller largemouth bass were eating zooplankton and insects, while the larger ones we collected were eating unknown fishes plus bluegills, logperch, Johnny darter, and largemouth bass YOY. The other potential top predators that are also sport fishes were also rare and included northern pike (we caught none, Gunderman caught four 22-30 in), channel catfish (Gunderman caught four 13-29 in, we none), and walleye (Gunderman caught two 22-26 in, we caught none). Gunderman noted that northern pike and walleyes require cold water (<73 F and moderate dissolved oxygen concentrations >3 mg/L), which only occurred at 12-15 ft in the deep basins (see Fig. 3 – the fish squeeze). Thus, these fish are expected to grow poorly during summer and be stressed. We concluded that there are not very many of these species in the lake, nor should they be stocked. The turbid conditions, many trees and stumps in the lake, and abundant forage should favor the reproduction of channel catfish; we have seen them expand dramatically in similar lakes. Other fish predators that were present in some numbers included: spotted gar, bowfin, brown and yellow bullheads, larger yellow perch, black crappies, and rock bass.

There is a large potential sport fishery for two other species: bluegills and black crappies, which were prominent in the Gunderman study and in ours. Bluegills were the most-abundant fish collected and they were represented by all year classes including YOY, which were abundant in the near shore seines. Bluegills were growing way above state averages during 2013 while we found yearlings growing faster, but other larger age groups were growing at state averages. Larger individuals were caught in offshore gill nets. Bluegills were eating zooplankton and insects, including *Hexagenia* (mayflies) naiads, which should promote good growth. For black crappies, we captured fewer individuals in mid-size ranges; YOY were abundant in seine hauls, and we captured a modest number of large, catchable adults in offshore gill nets. Gunderman found that their abundance estimates for black crappies were some of the highest in the state. Fish in Gunderman's study were growing almost 1-2 in above state averages, while those we caught were growing at state averages and reached 8 yr old and 12 inches in length. Black crappies were eating zooplankton and insects at small sizes and logperch, unknown fish, and largemouth bass YOY at larger sizes. Pumpkinseeds were uncommon, but the ones we did capture were large and were eating zebra mussels so there must be some left in the lake for them to eat. Yellow perch were uncommon in both studies, with few caught that were >4 yr old in this study and >5 yr old in Gunderman's study. Usually when we see this kind of truncated length distribution, we suspect fish predation, especially if many northern pike are present, but that was not the case in this study, so there must be other factors that have reduced their abundance, including harvesting.

<u>Drawdowns</u>

Drawdowns are useful techniques for controlling macrophytes and we have been involved in one study that performed a 4-ft drawdown over several years that had positive effects in controlling Eurasian milfoil, which was initially replaced by the native eelgrass *Valliseneria* the following spring. Gunderman conducted his study during 2013 with the prior winter experiencing a drawdown. We initially wanted to compare success of recruitment between his study and ours (a non-drawdown year) but realized this would be impossible because his study was done on 29 April-2 May and this would have been too early (YOY fish would be too small to be sampled adequately) to compare with our study on 14 July 2022. Gunderman did comment on the drawdown that was done the prior winter stating it did well in controlling starry stonewort and that it appeared to have no obvious effect on fish year class strength. A benthos study done in 2010 comparing a year with and without a drawdown showed that mayflies and isopods declined while there was no effect on other species. Studies have also shown that drawdowns control Eurasian milfoil, coontail, water lilies, water weeds, and bladderwort (an alga) and promote bushy pondweed, thin leaf pondweed, and cattails (Wandell and Wolfson 2000). As we noted above in our study of drawdowns, we observed that eelgrass was the first native macrophyte species to colonize the nearshore zone after it was re-watered.

<u>Macrophyte Control</u>

We discussed macrophyte control above, but some elements bear repeating. Aquatic plants are critical habitat for fish, providing spawning, fish-food organisms, shelter, and nurseries for young fishes as well as anchoring to the sediments and providing a wall of opposition to boat-generated and wind-caused currents that damage and erode shorelines. In addition, nutrients in a lake will, like a garden, produce a quantity of plants, be they weeds or tomatoes in a garden or macrophytes or algae in a lake. At the present time, macrophytes dominate this outcome in Templene Lake, and we did not see nor hear about excessive blue-green algae outbreaks. Our algae data from the lakes showed that overall algal abundance was low compared to other lakes in Michigan and that there were blue-green algae present, but they were low in abundance and not toxin-producers. We also noted that several of the lakes we have studied, went from macrophyte-dominated to algae-dominated and reversing that trend once initiated has not been successful. The situation in Templene Lake is further complicated by the presence of non-indigenous species, namely Eurasian milfoil, curly-leaf pondweed, and starry stonewort—all exotic species that can seriously degrade the quality of recreational experiences on the lake and damage fish spawning sites by covering them over with dense stands of plants. Bearing in mind the importance of macrophytes, one must be judicious in the application of methods to control these exotic macrophytes, making sure that native plants are protected and fostering their growth when the exotic ones are controlled. Eurasian milfoil is best controlled by herbicides, with recommendations for using a new one called Procellacor; however, drawdowns are very effective too when growths are confined to nearshore areas. Starry stonewort is an alga which is controlled using copper sulfate or harvested, both of which have drawbacks. Copper sulfate can accumulate in the sediments and kills snails, while harvesting can remove large quantities of plants but it is like mowing the lawn and has to be repeated. The drawdown discussed above is a good compromise, since it will kill starry stonewort with minimal side effects on fish recruitment and benthos.

Non-indigenous Species

There are at least six non-indigenous species in the lake: zebra mussels, Eurasian milfoil (undergoing annual treatment programs), curly-leaf pondweed (*Potamogeton crispus*), starry stonewort, and common carp. We noted another rare plant *Najas marina* with a dubious background as well. Probably all of these species were brought into the lake by boaters, fishers discharging bait into the lake instead of killing it, and other ways by attaching to items or being present in ballast water or water left in boats that were used in the Great Lakes or other contaminated inland Michigan lakes. There are several other invasive species that are not currently in the lake including the red swamp crayfish, round gobies, Quagga mussels, several viruses that have infected common carp and sport fishes such as largemouth bass and muskies, and the recent discovery of rock snot (*Didymosphenia geminata*) in the Manistee and Boardman River systems probably brought in by fly fishers from western states on their felt sole boots. We actually collected some of this alga (it looks like gray cotton, can have long streamers, hence its rock snot name, and covers large sections of rocks and the stream bottom decimating bottom-dwelling insects). The obvious solution to this problem is signs at the public access sites addressing people launching boats to clean them of any attached plants or debris, chlorinating any water left in the boat's bottom or ballast water pumps, or drying the boats out for a long period of time. This also applies to riparian boat owners, since Lake Templene is now a source of invasive species so people going to other lakes need to be aware; in addition, people coming from other places that are contaminated need to be aware and not contaminate Lake Templene. No live bait should be dumped after use into the lake nor should there be any stocking of fishes by residents, since they could carry diseases and parasites.

Shoreline Habitat Modifications

Rip rap and hardened structures along shorelines were commonly encountered and as noted impeded our efforts to find good places to seine. Riprap is not good fish habitat and there are more ecologically sound ways to retard boat traffic currents and wave action, including regulating boat speeds near shore. In addition, there is a website (Michigan Natural Shoreline Partnership) that promotes natural, environmentally sound ways to strengthen shorelines against wave activity and provides specific native plants to establish a better habitat both onshore to retard runoff as we noted above, which also favors insects and birds, and in the water (termed soft engineering) to promote more macrophytes and better habitat for fishes. Macrophytes are well known to slow down wave action before it gets to shore. Many studies have demonstrated how detrimental even just a dock in the water can be to macrophyte cover, which in turn affects fish diversity and density. Macrophytes are keystone organisms in lakes, especially ones with incessant boat traffic. They provide critical habitat for fishes (spawning, fish-food organisms, and nursery habitat), retard boat and storm waves, and most importantly maintain the critical balance of macrophytes vs. algae. We have observed many lakes in Michigan shift from macrophyte to algae dominated ecosystems in recent years; hence care needs to be exercised in the control of nuisance macrophytes in the lake.

Boat Traffic

There is a severe problem of boat traffic on Lake Templene and many other Michigan lakes. Boats have become faster, bigger, and the recent addition of wave boats to the scene has really exacerbated this problem. We (Freshwater Physicians 2019) did a study and review of the impact of boat traffic on a Michigan Lake which we can provide if interested. We have seen shallow lakes like Lake Templene have their deep basins de-stratified because of boat traffic which can release large quantities of phosphorus and ammonia during the summer period when nutrients are generally limiting in most lakes. However, what is worse is the re-suspension of sediments into the water column from these large boats, especially wave boats that create huge waves and currents which can also wreak havoc on shores, as testified by all the shorelines with rip rap, but also cause macrophytes to become separated from the substrates they inhabit. Re-suspended sediments release nutrients into the water column during summer, as noted above, when nutrients are generally limiting in lakes and contribute to more macrophyte growth and algae blooms including blue-green algae, which can have toxins associated with them which could cause health problems for susceptible swimmers. Regulations by the lake association to slow boat speeds within a set distance from shore and mandating that large boats, especially wave boats stay away from shore in deep water could be enacted to avoid causing more problems, which could eventually end up in their banning from the lake.

SUMMARY OF RECOMMENDATIONS

Limnological Considerations

1. Phosphorus and nitrogen, key nutrients that fuel aquatic plant growth, are one of our concerns for Lake Templene. Our water quality data showed that nitrates were unusually high during summer in Prairie Creek, the inlet to Lake Templene, and unusually high in the lake proper. Water clarity has been declining, there are extensive beds of aquatic plants in the lake, a symptom of over enrichment, the dissolved oxygen in the hypolimnion is hypoxic and expected to go anoxic by the end of summers, and algae may be increasing in the lake, since chlorophyll a values, which are a surrogate for algae, were very high, much higher than earlier values generated by Gunderman (2013). The algae data we collected from a surface sample at station A showed low abundance of algae, especially blue-greens (no toxin-producers present) and the sample was dominated by diatoms, optimal, fat-rich food for the abundant zooplankers *Daphnia* that dominate the population. The lake is large (870 acres) and the watershed is extensive, some 187 square miles, 67% of which is agriculture. **Recommendations**: Our recommendation along with those proposed by Gunderman (2013) is to work with farmers in the watershed to install best management practices to reduce nutrient runoff into Prairie Creek and to restore wetlands. MDNR has pledged to work with all agencies and parties in the area to effect these very worthwhile goals.

2. Pogo once wisely stated that "we have met the enemy and they are us". Residents are on septic tanks, maintain lawns that extend to the water's edge, are probably fertilizing and killing weeds with pesticides on those lawns, and we saw very few greenbelts to thwart runoff. The soil is mostly sandy in the adjacent lake land area, encouraging seepage of septic tank effluent and lawn fertilizer into the ground water (and through runoff on steep sloped banks) and thence into the lake. In an effort to see if contamination was widespread, we sampled one well and found no evidence of contamination. **Recommendations**: Riparians are key constituents and should be advocates to maintain and improve the water quality of Lake Templene. To address the septic tank issue, we suggest additional sampling of a large number of wells (sample before the water softeners) anonymously (summarize data by sections of the lake) and the public health department or other responsible entity should perform this sampling. Sampling wells could also be installed at key points around the lake and water chemistry done (nitrates for sure, bacteria *E. coli* too- there are now new DNA techniques that can distinguish human DNA from other possible sources). Finding of contamination should be an impetus to build sewers to remove the source of nutrients and improve public health concerns. In the meantime, septic tanks should be pumped yearly or every 2 yr to remove accumulated sludge and prevent more nutrients from seeping in the lake. Secondly, residents should change their thinking about "pretty lawns" and embrace a more enlightened view of the planet on which they reside and

engage in ecologically helpful measures to improve the environment in which they live. This would include: elimination or severe reduction in fertilization of lawns, no leaf burning, no washing of vehicles with high-phosphate detergents, disposal of leaves outside the watershed, planting of greenbelts (see Michigan Shoreline Protection website), and installation of water gardens to process runoff water before it enters the lake (see Appendix 1 for list of things to do). There are huge numbers of swans and geese on the lake- these should not be encouraged to stay by feeding and it may be necessary to do some reduction in the population through egg removal if the MDNR will give approval.

Fish Community Considerations

1. Gunderman reported that the lake is forage fish rich and predator poor, which we can confirm. Apparently the most common predator is the largemouth bass, whose abundance ranks among the best in the state, even though we were unsuccessful in assessing the abundance of the larger individuals and very few were collected in the Gunderman study. Growth data showed largemouth bass mostly growing at state averages during 2022, while Gunderman found they were growing at state averages through age 4 then declined in growth. We did adequately sample the smaller age groups and found that there was a large group of YOY largemouth bass present in the near shore zone, so successful reproduction certainly occurred during 2022. The other potential top predators that are also sport fishes were also rare and included northern pike, channel catfish, and walleye. **Recommendations**: We are sure that most bass fishers practice catch and release and that is encouraged, since the large fish take a long time to mature (a 15 inch fish is 6 years old), they are productive spawners, release allows another fisher to catch them again, and most large fishes, especially less fatty fishes like largemouth bass, are contaminated with mercury (see MDNR guidelines for how many meals can safety be eaten). Northern pike and walleyes are rare in the lake and will be stressed and not grow well during summer, since they are cool water fishes subjected to the fish squeeze depicted in Fig. 3. Enjoy those that are caught and do not stock any as the habitat is not adequate for their survival. Channel catfish should have done better than they are according to our catches (none), since the habitat in Lake Templene is ideal for this species. Their abundance should be monitored. Other fish predators that were present in some numbers included: spotted gar, bowfin, brown and yellow bullheads, larger yellow perch, black crappies, and rock bass. They should be appreciated for their contribution to control of the forage fish populations, ensuring good growth of surviving members.

2. There is a large potential sport fishery for two other species: bluegills and black crappies, which were prominent in the Gunderman study and in ours. Bluegills were the most-abundant fish collected. Bluegills were growing way above state averages during 2013 while we found yearlings growing faster, but other larger age groups at

state averages. Bluegills were eating zooplankton (which we noted was composed of a large percentage of *Daphnia*, excellent food) and insects, including *Hexagenia* (mayflies) naiads, which should promote good growth. For black crappies, we captured great numbers, including some large 12-in individuals and Gunderman found that their abundance estimates for black crappies were some of the highest in the state. Fish in Gunderman's study were growing almost 1-2 in above state averages, while those we caught were growing at state averages. Black crappies were eating zooplankton at small sizes and fish at larger sizes. Yellow perch, another popular sport fish, was uncommon, with few large fish caught. **Recommendations**: There are good populations of these two species in the lake with a number of predators that should help control their smaller cohorts promoting good growth of the larger individuals. One plea we would make is this: Gone are the days of cane pole fishers. Modern fishers have larger boats usually equipped with electric motors and sophisticated GPS, depth finders, and fish locators. These upgrades result in the potential to over harvest vulnerable fisheries, such as black crappies and bluegills during nesting and when they are visible on radar in offshore haunts. The goal should not be to "limit out", but to provide a good meal for the family, allowing some large centrarchids (sunfish) to propagate for future fisheries.

Drawdowns

1. Drawdowns have been done on occasion in Lake Templene. Gunderman commented stating it did well in controlling starry stonewort and that it appeared to have no obvious effect on fish year class strength. A benthos study showed that mayflies and isopods declined, while there was no effect on other species. Other studies have also shown that drawdowns control Eurasian milfoil, coontail, water lilies, water weeds, and bladderwort (an alga) in the drawdown zone and promote bushy pondweed, thin leaf pondweed, and cattails. We observed that Eurasian milfoil was eliminated and that eelgrass was the first native species to colonize the nearshore zone after was re-watered. **Recommendation**: Drawdowns are a useful tool, Lake Templene has the ability to do one with the dam, and the lake association has had success in controlling starry stonewort in the past. If starry stonewort is judged to be a nuisance and there is also Eurasian milfoil dense accumulations in the nearshore zone, a drawdown would be a worthwhile recommendation to ameliorate the problem. In addition to plant control, it consolidates, dries, and aerates flocculant sediments leading to more solid substrates. Our seining on the north end of the lake certainly identified one area (very mucky) that would benefit from a drawdown.

Macrophyte Control

1. We discussed macrophyte control above using drawdowns, but some elements bear repeating. Aquatic plants are critical habitat for fish and help to resist and modulate currents caused by boat-generated and wind-caused currents that damage and erode

shorelines. In addition, nutrients in a lake will, like a garden, produce a quantity of plants-- macrophytes or algae in a lake. At the present time, macrophytes dominate Lake Templene, and we did not see nor hear about excessive blue-green algae outbreaks, even though we detected some in our analyses, albeit at low abundances and non-toxin producers. We also noted the cautionary tale, that some lakes we have studied, went from macrophyte-dominated to algae-dominated and reversing that trend once initiated has not been successful. The situation is complicated by the presence of non-indigenous plant species that can seriously damage the quality of recreational experiences on the lake and damage fish spawning sites by covering them over with dense stands of plants. **Recommendation**: The goal of aquatic plant control should be the protection and enhancement of native plants and the control of non-indigenous ones. Eurasian milfoil is best controlled by herbicides, with recommendations for using a new one called Procellacor. Starry stonewort is an alga which is controlled using copper sulfate or harvested, both of which have drawbacks. Copper sulfate can accumulate in the sediments and kills snails, while harvesting can remove large quantities of plants, but it is like mowing the lawn and has to be repeated. The drawdown discussed above is a good compromise, since it will kill starry stonewort with minimal side effects on fish recruitment and benthos.

Non-indigenous Species

1. There are at least six non-indigenous species in the lake: zebra mussels, Eurasian milfoil, curly-leaf pondweed (*Potamogeton crispus*), starry stonewort, spiny water nymph *(Najas marina)*, and common carp. Probably all of these species were brought into the lake by boaters, fishers discharging bait into the lake instead of killing it, and other ways by attaching to items or being present in ballast water or water left in boats that were used in the Great Lakes or other contaminated inland Michigan lakes. There are several other invasive species that are not currently in the lake. **Recommendations**: The obvious solution to this problem is signs at the public access sites where boats are launched that mandate cleaning water craft and other items that may harbor exotic species, chlorinating any water left in the boat's bottom or ballast water pumps, or drying the boats out for a long period of time prior to launching. This also applies to riparian boat owners, since Lake Templene is now a source of invasive species so people in boats going to other lakes need to be aware; in addition, people coming from other places that are contaminated need to be aware and not contaminate Lake Templene. No live bait should be dumped after use into the lake nor should there be any stocking of fishes by residents, since they could carry diseases and parasites. Common carp if caught should be killed and their removal by bow fishers is encouraged.

Shoreline Habitat Modifications

1. Rip rap and hardened structures along shorelines are a common feature at Lake Templene. Riprap is not good fish habitat and reflects waves from wind and boat generated currents, stirring up nutrient laden sediments and releasing them into the lake fostering more aquatic plant growth. **Recommendations**: There are more ecologically sound ways (soft engineering) to retard boat traffic currents and wave action, including regulating boat speeds near shore. In addition, there is a website (Michigan Natural Shoreline Partnership) that promotes natural, environmentally sound ways to strengthen shorelines against wave activity and provides specific native plants to establish a better habitat both onshore to retard runoff as we noted above, which also favors insects and birds, and in the water to promote more macrophytes and better habitat for fishes. Macrophytes are well known to slow down wave action before it gets to shore. Many studies have demonstrated how detrimental even just a dock in the water can be to macrophyte cover, which in turn affects fish diversity and density.

Boat Traffic

1. There is a severe problem of boat traffic on Lake Templene and many other Michigan lakes. Boats have become faster, bigger, and the recent addition of wave boats to the scene has exacerbated this problem. We have seen shallow lakes like Lake Templene have their deep basins de-stratified and sediments in nearshore areas re-suspended because of boat traffic which can release large quantities of phosphorus and nitrogen during the summer period when nutrients are generally limiting in most lakes. **Recommendations**: The lake association should disseminate to the riparians and post at access sites, suggestions or rules for large boats, especially wave boats, to stay within a set distance off shore and go no wake in shallow water. If problems continue and these rules are ignored, wave boats should be considered for banning from 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 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.

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

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

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

7. LEAVE THE SHORELINE IN ITS NATURAL STATE; PLANT GREEN BELTS. Do not fertilize lawns down to the water's edge. The natural vegetation will help to prevent erosion, remove some nutrients from runoff, and be less expensive to maintain. Greenbelts should be put in to retard runoff directly to the lake. See website: Michigan Shoreline Partnership for guidelines, plants to install, and recommendations for how to treat your lake shore to maximize healthy ecological ecosystems.

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/SWANS. Waterfowl droppings are rich in nutrients and bacteria.

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