Picture 1. Ogemaw Lake, 16 August 2017

A FISHERIES AND LIMNOLOGICAL SURVEY OF

OGEMAW LAKE

WITH RECOMMENDATIONS AND A MANAGEMENT PLAN

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INTRODUCTION

We were asked to perform a fishery investigation of Ogemaw Lake located east of West Branch, MI in Ogemaw County, and to develop short-term and long-term fish management plans for the lake. Ogemaw Lake is a mesotrophic lake bordering on eutrophic with an extensive shallow littoral zone, a number of islands, and a 24 - ft deep hole in the middle of the lake. The lake is ringed with many houses which are all on septic tanks, and there are islands and a few long, narrow passage ways and canals on various parts of the lake which also berths many boats. There is a considerable amount of sand on the bottom in littoral areas (and throughout the watershed) and there are extensive beds of aquatic plants along most of the shoreline and out to moderately deep water, which can act as excellent habitat for insect prey and good spawning sites for sunfishes, but can also be a detriment to boat and fishing activity when excessive growth develops. Eurasian milfoil and starry stonewort are also found in the lake.

The lake is a 437-acre lake according to Progressive AE and is fished extensively by residents. It has been stocked with at least 10 species of fishes in the past, including trout (species not noted, probably rainbow trout) (Appendix 2).

HISTORY

The lake has been monitored by Pullman (2009), who studied aquatic plants in the lake. He found 24 species, including Eurasian milfoil during 2007 and suggested that zebra mussels were present. We saw no evidence of them during our sampling, either by observing rocks and vegetation while seining, or in the diets of fish we examined. Follow-up studies were done by Progressive AE (2016) during June and July. They assessed the abundance and distribution of aquatic plants, produced a depth-contour map (modified for this report), and a plant biovolume map. They found 31 species of aquatic plants, with the most widespread being: Illinois pondweed (77% of sites), wild celery (eel grass) (64%), and the alga *Chara* (59%). Unfortunately, two exotic species were also noted: Eurasian milfoil (11%) and a new addition, Starry stonewort (11%). Their philosophy is to focus on spot treatment of places where the Eurasian milfoil and starry stonewort grows and support survival of native species, because of their importance in supporting a number of important considerations (fish food, fish shelter, spawning substrate, inhibiting sediment resuspension) for Ogemaw Lake.

Crawford (2009) provided an assessment of fish habitat, discussed fish management proposals, and made other recommendations. Our data show the lake is mesotrophic because of some dissolved oxygen on the bottom during stratification, high water clarity, and moderate nutrient concentrations.

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

PHYSICAL PARAMETERS

Depth

Depth is measured in several areas with a sonic depth finder or a marked sounding line. We sometimes run transects across a lake and record the depths if there are no data about the depths of the lakes as we did in this study. These soundings were then superimposed on a map of the lake and a contour map constructed to provide some information on the current depths of the lake.

Acreage

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

Hydrographic Map

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

Sediments

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

Light Penetration

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

Temperature

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

CHEMICAL PARAMETERS

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

Temperature Stratification

Temperature governs the rate of biological processes. A series of temperature measurements from the surface to the bottom in a lake (temperature profile) is very useful in detecting stratification patterns. Stratification in early summer develops because the warm sun heats the surface layers of a lake. This water becomes less dense due to its heating, and "floats" on the colder, denser waters below. Three layers of water are thus set up. The surface warm waters are called the epilimnion, the middle zone of rapid transition in temperatures is called the thermocline, and the cold bottom waters, usually around 39 F (temperature of maximum density), are termed the hypolimnion. As summer progresses, the lowest cold layer of water (hypolimnion) becomes more and more isolated from the upper layers because it is colder and denser than surface waters (see Fig. 1 for documentation of this process over the seasons).

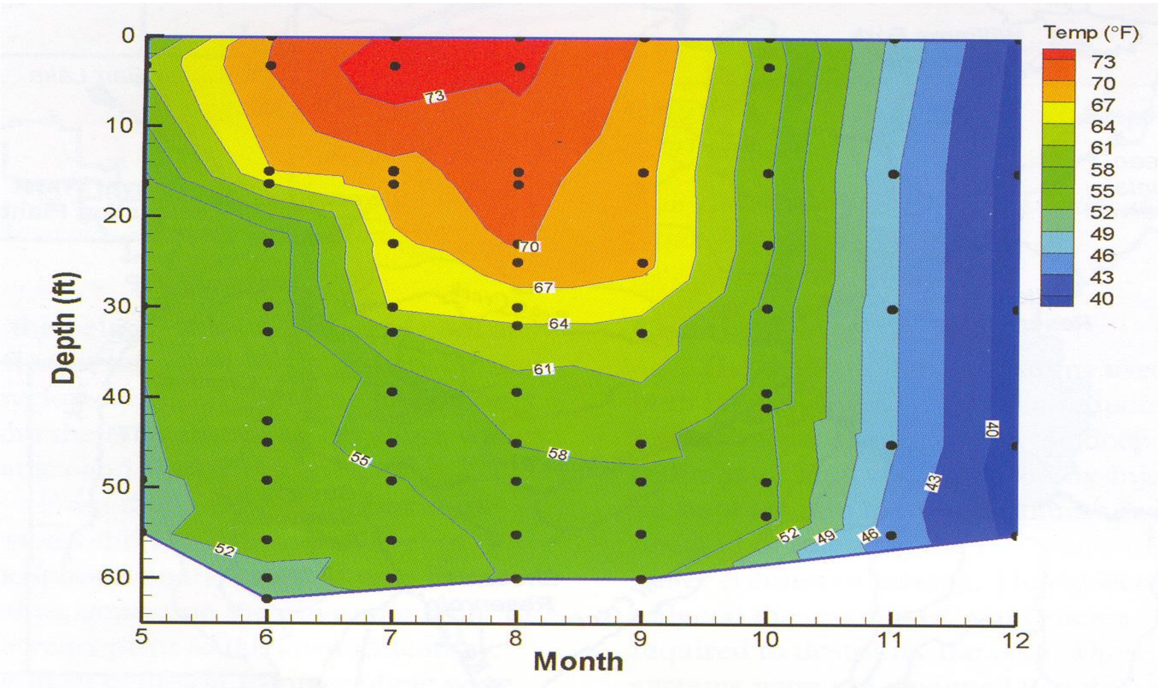


Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red yellow and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during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

When cooler weather returns in the fall, the warm upper waters (epilimnion) cool to about 39 F, and because water at this temperature is densest (heaviest), it begins to sink slowly to the bottom. This causes the lake to "turnover" or mix (blue part on right of Fig. 1), and the temperature becomes a uniform 39 F top to bottom. Other chemical variables, such as dissolved oxygen, ammonia, etc. are also uniformly distributed throughout the lake.

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

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

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).

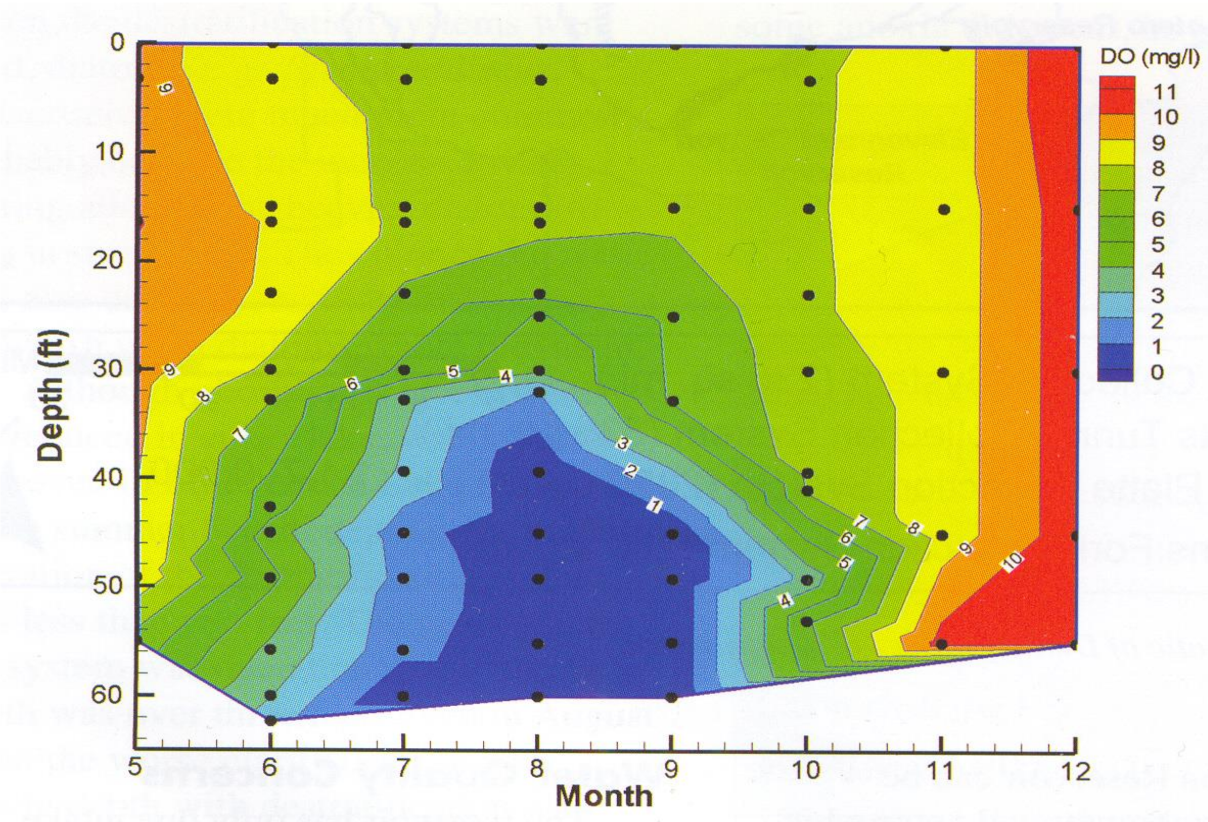


Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when 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 here and also changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic).

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

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

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

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 29-hour cycle. During the day in summer, plants photosynthesize and produce oxygen, while at night they join the animals in respiring (creating CO_2) and using up oxygen. This creates a diel cycle of high dissolved oxygen levels during the day and low levels at night. These dissolved oxygen sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

pH

The pH of most lakes in this area ranges from about 6 to 9. The pH value (measure of the acid or alkaline nature of water) is governed by the concentration of H (hydrogen) ions which are affected by the carbonate-bicarbonate buffer system, and the dissociation of carbonic acid (H_2CO_3) into H + ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO_2 from the carbonate-bicarbonate system. The pH will rise as a result. During evening hours, the pH will drop due to respiratory demands (production of carbon dioxide, which is acidic). This cycle is similar to the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO_2 during the day in photosynthesis there is a drop in CO_2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO_2), thus causing a rise in CO_2 concentration and a concomitant decrease in pH toward a more acidic condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution, which would cause deviations from expected values. In the field, pH is measured with color comparators or a portable pH/conductivity meter and in the laboratory with a pH meter.

Alkalinity

The amount of acid (hydrogen ion) that needs to be added to a water sample to get a sample to a pH of 4.5 (the endpoint of a methyl-orange indicator) is a measure of the buffering capacity of the water and can be quantitatively determined as mg/L or ppm as calcium carbonate ($CaCO_3$). This measurement is termed total alkalinity and serves as an indicator of basic productivity and as an estimate of the total carbon source available to plants. Alkalinity is a measure of hydroxides (OH^-), carbonates ($CO_3^{=}$) and bicarbonates present. Plants utilize carbon dioxide from the water until that is exhausted and then begin to extract CO_2 from the carbonate-bicarbonate buffer system through chemical shifts. As discussed before, this decrease in CO_2 concentrations causes great pH increases during the day and a pH drop during the night. There are two kinds of alkalinity measured, both based on the indicators, which are used to detect the end-point of the titration. The first is called phenolthalein alkalinity (phth) and is that amount of alkalinity obtained when the sample is titrated to a pH of 8.3. This measurement is often 0, but can be found during the conditions previously discussed; that is, during summer days and intense photosynthesis. Total alkalinity was noted above and includes phenolthalein alkalinity.

Hardness

Like alkalinity, hardness is also a measure of an ion, though these are divalent cations, positive double charged ions like calcium (Ca^{++}) and magnesium (Mg/L++). Again, the units of hardness are mg/L as $CaCO_3$. A sample of water is buffered and then an indicator is added. Titration to the indicator endpoint using EDTA completes the analysis. As with all our analyses, for more detail, consult Standard Methods. Alkalinity and hardness are complementary, so that comparing the two readings can give information about what ions are present in the system and confirm trends seen in other data. Alkalinity and hardness are complementary because every calcium ion must have a bicarbonate ion or other such divalent negative ion and vice versa; each carbonate or hydroxide ion must have a divalent or monovalent anion associated with it. For example, we might find high chlorides from street run-off in a particular sample. Since chlorides are probably applied as calcium chloride ($CaCl_2$), we would confirm our suspicions when hardness (a measure of Ca^{++} ions) was considerably higher than alkalinity. If alkalinity were higher than hardness it would indicate that some positive anion like potassium (K^+) was present in the lake, which was associated with the bicarbonate and carbonate ions but was not measured by hardness. Generally speaking, high alkalinity and hardness values are associated with a greater degree of eutrophication; lakes are classified as soft, medium, or hard-water lakes based on these values.

Chlorides

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

Phosphorus

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

Nitrogen

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

BIOLOGICAL PARAMETERS

Algae

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

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

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

The types of algae found in a lake serve as good indicators of the water quality of the lake. The algae are usually microscopic, free-floating single and multicellular organisms, which are responsible many times for the green or brownish color of water in which they are blooming. The filamentous forms, such as *Spirogyra* and *Cladophora* are usually associated with aquatic macrophytes, but often occur in huge mats by themselves. The last type, *Chara*, a green alga, looks like an aquatic macrophyte and grows on the bottom in the littoral zone, sometimes in massive beds. It is important to understand the different plant forms and how they interact, since plants and algae compete for nutrients present and can shade one another out depending on which has the competitive advantage. This knowledge is important in controlling them and formulating sensible management plans. Samples are collected using a No. 10 plankton net (153-micron mesh), preserved with ethanol and examined microscopically in the laboratory.

Macrophytes

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

Zooplankton

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

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

Zooplankton is collected by towing a No. 10 plankton net (153 microns) through the water and the resulting sample is preserved with 10% formaldehyde and then examined microscopically in the laboratory. Qualitative estimates of abundance are usually given.

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 requires high dissolved oxygen at all times and good water quality to survive, so when present it indicates excellent water quality is present. We examine samples from deep water stations for the presence of organisms, as certain types live in low to no dissolved oxygen conditions, whereas other kinds can only exist when their high dissolved oxygen needs are satisfied.

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

Fish

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

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

RESULTS

WATERSHED

Ogemaw Lake is located in Ogemaw County (Mills and Churchill townships) and is in the Rifle River watershed. Water flows out of Ogemaw Lake through a culvert on the west side of the lake (see Fig. 4) near the private access site. The local watershed for the lake is composed of the land surrounding the lake which has water that lands on it flow into the lake. Water flows into the lake via Petersen Creek, which may be a good northern pike spawning creek. There are many houses located on Ogemaw Lake (Fig. 3). There are lawns and large areas of grasses and shrubs and large forested areas outside the ring of houses. Agricultural land is nearby in several localities. The houses around the lake are still on septic tanks, which have been shown to be major sources of nutrient enrichment to lakes. There is also Eurasian milfoil and starry stonewort in the lake which are serious threats to ecosystem integrity since they can expand and cover large areas of the substrate if conditions are optimal.

The local riparian zone is very important also, especially that band right at the lake interface with land (the riparian zone: see Appendix 1 for lawn care and other recommendations). Since most of the soil is sandy, water from septic tanks percolates through much faster into the groundwater and fewer nutrients are absorbed by soil than it would with loamy soils. Things that can be done to inhibit entry of undesirable and deleterious substances into the lake are: planting greenbelts (thick plants that can absorb nutrients and retard direct runoff into the lake) along the lake edge, reducing erosion where ever it occurs, reducing or eliminating use of fertilizers for lawns, cutting down on road salting operations, not feeding the geese or ducks, no leaf burning near the lake, prevention of leaves and other organic matter from entering the lake (this does not apply to woody debris, since it is important fish habitat), and care in household use of such substances as fertilizers, detergents to wash cars and boats, pesticides, cleaners like ammonia, and vehicle fluids, such as oil, gas, and antifreeze (summarized in Appendix 1). Chlorides (discussed later) are one indicator of runoff and your concentrations were unusual, since they were high in surface water (82 mg/L) but much lower at mid depths and bottom (14-16 mg/L). So we have the conundrum of good news for most of the lake, since 14-16 mg/L is an indication of good water quality and low runoff, while 82 mg/L is elevated. This could be due to some anomaly associated with stratification; more sampling will be needed to elaborate on these data.

STATION LOCATION

Ogemaw Lake is a 437-acre lake located east of West Branch, MI. We established two types of stations on Ogemaw Lake for sampling various parameters in this study (Fig. 4, and Table 1). Water chemistry and zooplankton were sampled at the deepest site (station A), while station numbers and an accompanying code (S=seine, T=trap net) mark the location for sampling fish. These sites were chosen in various locations around the lake to maximize catch of fishes (Table 1, Fig. 4). Fishes were collected using seines at five stations and trap nets at six stations. Gill nets were not deployed at the request of the lake association.

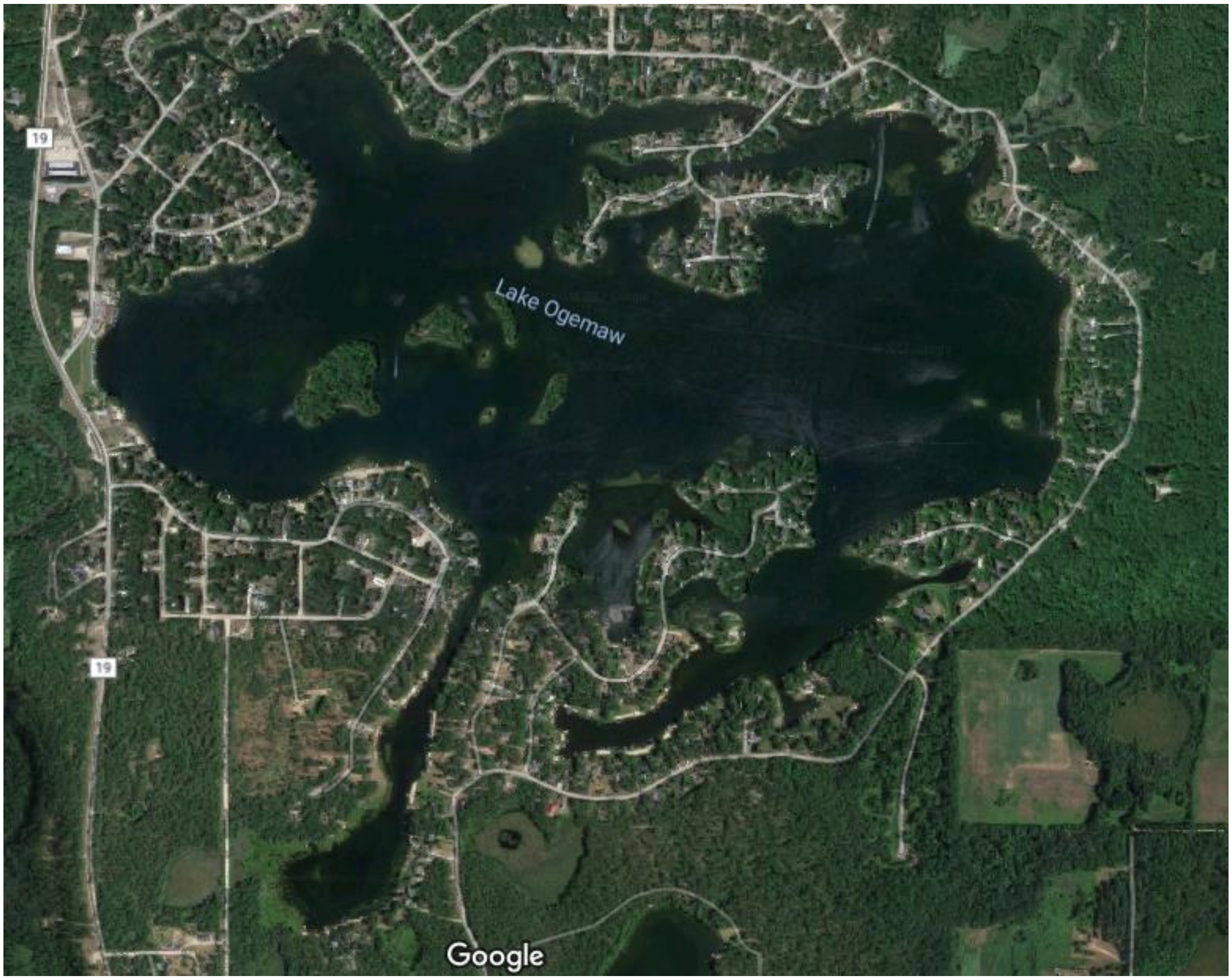


Figure 3. Google map of Ogemaw Lake showing the extensive development around most of the lake, the widespread existence of islands and canals, and the forested area away from the lake in the watershed.

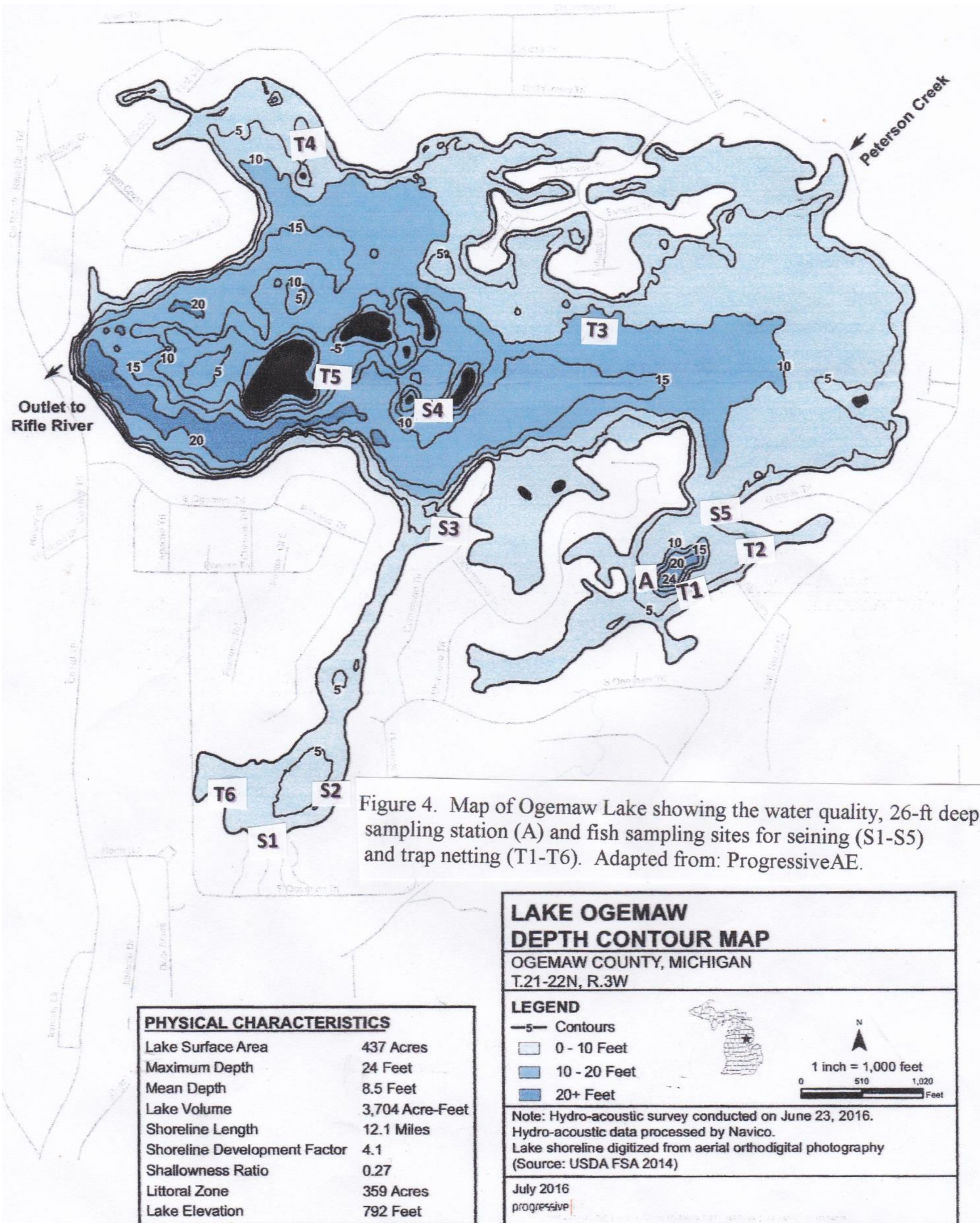


Figure 4. Map of Ogemaw Lake showing the water quality, 26-ft deep sampling station (A) and fish sampling sites for seining (S1-S5) and trap netting (T1-T6). Adapted from: ProgressiveAE.

Table 1. Date, time, GPS coordinates, and depth of stations where various gear were deployed on Ogemaw Lake, Ogemaw County, MI, 15-17 August 2017. T = trap net, S = seine. See Table 5 for definition of fish codes. * = YOY (young-of-the-year). TD = total distance of seine haul.

STA	TIME START	TIME END	DEPTH (FT)	GPS	GPS	FISH SPECIES CAUGHT
A	15-Aug	15-Aug	8	44 14 28.9 N	84 02 41.2 W	WATER QUALITY SAMPLE
T1	15-Aug	16-Aug				
	1348	1320	8	44 14 27.7 N	84 02 39.6 W	5 PS, 1 LB
T1	16-Aug	17-Aug				
	1325	1112	8	44 14 27.7 N	84 02 39.6 W	8 YB, 2 PS; THREW BACK 5 BG,1PS
T2	15-Aug	16-Aug				
	1359	1330	4	44 14 32.0 N	84 02 29.6 W	4 PS, 4 YB
T2	16-Aug	17-Aug				
	1342	1118	4	44 14 32.0 N	84 02 29.6 W	ZZ (NO FISH)
T3	15-Aug	16-Aug				
	1414	1220	10	44 14 52.3 N	84 02 43.6 W	1 BG, 1 BC, 1 NP, 1YB
T3	16-Aug	17-Aug				
	1223	1000	10	44 14 52.3 N	84 02 43.6 W	2 YB, 1 BG, 1 LB (18 IN)
T4	15-Aug	16-Aug				
	1451	1234	8	44 15 05.5 N	84 03 22.7 W	4 YB, 3 PS;BG, 15 BG THROWN BACK
T4	16-Aug	17-Aug				
	1241	1010	8	44 15 05.5 N	84 03 22.7 W	3 YB, 1 BG, 1 LB
T5	15-Aug	16-Aug				
	1459	1251	9	44 14 46.2 N	84 03 22.4 W	ZZ (NO FISH)
T5	16-Aug	17-Aug				
	1251	1019	9	44 14 46.2 N	84 03 22.4 W	1 BG
T6	15-Aug	16-Aug				
			6	44 14 11.2 N	84 03 287.5 W	ZZ (NO FISH)
T6	16-Aug	17-Aug				
			6	44 14 11.2 N	84 03 287.5 W	1 LB YOY
S1	16-Aug	16-Aug		TD=25 M		
	1539	1542	4	44 14 10.9 N	84 03 24.9 W	26 BG, 15 LB, 12PS
S2	16-Aug	16-Aug		TD=25 M		
	1544	1600	4	44 14 18.6 N	84 03 17.2 W	1 YP, 1 PS
S3	16-Aug	16-Aug		TD=25 M		
	1612	1630	4	44 14 33.2 N	84 03 04.8 W	1 NP*, 11 BG,11PS,15YP,1MM,36LB
S4	16-Aug	16-Aug		TD=80 M		
	1634	1650	4	44 14 44.8 N	84 03 09.6 W	3 BG, 14 LB,17YP
S5	16-Aug	16-Aug		TD=70 M		
	1701	1735	4	44 14 34.2 N	84 02 33.7 W	1 BG, 3 PS

PHYSICAL PARAMETERS

Depth

Ogemaw Lake is a shallow lake with one deep hole around 26 ft (Fig. 4). The area of Ogemaw Lake is 437 acres and of that 359 acres (82%) is littoral (shallow) zone. This area is extensive and highly vegetated. In addition, there are many canals, backwaters, and convoluted shorelines (12 miles) which are good fish habitat, but allow more development and access to the lake. As a result, we predict that Ogemaw Lake would be very productive with so much of its area shallow. Progressive AE (Fig. 4) provided information on what is known as shoreline development. If a lake were perfectly round, the value would be 1; Ogemaw Lake's value is 4.1, which is very high and reflective of the point we made above. Aquatic plants are keystone habitats in a lake for fishes; they provide aquatic insects for food, spawning habitat, and probably most importantly, nursery and shelter for smaller fishes. We clearly recognize that Eurasian milfoil and starry stonewort can be at the opposite end of the spectrum, since it grows so thick it can provide too much shelter for bluegills for example, leading to lack of exploitation by predators and stunting. However, in Ogemaw Lake we believe that because of the good water clarity, predators have the advantage, so it behooves the younger fish to have more aquatic plant cover to promote higher survival to adulthood. One of the strange findings in this regard is the lack of minnows in any of our seine hauls, which clearly indicates severe fish predation.

Acreage

Ogemaw Lake is 437 acres and is extensively developed around the lake with fulltime and seasonal homes. It also has a private access site on the west side (Fig. 3, 4). The extensive macrophyte littoral zone is acting like wetlands, providing many ecological services for Ogemaw Lake. These areas are critical nursery area for many small fishes (including a small northern pike we seined), which can grow there and then enter the lake proper later in development.

Light Penetration

The Secchi disc (measure of water transparency) readings during 15 August 2017 at station A was 3.5 m (12.3 ft). Lakes are classified according to their water transparency as follows: eutrophic <7.7 ft, mesotrophic 7.5-15 ft, and oligotrophic >15 ft. According to this classification, Ogemaw is a mesotrophic lake. The fact that there was still some dissolved oxygen on the bottom of the lake and its low nutrients, also tends to make the lake mesotrophic.

Temperature/Dissolved Oxygen

Water temperature is intimately associated with the dissolved oxygen profiles in a lake. The summer profile is the one that most characterizes a lake and the stratification impacts are very important. A lake goes through a series of changes (see introductory material-Temperature) in water temperature, from spring overturn, to summer stratification, to fall over turn, to winter conditions. During both summer and winter rapid decomposition of sediments and detritus occurs when bottom waters are fertile and can cause degraded chemical conditions on the bottom (to be discussed). Because the lake is essentially sealed off from the surface when it is stratified during summer, no dissolved oxygen can penetrate to the bottom and anoxia (no dissolved oxygen conditions- a dead zone) can result. This has implications for the aquatic organisms (fish will not go there) and chemical parameters (phosphorus is released from the sediments under anoxic conditions, which then contribute these nutrients to the lake during the fall overturn). One advantage of the lake being mostly littoral zone (82% is shallow), is that the internal loading effect (nutrients released during summer to fuel macrophyte and algae blooms after spring and fall turnover) is smaller than most lakes with many deep basins.

During early summer (15 August 2017), when we measured the temperature/oxygen profile, the dissolved oxygen measurements we showed that at the deep spot, there was a thermocline between 13 ft (4 m) and 16 ft (5 m), but there was some dissolved oxygen all the way to the bottom (1.2 mg/L on the bottom). Unfortunately, concentrations were low and most fish would be prevented from residing below 20 ft where concentrations were 1.6 mg/L or less (Table 2, Fig. 5). Although Ogemaw Lake is not yet at a place where anoxia is prevalent on the bottom during summer, it may be close to a tipping point. Our sampling was in mid-August and anoxia could develop later in the year or in years with extensive hot, calm weather. As noted if anoxia develops, there are two consequences that may develop: anoxia effectively makes the entire water volume below a certain depth unavailable to fish. Anoxia can also promote phosphorus regeneration from bottom sediments, but so far there is little evidence of this happening, since water chemistry data (discussed below – Table 3) showed no buildup of predictive nutrients, such as SRP, TP, or ammonia. Most warm water fishes require at least 3 mg/L while cool water fish, such as northern pike and walleye require 5 mg/L. Note that the optimal water temperature for walleyes, northern pike, and smallmouth bass is around 22 C (72 F) and their upper lethal temperature is around 30-31 C. The surface water temperature during out study was near 24 C. Hence these cool water fishes will be subjected to the squeeze noted in Fig. 6: warm temperatures in surface water forces them downward, while no dissolved oxygen in the preferred bottom cool waters of the lake forces them into too warm surface waters. As a result, northern pike, and especially walleye, will be stressed and probably not grow well during this period of the year. Some walleyes may die. This finding should be kept in mind when decisions regarding whether to plant more walleyes are made. This point is important for fish management considerations.

Table 2. Dissolved oxygen (mg/L) and water temperature (F) profile for station A (26 ft.) 16 August 2017 on Ogemaw Lake, Ogemaw County (see Fig. 4 for station location).

DEPTH -M	TEMP C	DO MG/L
0	23.8	7.9
1	23.7	7.9
2	23.3	7.8
3	22.9	7.6
4	22.6	6.8
5	19.3	3.3
6	15.5	1.6
7	13.2	1.3
8	12.6	1.2

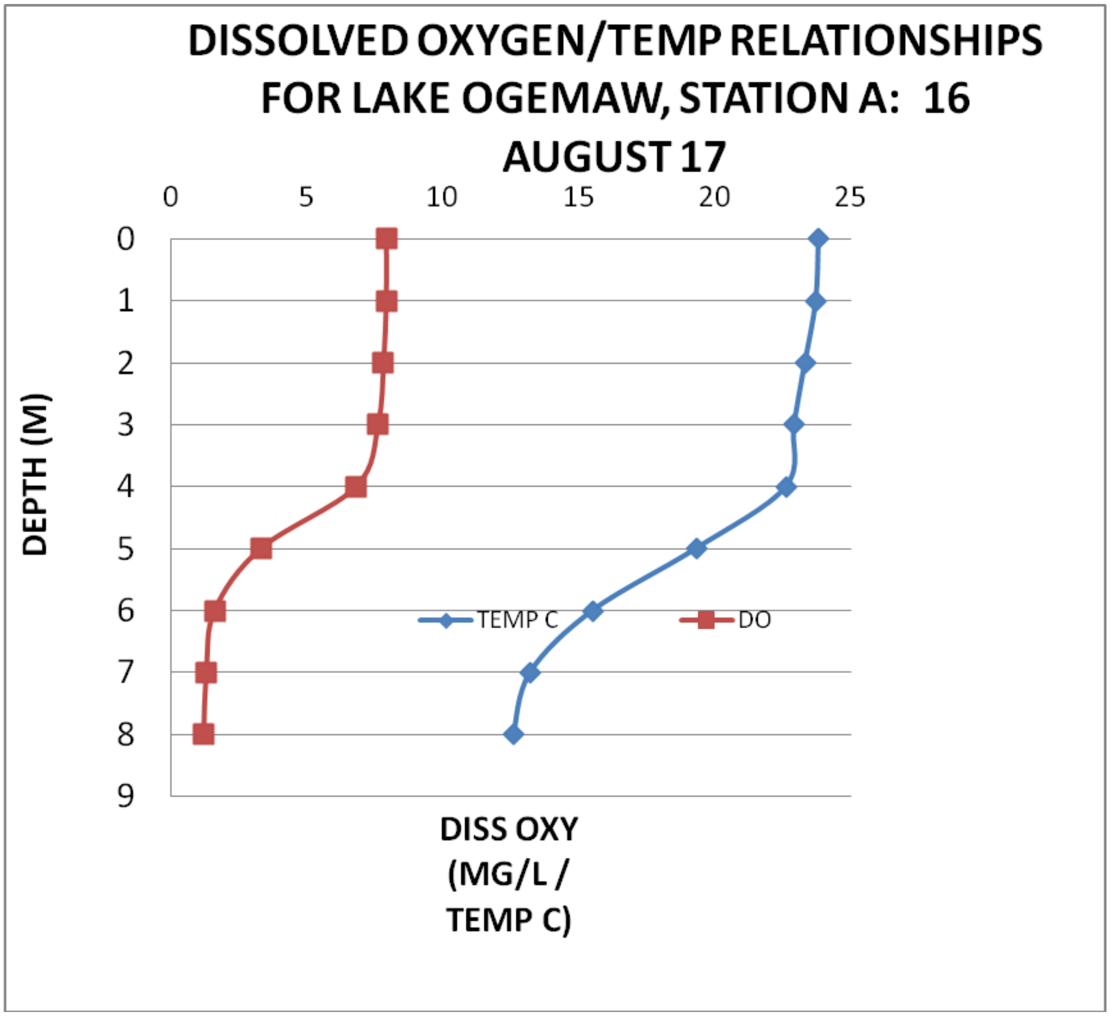


Figure 5. Dissolved oxygen (mg/L) and water temperature (C) profile for station A, Ogemaw Lake, 16 August 2017.

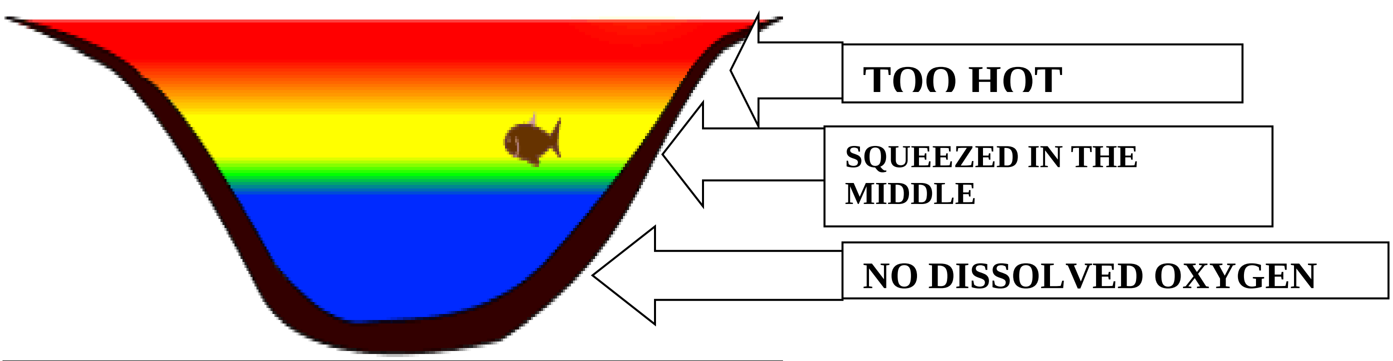


Figure 6. Depiction of the dissolved oxygen concentrations in a stratified lake, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where

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.

CHEMICAL PARAMETERS

pH

The pH (how acid or alkaline water is) for Ogemaw Lake during 15 August 2017 at station A (26 ft.) showed a typical pattern with similar values from surface and mid depth (8.67-8.46) to a more acidic nature on the bottom (7.99 – Table 3). The pH is highest at the surface where algal and aquatic plants remove carbon dioxide and increase pH, while it is lowest on the bottom where decomposition of bottom sediments increases the CO^2 produced and reduces pH.

Table 3. Conductivity (uSiemens), pH, chlorides (CL), nitrates (NO3), ammonia (NH3), total phosphorus (TP), and soluble reactive phosphorus (SRP) for Ogemaw Lake, 15 August 2017. See Fig. 4 for location of station A. All concentrations are in mg/L.

DEPTH	Ph	COND	CL	NO3	NH3	SRP	TP
SURF	8.67	350	82	0.11	<0.01	0.005	0.010
4 m	8.46	419	16	0.08	0.05	<0.005	
8 m	7.99	443	14	0.07	0.02	0.006	0.064

Chlorides

Chloride concentrations in Ogemaw Lake were somewhat of an enigma: high at the surface (82 mg/L) and lower at the mid and bottom (14-16 mg/L) (Table 3). Chloride ions are conservative ions, which means they are not altered by biological or chemical activity; they can only change with evaporation or input of water of differing concentrations of chlorides. They can derive from septic tank effluent, road salt runoff, or can be naturally occurring. Therefore, they accumulate in a lake and give a good impression of the past history of inputs of that ion, as well as co-occurring substances from runoff, such as nutrients, toxic substances, and sediment. Usually we measure similar concentrations of chlorides throughout the water column, so either there was some runoff of high chloride water or some other anomaly associated with stratification that we have not observed before. The low concentrations in bottom waters indicate that source inputs of chlorides in Ogemaw Lake are low historically, with no suggestion of excessive septic tank or road salt runoff so far. Part of the reason for these low values may be input from groundwater and/or Peterson Creek, which may be dominated by rainwater which has low chloride concentrations. The watershed around Ogemaw Lake is mostly forested which is also a positive feature.

Phosphorus

We are interested in phosphorus (P) because P is generally the limiting nutrient for plant growth and the level of concentrations can indicate the trophic state or amount of enrichment in the lake. Soluble reactive phosphorus (SRP) measures only that P which is dissolved in the water, which is the form that is readily available for algal and plant growth. Total P would be all the P in the water, dissolved and that tied up in algae or other detritus. During summer, SRP values throughout the water column were at trace levels (<0.005-0.006 mg/L), probably because algae and aquatic plants take up all the phosphorus (and nitrogen) for growth (Table 3). Phosphorus is probably limiting in surface waters at this time in Ogemaw Lake. We also measured total phosphorus (TP) at the surface of Ogemaw Lake as 0.010 while it was 0.064 mg/L at the bottom. The criteria for trophic status for TP are: oligotrophic <0.10 mg/L, mesotrophic 0.010-0.020 mg/L, and eutrophic > 0.020 mg/L. The surface value designates Ogemaw as in the oligotrophic to mesotrophic range, probably because of uptake of most phosphorus by plants. However, the bottom concentration was three times as high as the eutrophic indicator, making Ogemaw Lake eutrophic.

We concluded two things from these data: first, P is probably limiting in Ogemaw Lake in surface waters during summer and will stop growth of algae and plants until more phosphorus enters the lake (limiting nutrient). One way for that to happen is excessive water skiing and boating in the lake, which can stir up bottom sediments in shallow water, resulting in the release of phosphorus and promotion of plant growth. Phosphorus could enter the lake from runoff, continuing septic tank flow into groundwater, and by lawn fertilization. Residents need to do all they can to prevent nutrients from entering the lake so as to preserve the current water quality they do enjoy and so as not to stimulate more macrophyte growth. See Appendix 1 for suggestions. Second, it indicates that there is some accumulation of phosphorus on the bottom, either due to decomposition or settling of organic matter to the bottom.

Nitrates

Nitrate is very important since it too is a critical plant nutrient as well as P; however, blue-green algae can generate their own nitrogen, favoring them when nitrate concentrations are depleted. Nitrates in Ogemaw Lake during 15 August 2017 ranged from 0.07 mg/L on the bottom to 0. 11 mg/L at the surface (Table 3). These are extremely low concentrations of nitrate that were similar throughout the water column. As noted, we usually see trace concentrations of nitrates in surface waters as we observed with SRP, so it appears that there is inadequate P and N in the lake during this summer period and there is no generation of additional nitrates due to decomposition.

Ammonia

Ammonia is also a plant nutrient, but it can be toxic to fish in high concentrations. We usually measure negligible levels in surface water due to algal uptake and conversion to nitrates, while large concentrations are measured on the bottom, due to decomposition and under anoxic conditions. Ogemaw Lake had low levels of ammonia throughout the water column during 15 August 2017 (>0.01-0.05 mg/L - Table 3), which is another positive feature of the water quality on the bottom of the lake, due to the presence of dissolved oxygen near bottom. Worse conditions could develop later in the year which could allow more degraded conditions. Ammonia is formed by the decomposition of bottom sediments under low or no oxygen present. During fall turnover, this nutrient along with P compounds will be mixed into the lake, producing next year's crop of algae and macrophytes. However, it appears that because of the presence of dissolved oxygen and a small area that is deep in Ogemaw Lake, this phenomenon of "internal loading" should be minimal in the lake.

Hydrogen Sulfide

Hydrogen sulfide is a toxic substance produced under conditions of no dissolved oxygen (anoxia) from the decomposition of organic matter on the bottom. It is the rotten-egg smelling chemical; it was zero on the bottom, which was expected since there was dissolved oxygen present.

Conductivity

Conductivity is a measure of the ability of water to conduct current and is proportional to the dissolved solutes present. During our early summer survey, conductivity measures were as expected, lowest in surface waters (350 uS), more at mid depth (419 uS), and the most on the bottom (443 uS), due to accumulation of matter in bottom waters (Table 3). We would have expected high conductivity in surface water due to the high chlorides we measured, but apparently it had little effect on the readings. These are moderately low values, compared with other lakes, partially explained by the low chlorides which contribute to the conductivity measurement.

BIOLOGICAL PARAMETERS

Algae

We did not sample algae in Ogemaw Lake, but wanted to ensure that residents be on the lookout for this exotic species, called starry stonewort, which has been observed in Ogemaw Lake and is the object of control measures. Note this species is an alga, and is a very destructive plant which can alter dissolved oxygen patterns and cover spawning sites for warm water centrachids. It looks a lot like *Chara*, another green alga, which is usually crusty when rubbed on the fingers, but is somewhat different and looks more tubular.

Aquatic Macrophytes

Ogemaw Lake was populated with many species of macrophytes based on observations of Pullman (2009), who found 24 species, including Eurasian milfoil during 2007. During a 2016 study Progressive AE (2016) studied aquatic plants and found 31 species of aquatic plants, with the most widespread being: Illinois pondweed (77% of sites), wild celery (eel grass) (64%), and the alga *Chara* (59%). Unfortunately, two exotic species were also noted: Eurasian milfoil (11%) and starry stonewort (11%). Aquatic plants are widespread in Ogemaw Lake, mostly due to the shallow nature of the lake where 82% is littoral zone. Plants are a very important component of the lake ecosystem serving several functions. They are shelter and nurseries for young fish, they are spawning substrates for some species (e.g., minnows), they produce many insects which are important food for fishes, and help to retard wave action from re-suspending sediments and releasing limiting nutrients promoting algal and macrophyte growth. Some of aquatic plants observed while seining and pulling in nets with accompanying plants, include one invasive species: Eurasian milfoil *(Myriophyllum spicatum)* and several native species including: bulrushes *Scirpus*, cattails *Typha* spp. eel grass *Vallisneria*, thin-leafed naiads *Najas* spp., and large-leafed pondweed *Potamogeton amplifolius*. We accept that access to and from residences and beach areas are important for riparians and that invasive plant species need to be controlled. However, there should be an emphasis on maintaining native species and spot treatment of exotics. Macrophytes are critical components of the ecosystem, not only for fish, but for sustaining good balance among food web components. The alternative to macrophytes is algae, so you do not want to reach a tipping point where algae dominate the lake and shade out aquatic plants.

Zooplankton

Zooplankters are small invertebrates present in most lakes and ponds (See Picture 3 for an example of a copepod and Picture 4 for an example of *Daphnia*, a cladoceran). They are critical connectors between plants (they mostly eat algae) and fish, since they are important as food for larval fish and other small fishes in the lake and are indicators of the amount of predation that fish exert on these organisms. A lack of the large zooplankter *Daphnia* can indicate stunting by bluegills. Zooplankton we collected at the deep station A (Fig. 4) was comprised of 14 taxa represented by two groups: cladocerans (43% of the total) and copepods (57%) (Table 4). These two groups (cladocerans and copepods) are different in two respects: cladocerans are usually slow, important fish food, large, and more efficient at eating algae than copepods, thus helping to improve water clarity. Copepods are fast, more difficult to catch by fish, and are less efficient than cladocerans at eating algae. There was a diverse group of these organisms in Ogemaw Lake (n=14) and they were typical of most inland lakes. The most abundant taxa included: *Daphnia* (see Picture 4) – 5% of total, *Bosmina* – 12%, *Ceriodaphnia* – 14%, calanoids C1-C5 (juvenile stages of copepods) – 11%, cyclopoids C1-C5 – 25%, and *Skistodiaptomus* – 10%. One important aspect we consider is the abundance of *Daphnia* (5%) and *Bosmina* (12%), since these are important indicators of fish predation and the ability of zooplankton to control algae in the lake. First, *Daphnia* was found but at relatively low densities, while *Bosmina* was found in higher densities (12% of totals). Examination of the diet information reveals that three species of fishes, YOY (young-of-the-year) bluegills, largemouth bass, and yellow perch were all eating large amounts of *Bosmina*. No *Daphnia* were observed in stomachs (they were only examined qualitatively), although we expect that they were the first zooplankters eaten in early summer since *Daphnia* is slow, energy-rich, large, and an easy target for fishes and the reason for their low abundance. *Bosmina*, which are somewhat smaller than *Daphnia*, was fairly abundant (12% of totals) so it represents a readily available food supply which most of the planktivores in Ogemaw Lake were feeding on (discussed below in fish section). Some *Acroperus harpae* (Chydoridae) were also eaten by Ogemaw fishes. These zooplankters are associated with the bottom and usually not collected in vertical tows.

Therefore, since we found large quantities of these relatively large zooplankters (*Bosmina*) present in the lake it indicates that at least during summer fish predation was not severe, as is often seen in lakes dominated with planktivores (zooplankton eaters), such as small bluegills, yellow perch, and black crappies. Usually in these cases we see no *Daphnia* in our samples and very few if any *Bosmina* either. These situations usually result in stunting of prey fish, so we believe that this is not happening in Ogemaw Lake. In cases noted above, biologists usually address this situation by stocking more predators to reduce the numbers of small prey fish, which can result in increased water clarity, since remaining large zooplankton will eat more algae. Our fish sampling confirmed that there were moderate numbers of small bluegills present, but they were confined to the near shore zone in the aquatic plants, and apparently did not go offshore much into the open water during our sampling in August. We have seen large numbers of YOY bluegills in our trap nets in moderately deep water in other studies, which we did not observe in your lake. Their presence near shore, rather than offshore, may likely be due to the clear water, abundant vegetation, and presence of predators: largemouth bass and bullheads. Our diet data confirmed that largemouth bass were eating many bluegills, largemouth bass, and yellow perch. We also noted that yellow bullheads, which mostly feed at night, were really consuming large numbers of bluegills. It is well known that bluegills will remain in plant cover and feed more on benthos than zooplankton if predation threats are severe.

Table 4. A listing of the abundance (% composition based on counting a random sample of 114 organisms) of zooplankton species (see Picture 3-4) collected from station A in Ogemaw Lake, 22 August 2017 (see Fig. 4 for station locations).

Taxon	Order	Sub Order	Family	Count	% Comp
Acroperus harpae	Cladocera	Eucladocera	Chydoridae	1	1
Bosmina longirostris	Cladocera	Eucladocera	Bosminidae	14	12
Ceriodaphnia laticaudata	Cladocera	Eucladocera	Daphnidae	5	4

Ceriodaphnia spp.	Cladocera	Eucladocera	Daphnidae	16	14
Daphnia mendotae	Cladocera	Eucladocera	Daphnidae	5	4
Daphnia rosea	Cladocera	Eucladocera	Daphnidae	1	1
Diaphanosoma birgei	Cladocera	Eucladocera	Sididae	7	6
Calanoid C1-C5	Eucopepoda	Calanoida	Many	13	11
Cyclopoid C1-C5	Eucopepoda	Cyclopoida	Cyclopidae	28	25
Mesocyclops edax F	Eucopepoda	Cyclopoida	Cyclopidae	1	1
Mesocyclops edax M	Eucopepoda	Cyclopoida	Cyclopidae	7	6
Skistodiaptomus oregonensis F	Eucopepoda	Calanoida	Diaptomidae	11	10
Skistodiaptomus oregonensis M	Eucopepoda	Calanoida	Diaptomidae	3	3
Tropocyclops prasinus mexicanus F	Eucopepoda	Cyclopoida	Cyclopidae	2	2
			TOTALS	114	100

Picture 2. A copepod (zooplankter).

Picture 3. *Daphnia*, a large zooplankter, adept at eating algae.

Fish

Fish Species Diversity

We collected fish using a 50-ft seine at five stations (see Fig. 4, Picture 4) and six trap nets at six stations (Fig. 4, see Picture 5) (set twice for 24 hr each time) with some of the resulting fish shown in Picture 6 (from a trap net). Nets were deployed on 15-17 August 2017 (see Table 1 for times and catches); trap nets were picked up after having been left overnight for about 24 h; nets were reset the next day for 2 consecutive days of trap netting. Most fish were released; we kept enough for an adequate sample for ageing and diet analyses (see Table 5). We never want to kill too many fish, especially top predators, as they are so important to fish community balance in a lake. This is one of the reasons we did not utilize gill nets, which would have provided a better sample of the some of the top predators in the lake. We could have used a few more large fish (especially largemouth bass and northern pike and walleyes if present), but the ones we did catch provided a sample for some basic information on the lake.

Picture 4. The 50-ft seine used to collect fishes at station S2 (see Fig. 4) from Lake Ogemaw, 16 August 2017.

Picture 5. Type of trap net used in Ogemaw Lake, 16 August 2017. Note fish in far end of net and attached macrophytes.

The lake, based on our catches, had a low diversity of fish species, (nine); all were native (Table 5). We suspect there are other species present in the lake, including walleyes and channel catfish, which have been stocked in the past. Bowfin and longnose gar may also be present. The Crawford (2009) study noted the presence of three other species we did not collect: rock bass, minnows, and brook silversides. We did collect a large number of bluegills that ranged from 1.1 to 6.8 inches. We also collected 47 pumpkinseeds that ranged much larger than the bluegills (2.2-8.2 inches). Pumpkinseeds are known for eating mollusks and there are apparently a good supply of snails and clams in the lake. We particularly noted the presence of mystery banded snails that were very common among the vegetation and eaten by pumpkinseeds along with other snails and aquatic insects. One black crappie was collected that was 11.5 inches. These are important mid-water predators, and we would have liked to have seen more in our catches, since they are efficient predators of bluegills and other small forage and they are excellent for sport fishers.

Two members of the perch family were collected: yellow perch and Iowa darters. The yellow perch ranged 3.5 to 7 inches and are outstanding sport fish, because they are readily caught and excellent table fare. We captured a large number of these fish (mostly YOY), indicating that they are prevalent in the lake, but have not grown to large sizes, based on our data. Usually if yellow perch are present they are heavily preyed on by top predators, especially northern pike and walleye, but we expect that channel catfish and bullheads would also feed on them. The fact that we got large numbers of YOY fish indicates that they had a good year class in 2017 and that they had good survival, probably because of the widespread availability of macrophytes, which have provided good cover and good benthic food for these small fishes. In addition, there are adequate spawning sites for this species (see Crawford 2009 for more on spawning sites for fishes in Lake Ogemaw). The second species is the Iowa darter (1.5 in), which we only found in the stomach of a 4.1-inch largemouth bass. They are apparently rare in the lake. Another rare species we collected was the mudminnow. These are rare in lakes with many predators, but apparently there was enough aquatic vegetation to provide cover so they all were not extirpated. The two we got were 1.8-2.4 inches. The fact that there was enough cover for mudminnows to survive and not minnows (none were collected) is a strange finding, since mudminnows are decimated under severe predation pressure from top predators like largemouth bass.

There were two top predators collected: largemouth bass (very common) and northern pike (very rare). We saved 65 largemouth bass that were 1.7-18 inches long. Many YOY were collected and released indicating that this species is reproducing well and had good survival of its young during 2017. This suggests that no stocking of this species should be required. Largemouth bass are very efficient predators, but they will be restricted in their predation by the extensive aquatic vegetation. They are probably the most abundant predator in the lake, although bullheads may give them severe competition. We collected one northern pike that was 21 inches and released. We also got what may be a rare finding: a YOY northern pike that was 6 inches long from a seine haul. The presence of this YOY is a great sign that some reproduction of northern pike has occurred during spring of 2017. This could have occurred in Peterson Creek or any of the canals and back water areas where spawning may have happened. Northern pike still appear to be rare in the lake, but this is a good sign for that species.

Yellow bullheads are mostly nocturnal feeders and voracious predators, eating large numbers of bluegills and other fishes (see Picture 7). Some of the predation we observed was probably due to them being in close proximity to fish in the trap net, but it is difficult to determine where the prey was obtained. It does show what a dramatic impact these fish can have on prey fish, such as bluegills. In addition, black crappies (which appear to be rare) and yellow perch also are predaceous at larger sizes and act as top predators. It appears from what we know about northern pike (and walleyes) and our diet information, that the dearth of northern pike probably has fostered a higher population of yellow perch in your lake, since yellow perch are a preferred prey item, if not enough soft-rayed fishes (minnows) of sufficient size are available. However, from our sampling we noted that the longest yellow perch we got was only 7 inches. We have already noted that northern pike and walleye are probably stressed during summer because of the lack of dissolved oxygen in the bottom waters of the lake during late summer. Degraded dissolved oxygen environments may be partially responsible for the low abundance of northern pike and walleyes. We should also note that it appears that walleyes are also rare in the lake, since we obtained none, despite stocking many in the past. They too would be stressed due to the sub optimal conditions during summer stratification (see Fig. 6).

In addition to top predators, the lake also contains a good population of bluegills and some huge pumpkinseeds were also documented (up to 8.2 inches). The bluegills we collected attained a maximum size of only 6.8 inches; something that was noted by Crawford (2009). The sandy habitat and macrophyte-covered areas are prime habitat for many minnow species and Crawford (2009) in his study noted them in the shoreline areas. However, in our talks with riparian fishers, they note that they have not seen minnows and that what was observed was probably bluegills. We captured no minnows in any of our five seine hauls with a 50-ft seine in a diverse number of habitats in the lake; this is very unusual. It should also be noted that over 2,500 pounds of fathead minnows have been stocked in the lake, including apparently 60,000 in November after we conducted our study. The only hypothesis we can advance is that largemouth bass (and the other predators of Ogemaw Lake) may have reduced their populations to non-detectable low levels, which we have observed in other lakes (due to largemouth bass predation in one lake, and too many walleyes in another). We would have expected some minnows to survive, considering the vast aquatic plant beds in the lake, but fathead minnows are seldom found or common in other lakes we have studies with minnow populations. Lastly, brook silversides (they are the fish that make small ripples on the surface of the water in calm periods) were also noted by Crawford (2009); we did not catch any of them either. In lakes in which they are present that we have sampled in the past, they are abundant, visible because of their dimpling of surface water while feeding, and we usually catch large numbers of them. In addition, these lakes have had a large suite of predators present. Apparently they too have succumbed to severe predation, which is the only obvious explanation for their absence from our sampling efforts.

Picture 6. Fishes captured in Ogemaw Lake trap net, 16 August 2017. Shown are: pumpkinseeds and yellow bullheads.

Picture 7. One of many yellow bullheads collected in trap nets showing their voracious appetite for prey fish (in this case bluegills).

Table 5. Fish code, common name, scientific name, sample sizes, and length ranges of the fishes saved or observed from Ogemaw Lake, 15-17 August, 2017. Most were released.

Fish Code	Taxon	Scientific Name	Sample Size	Length Range (In)
BG	BLUEGILL	*Lepomis macrochirus*	48	1.1-6.8
BC	BLACK CRAPPIE	*Pomoxis nigromaculatus*	1	11..5
ID#	IOWA DARTER	*Etheostoma exile*	1	1.5
LB	LARGEMOUTH BASS	*Micropterus salmoides*	65	1.7-18
MM	MUDMINNOW	*Umbra limi*	2	1.8-2.4
NP*	NORTHERN PIKE	*Esox Lucius*	2	6-21
PS	PUMPKINSEED	*Lepomis gibbosus*	47	2.2-8.2
YB	YELLOW BULLHEAD	*Ameiurus natalis*	15	6.2-13
YP	YELLOW PERCH	*Perca flavescens*	30	3.5-7

*=released alive.
#=found in largemouth bass stomach.

Fish Diets

We collected one black crappie, which testifies to their low abundance in Ogemaw Lake, despite being stocked in the past. This fish was rather large (11.5 in) but had no food in its stomach (Table 6). The diet of bluegills was almost exclusively insects with some snails and plants. Fish caught ranged in size from 1.1 to 6.8 inches. The smaller 2.9-3.9-inch group ate amphipods *Hyalella*, zooplankton, and some snails. Somewhat bigger fish (4-4.9 in) fed on a similar group of organisms, including dragonflies, amphipods, ants, snails, mayflies, water mites, algae *Chara*, and zooplankton (*Bosmina*). Fish 5-6.4 in ate fingernail clams, algae *Chara*, mystery banded snails, ostracods, caddisflies, and dragonflies. In many other lakes we work on, at this time of the year, the bluegills are struggling to find food and often we see these fish eating only algae and aquatic plants, which do not provide them with much energy. Hence, we expect their populations are doing well in the Ogemaw Lake since they are eating a diverse food supply. Two other points: first, we were surprised that the largest fish we got was only 6.8 inches, which is a nice fish, but we expected to see some bigger individuals. Crawford (2009) also noted this for the bluegill population. We did see bigger pumpkinseeds which ranged up to 8 inches. Second, there is a healthy benthos diversity in the lake, since there were amphipods and especially mayflies which require high concentrations of dissolved oxygen year round.

We saved 65 largemouth bass which ranged from 1.7 to 18 inches. Small YOY (1.7-3 in) had a diverse diet including: mayflies, zooplankton *Bosmina*, chironomids, and dragonflies. Fish 3-6 inches ate mayflies, chironomids, ants, algae *Chara*, dragonflies, and one ate an Iowa darter (1.5 in long), showing some switch to piscivory at larger sizes, but not as much as we expected. The one 7.8-in largemouth bass we caught was also piscivorous eating a 3-in yellow perch. The largest largemouth bass we collected was 18 in; it was released. Again two points regarding these findings: first, small largemouth bass were eating zooplankton *Bosmina*. We discuss this in depth in the zooplankton section, but it shows that small fish were NOT eating *Daphnia* (the largest cladoceran), which is our key zooplankter and indicator of severe fish predation on zooplankton. Some of that predation may have already occurred reducing *Daphnia* numbers and forcing largemouth bass and other small planktivores to switch to *Bosmina*. Second, we hypothesize that the lack of minnows (discussed later) is probably due to severe predation by the top predators in the lake, especially largemouth bass, which are well known to decimate minnow populations in some cases. However, although some predation on fishes was documented, it was not as intense as we thought it might be. But, there are many other predators in the lake, including channel catfish, northern pike, black crappies, bullheads, and large yellow perch, which also would target any minnows in the lake.

Of the 47 pumpkinseeds, we saved, fish ranged from 2.2 to 8.2 inches, much larger than the maximum size of bluegills we caught. The diet was composed of mollusks and insects. Fish 2-3.7 in were eating snails and chironomids. Fish 4.1-6 in ate snails, dragonflies, fingernail clams, caddisflies, snails, a wasp, and the banded mystery snail. The largest individuals 6.7-8.2 in ate caddisflies, snails, ants, and a large number of banded mystery snails. Note: the banded mystery snail *Viviparus georgianus* is a non-indigenous species recently introduced to mid west lakes. It can become abundant, competes with native snails, and can increase largemouth bass mortality of eggs if they infest nests in the spring. They appear to be abundant in Ogemaw Lake.

We collected 15 yellow bullheads from Ogemaw Lake. Trap nets are particularly effective for bullheads but we still think they are common in the lake. Some of the predation we documented was probably due to the intimate confinement of bluegills and yellow bullheads in the same net; some trap net hauls however did not have bluegills in them, so that the predation occurred outside the net. Fish we collected (15) ranged from 6.2 to 13.1 inches and were almost exclusively piscivorus. They ate large numbers of bluegills (eight in one fish – see Picture 7). They also ate a yellow perch, adding another predator that feeds on this species. A crayfish was also found in one fish stomach. As can be noted from these data, bullheads (and there may be other species – black and brown in the lake) can be voracious feeders and eat a considerable amount of forage from the lake, helping to control stunting. We should also note, that despite many channel catfish being stocked in the lake, we caught none in our sampling. Catfish, like bullheads, seem to be particularly susceptible to trap nets, so their absence from our gear would suggest they are uncommon in the lake, despite that many have been stocked in the past.

We saved 30 yellow perch (3.5-7 in) from our sampling activities (Table 6). Yellow perch usually go through a change in diet from zooplankton early on, to benthos, to fish. Lake Ogemaw yellow perch were almost exclusively eating zooplankton, insects, and mollusks. Fish 3.5-4 in (YOY) were feeding on zooplankton *Bosmina*, mayflies, chironomids, and dragonflies. The larger fish 4 to 7 in were eating: mayflies, dragonflies, and snails. No fish were found in any stomachs. In addition, we did not get any large yellow perch (those >7 in). Yellow perch and walleyes are susceptible to gill nets, which may have given a better representation of the larger yellow perch (and walleyes) in the lake. It should be noted as we discussed above, that small yellow perch are also predators of zooplankton and they too were eating *Bosmina*, rather than *Daphnia*.

Table 6. Listing of the species collected, length, weight, sex, and diet information for fishes from Ogemaw Lake, Ogemaw County, MI 15-17 August 2017. NA = not available, ZOOP = zooplankton, M = male, F= female, 1= poorly developed gonads, 2=moderately developed, 3=well developed, 4=ripe running, and 5=spent. I = immature, MT = empty stomach, CHIR = Chironomidae, MT = empty stomach, xx = unknown. See Table 5 for a definition of fish species codes. TN=trap net, S=seine. N= sample size. See Fig. 4 and Table 1, 5 for station locations and code definitions.

		LENGTH	**WEIGHT**		
STATION	**SPECIES**	**INCHES**	**OUNCES**	**SEX**	**DIET**
		BLACK	**CRAPPIE**	n=1	
TN3	BC	11.5	15.7	F1	
		BLUEGILL	n=48		
S3	BG	1.1	0.01	II	

S3	BG	1.3	0.02		
S3	BG	1.3	0.02	II	ZOOPLANKTON
S3	BG	1.3	0.02	II	
S3	BG	1.4	0.02		
S3	BG	1.4	0.03		
S1	BG	1.4	0.03		
S1	BG	1.4	0.03		
S4	BG	2.2	0.1		
S4	BG	2.3	0.1		
S1	BG	2.4	0.1		
S1	BG	2.4	0.2		
S4	BG	2.6	0.2		
S1	BG	2.9	0.2	II	HYALELLA, SNAILS
S1	BG	3.3	0.4		
S1	BG	3.4	0.4		
S3	BG	3.4	0.4	F1	
S3	BG	3.5	0.4		
S1	BG	3.5	0.5		
S1	BG	3.7	0.5		
S1	BG	3.8	0.6		
S1	BG	4.0	0.6	F1	ANTS, SNAILS, MAYFLIES, BEETLES
S1	BG	4.0	0.6		
S1	BG	4.1	0.7		
S1	BG	4.1	0.7		
S1	BG	4.1	0.7		
S1	BG	4.1	0.6		
S3	BG	4.1	0.7	F1	HYALELLA, MAYFLIES, CHARA, WATER MITE
S1	BG	4.2	0.6		
S1	BG	4.3	0.8	M1	DRAGONFLY
S1	BG	4.6	0.9		
S3	BG	4.6	1.0	F1	ABUNDANCE OF ZOOPLANKTON BOSMINA
S1	BG	4.8	1.2		
S1	BG	4.8	1.1		
S1	BG	4.9	1.3		
TN1	BG	4.9	1.4	F1	STRINGY PLANTS, CHARA?
TN3	BG	5.0	1.2	M1	
S1	BG	5.0	1.4	M1	CADDISFLIES, OSTRACODS, 3 MYSTERY BANDED SNAILS
S1	BG	5.0	1.3		
S1	BG	5.0	1.4		
S1	BG	5.4	2.2	F3	PLANTS
TN1	BG	5.5	2.6	M1	ABUNDANCE OF AQUATIC PLANTS
S4	BG	6.0	2.5	M1	LARGE DRAGONFLY NAIAD

S5	BG	6.1	2.9	M1	4 BANDED MYSTERY SNAILS, 10 CADDISFLIES
S4	BG	6.1	2.6	M1	ANT, FINGERNAIL CLAM (SPHAERIIDAE)
S3	BG	6.4	3.2	M1	CHARA, PLANT MATERIAL
TN4	BG	6.5	3.1	M1	
TN1	BG	6.8	3.9	M1	ABUNDANCE OF VALLISNERIA EEL GRASS
	LARGEMOUTH BASS			n=65	
S3	LB	1.7	0.05	II	
S1	LB	1.7	0.04		
S3	LB	1.8	0.05		
S1	LB	1.8	0.05		
S1	LB	1.8	0.1		
S3	LB	1.8	0.1	II	MAYFLY SIPHLONURIDAE
S1	LB	1.8	0.04		
S1	LB	1.8	0.04		
S1	LB	1.8	0.05		
S3	LB	1.9	0.1		
S1	LB	1.9	0.1		
S3	LB	1.9	0.1	II	ZOOPLANKTON BOSMINA, CHIRONOMIDS, MAYFLIES
S3	LB	1.9	0.1	II	
S3	LB	1.9	0.1	II	
S3	LB	1.9	0.1		
S3	LB	1.9	0.1		
S1	LB	1.9	0.1		CHIRONOMIDS, DRAGONFLIES
S1	LB	1.9	0.05		
S1	LB	1.9	0.1		
S1	LB	1.9	0.04		
S1	LB	1.9	0.1		
S3	LB	2.0	0.1	II	
S3	LB	2.0	0.1	II	
S3	LB	2.0	0.1		
S1	LB	2.0	0.1		INSECT PARTS
S3	LB	2.0	0.1		ZOOPLANKTON, MAYFLIES, CHIRONOMIDS
S3	LB	2.0	0.1	II	
S3	LB	2.0	0.1		3 MAYFLIES CAENIS
S3	LB	2.0	0.1		
S3	LB	2.0	0.1		
S3	LB	2.1	0.1	II	ZOOPLANKTON BOSMINA, CHIRONOMIDS, MAYFLIES
S3	LB	2.1	0.1		5 MAYFLIES, ZOOPLANKTON CHYDORUS
S3	LB	2.2	0.1	II	1 MAYFLY
S3	LB	2.2	0.1		
S4	LB	2.2	0.1		

S4	LB	2.2	0.1		
S3	LB	2.2	0.1	II	ZOOPLANKTON CHYDORUS?
S3	LB	2.2	0.1		
S4	LB	2.2	0.1		
S4	LB	2.3	0.1		
S3	LB	2.4	0.1	II	
S4	LB	2.4	0.1		ZOOPLANKTON
S3	LB	2.4	0.1		
S4	LB	2.4	0.1		
S4	LB	2.4	0.1		
S4	LB	2.4	0.1		
S4	LB	2.4	0.1		
S3	LB	3.0	0.2	II	2 MAYFLIES
S3	LB	3.0	0.2		ANTS, MAYFLIES, CHIRONOMID LAR AND PUPA
S3	LB	3.1	0.2	II	ANTS
S3	LB	3.2	0.2		3 MAYFLIES- ONE LARGE
S3	LB	3.4	0.3	II	
S4	LB	3.8	0.4	F1	CHARA, DRAGONFLIES
TN4	LB	4.1	5.8	M1	IOWA DARTER 38 MM
S3	LB	4.1	0.5	F1	ADULT DRAGONFLY
S3	LB	4.1	0.4	F1	
S4	LB	4.1	0.4		MAYFLIES
S3	LB	4.3	0.5		
S3	LB	4.3	0.6	F1	
S4	LB	4.9	0.9	F1	
S4	LB	5.0	1.1	CC	
S4	LB	5.2	1.1	M1	
S3	LB	6.0	0.5	F1	
S3	LB	7.8	4.6	II	YELLOW PERCH 75 MM
TN3	LB	18.0			
	MUDMINNOW	n=2			
S3	MM	1.8	0.05		
S3	MM	2.4	0.1		
	NORTHERN PIKE	n=1			
TN3	NP	21.0	ND		ND
S3	NP	6.0	ND		ND
	PUMPKINSEED	N=47			
S3	PS	2.2	0.1	II	SNAILS, CHIRONOMIDS
S1	PS	2.3	0.1	II	
S3	PS	2.9	0.3	II	SNAILS
S3	PS	3.2	0.4		

S1	PS	3.7	0.6	CC	
S1	PS	3.7	0.6		
S3	PS	3.9	0.8		
S3	PS	4.0	0.9		
S1	PS	4.1	0.7	F1	SNAILS, 2 DRAGONFLIES
S1	PS	4.2	0.9		
S3	PS	4.3	1.0		
S3	PS	4.4	1.1		
S3	PS	4.5	1.3	M1	SNAILS, FINGERNAIL CLAMS
S3	PS	4.7	1.3		
S1	PS	4.9	1.7	F1	
S3	PS	5.0	1.7		
S3	PS	5.0	1.8	F1	SNAILS GYRAULUS
S3	PS	5.2	1.9		
S1	PS	5.2	1.9		
S3	PS	5.2	2.0	M1	SNAILS
S1	PS	5.3	1.9		
S3	PS	5.6	2.1	M1	CADDISFLIES, SNAILS, WASP
S4	PS	5.7	2.3	M1	SNAILS
S5	PS	5.8	2.3	M1	3 BANDED MYSTERY SNAILS
S4	PS	5.8	2.8	M1	
S1	PS	5.9	2.6		
S2	PS	5.9	2.8	F1	15 CADDISFLIES
S1	PS	5.9	2.8		
TN2	PS	6.0	3.6	M1	SNAILS, CADDISFLIES
S1	PS	6.0	2.8		
S4	PS	6.2	3.3	M1	5 CADDISFLIES, 2 SMALL SNAILS
TN2	PS	6.3	3.3	F2	
S5	PS	6.3	3.5	M1	3 CADDISFLIES, 2 SNAILS
TN3	PS	6.3	3.3	M1	55 ANTS
S1	PS	6.3	3.8	M1	3 SNAILS
TN2	PS	6.5	3.5	F2	
S5	PS	6.7	4.9	M1	SNAIL GYRAULUS, BANDED MYSTERY SNAIL
TN2	PS	6.8	4.1	F1	BANDED MYSTERY SNAIL
TN2	PS	6.9	4.3	M1	2 BANDED MYSTERY SNAILS
TN4	PS	6.9	4.6	F1	ANTS, BANDED MYSTERY SNAIL
S1	PS	6.9	4.8	F2	
TN2	PS	7.0	4.9	F1	
S4	PS	7.1	4.7	M1	BANDED MYSTERY SNAIL, LADYBUG
TN4	PS	7.1	4.4	F3	
TN2	PS	7.2	4.3	F2	
TN1	PS	8.2	8.4	MII	5 MYSTERY BANDED SNAILS
TN4	PS	8.2	7.0	F1	

	YELLOW	**BULLHEAD**	n=15		
TN2	YB	6.2	1.8	II	
TN4	YB	10.0	9.5	F5	BLUEGILL 70 MM
TN4	YB	10.3	11.0	F5	
TN2	YB	10.4	11.5	M1	
TN2	YB	10.8	12.0	M1	
TN4	YB	10.9	14.7	II	BLUEGILL 62,72,98,63,56,67,68,62 MM
TN4	YB	11.0	12.1	M1	
TN3	YB	11.1	13.1	M1	
TN4	YB	11.2	14.4	M1	3 BLUEGILLS 80,82,86 MM; FISH REMAINS
TN2	YB	11.2	13.1	F5	
TN4	YB	11.4	13.4	F2	
TN3	YB	12.2	13.9	M1	YELLOW PERCH 98 MM
TN2	YB	12.3	16.2	M1	1 BLUEGILL; CRAYFISH
TN4	YB	12.9	24.7	M1	2 BLUEGILLS 120 AND 122 MM, XX FISH, CRAYFIS
TN3	YB	13.1	20.1	M1	BLUGILL 90 MM

	YELLOW	**PERCH**	n=30		
S4	YP	3.5	0.3		
S4	YP	3.5	0.3		
S3	YP	3.6	0.3	F1	
S4	YP	3.6	0.3		MAYFLIES
S3	YP	3.7	0.3	F1	ZOOPLANKTON BOSMINA
S3	YP	3.8	0.4	M1	MAYFLIES, CHIRONOMIDS, ZOOP. BOSMINA
S3	YP	3.8	0.4	F1	2 DRAGON FLIES
S3	YP	3.8	0.3	M1	CHIRONOMIDS, ZOOPLANKTON
S3	YP	3.9	0.4	F1	PLANTS, INSECT PARTS
S4	YP	3.9	0.4		
S3	YP	3.9	0.4	F1	ZOOPLANKTON, MAYFLIES
S4	YP	3.9	0.4		
S4	YP	3.9	0.4		
S4	YP	4.0	0.4		
S4	YP	4.0	0.4		
S4	YP	4.0	0.4		
S3	YP	4.1	0.5	F1	19 MAYFLIES
S4	YP	4.1	0.4	F1	
S4	YP	4.1	0.4		
S3	YP	4.1	0.5		
S4	YP	4.1	0.4		
S4	YP	4.2	0.5		
S4	YP	4.3	0.5		
S3	YP	4.4	0.5	F1	MAYFLIES, DRAGONFLIES, SNAILS

S4	YP	4.5	0.6		
S4	YP	4.6	0.7		
S4	YP	4.8	0.8	F1	
S3	YP	5.4	1.2	F1	3 DRAGONFLIES
S2	YP	6.6	2.3	F1	DRAGONFLY
S3	YP	7.0	2.7	F1	

There is/was another species that we did not catch but was listed by Crawford (2009) as present in the lake during his study. This fish is probably confused with minnows in the lake and is called the brook silversides. They have a 2-year life cycle, grow up to 2-3 inches, and can be seen feeding at the surface, sometimes jumping out of the water when they are chased by predators. Again this is another good member of the fish community adding another prey species but why it was not observed during our extensive efforts remains a mystery. Usually it is abundant when present, even when there are abundant predators like largemouth bass. This suggests some severe predation is ongoing on the prey fish community in the nearshore zone.

The lack of any minnows in Ogemaw Lake fish collections is surprising. They too were noted in the Crawford (2009) study, but despite extensive effort with a 50-ft seine at five sites on the lake, NONE were caught. Discussions with a riparian owner who is also a fisher, suggested that no minnows are present in the lake based on his observations. As we noted for the brook silversides, this is surprising and indicative of severe fish predation or perhaps disease, but no die offs have been reported to us. We have worked on other lakes which lacked minnows In these studies we have done in the past that are pertinent to this situation, we found that one lake studied was subject to winterkill, which resulted in a fish fauna that had a lack of largemouth bass which were intolerant of the low dissolved oxygen. After the lake was dredged, they introduced largemouth bass, and they extirpated all the other prey fishes in the lake (mudminnows, other minnows, darters, pumpkinseeds, and most of the yellow perch) leaving only a largemouth bass-bluegill fish community. In the other lake, there was a fish community comprised of many species of minnows (bluntnose, golden shiner, spottail shiner, spotfin shiner, and two species of darters) and bluegills/pumpkinseeds in the nearshore, when a mistake was made in stocking too many walleyes. The resident fishers noted that there were no longer minnows in the near shore zone which was confirmed by our studies and not only were there no minnows, but no sunfish either. In both cases we attributed the loss of these species to severe predation by largemouth bass in one case and walleyes in the other, both due to inauspicious stocking. These are cautionary tales: in some cases predators can destroy prey fish populations.

Walleye is another top predator of interest obviously to Ogemaw Lake fish mangers, since 215,880 fish have been stocked into Ogemaw Lake in the recent past: 1980 and 1996-2017 (see Appendix 2) including 500 during November 2017. We did not collect any walleyes, but this is probably due partially to the lack of use of gill nets, but we collect them on occasion in trap nets, so that indicates they are rare in the lake, despite the extensive stocking. We are not surprised at this, since walleyes are not native and they are cool water fishes like northern pike, and so suffer, may die, and grow poorly during summer stratification when they get into the fish squeeze shown in Fig. 6. Walleyes are known predators on bottom-dwelling fishes, especially yellow perch and can control stunted bluegill and yellow perch populations (Schneider 1995, Schneider and Lockwood 1997), and with their specialized eyes, do most of their feeding at night or under low-light conditions. They are also known to be prominent predators during winter. They would be another predator that would target yellow perch and perhaps minnows, which could reduce these prey fish's abundances in the lake. However, we did catch quite a few yellow perch, especially YOY, which occupy the same habitat as minnows. Walleyes would prefer minnows over spiny rayed perch and minnows may be exposed more to predation effects at night, since they tend to occupy open water rather than hiding in the aquatic plants. This same scenario may also favor the demise of minnows over yellow perch during the day time by largemouth bass predators. Minnow species are an excellent addition to the fish fauna, since they utilize resources that none of the other fish consume (algae and detritus and probably some insects) and they add an important forage fish for top predators, such as yellow perch, northern pike, and largemouth bass. These species contribute to species diversity we strive for in the fish community, which is important for maintaining stability under the different stressors of the environment and varying population swings of the predators in the lake. The analogy to a diverse stock portfolio is apt here. Stocking minnows into Ogemaw Lake seems counter-productive, since they have been stocked in the past (2,511 pounds of fathead minnows) and we caught none in our extensive sampling during 2017 nor have any been seen by residents in the nearshore zone. Fathead minnows are never common in any of the lakes we work on either; bluntnose minnows are usually the most common followed by spotfin shiners, and sometimes emerald shiners. Golden shiners are highly recommended if they would survive, since they reproduce well and grow to large sizes (10 in sometimes) providing prey for large predators. Interestingly, in Lake Ogemaw we were unable to get a good evaluation of the presence of large largemouth bass or walleyes, but we know from the Crawford study (2009) and reports by fishers that there are good populations of largemouth bass present (we collected two in the 6-7 in range and one 18 in specimen – Table 5) and perhaps there are a few walleyes left from previous fish plantings that may be exerting excessive pressure on the forage fish populations.

The panfish community in Ogemaw Lake is comprised of bluegills, pumpkinseeds, black crappies, and largemouth bass, all members of the sunfish (Centrarchidae) family. This complex is the backbone of any warm-water lake fish community and is usually self-sustaining, since the largemouth bass have adequate spawning substrate (Ogemaw has many gravelly and sandy shores) and can usually control the panfish and prevent stunting. This complex has co-evolved over thousands of years so any interventions by humans, especially to a well-established unperturbed ecosystem, beg for complication and failure. The high diversity of vertebrate and invertebrate prey is being consumed by the bluegills, black crappies, and small largemouth bass along with help from bullheads and yellow perch, so it appears that a considerable amount of your prey resources are being efficiently converted into fishable biomass.

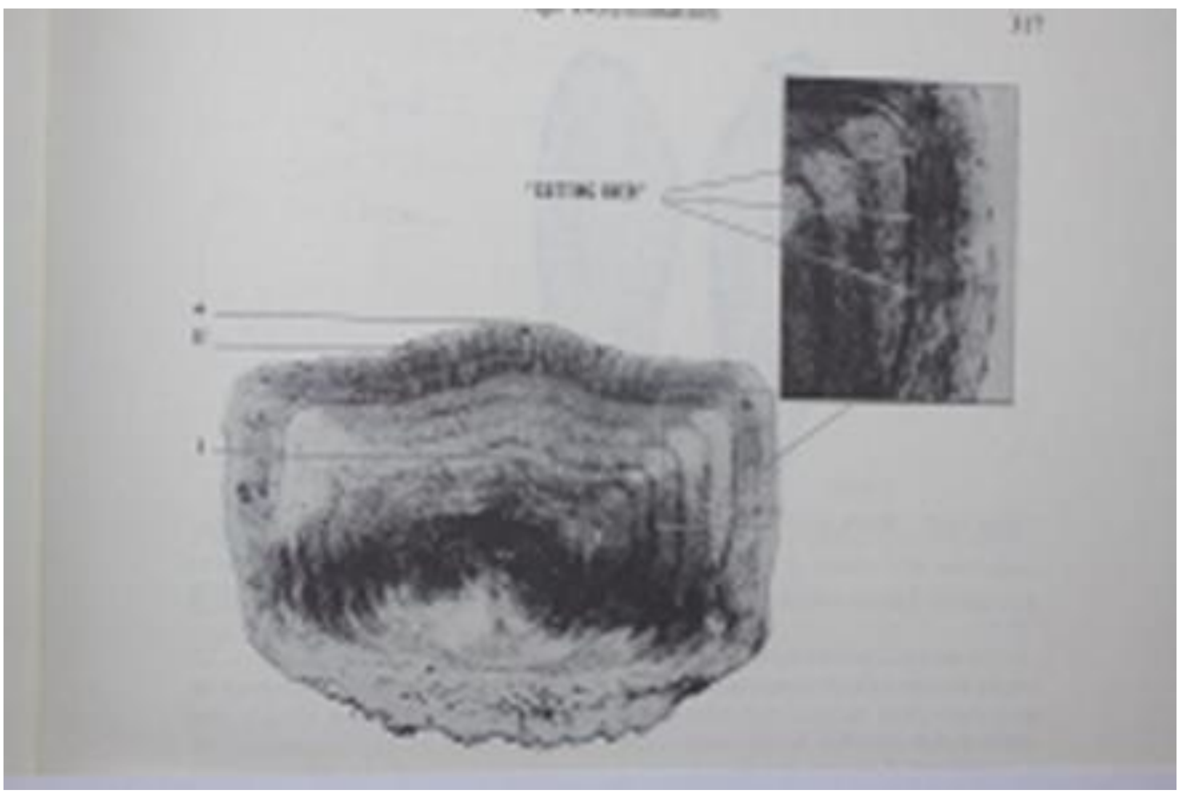
Mercury in fish

Just a note about mercury. It is a problem in most of Michigan's inland lakes. Most mercury comes to the watersheds of lakes through deposition from the air with most coming from power plants burning coal. The elemental mercury is converted to methyl mercury through bacterial action or in the guts of invertebrates and animals that ingest it. It becomes rapidly bioaccumulated in the food chain, especially in top predators. The older fishes, those that are less fatty, or those high on the food chain will carry the highest levels. Studies we have done in

Michigan lakes and studies by the MDNR have shown that large bluegills, yellow perch, largemouth bass, black crappies, northern pike, and walleyes all contain high levels of mercury. This suggests that fishers should consult the Michigan fishing guide for recommendations on consumption, limit their consumption of large individuals, and try to eat the smaller ones. It also suggests that a trophy fishery (catch and release) be established for top predators, such as largemouth bass and northern pike (which is probably generally followed anyway – this is more incentive), and some of the larger individual bluegills, pumpkinseed, and yellow perch in the lake.

Fish Growth

Growth of the fishes we collected was determined by ageing a sample of fish of various sizes using multiple scales under a microscope (see Picture 8) and comparing the age of fish from Ogemaw Lake with Michigan DNR standards (Latta 1958, Laaarman 1963). Bluegills are common in Ogemaw Lake and those we aged (n=47) were growing at MDNR averages through age 2, but then were growing slower at ages 3-5 (Table 7, Fig. 7). The fish we aged ranged from 1.1 to 6.8 inches, so there is a good size range of fish present but we expected to catch more larger individuals. The scattered aquatic plant beds present in the lake, gravel/sandy substrate for spawning, the good diversity and abundance of benthos, and abundance of zooplankton *Bosmina* are apparently providing food and good habitat for bluegill shelter and sufficient food for modest growth.



Picture 8. Scale of a fish showing the annuli (rings on the scale) and places where they squeeze together or cross over, indicating a year's growth.

Table 7. Growth of selected fishes collected from the Ogemaw Lake, Ogemaw Co., 15-17 August 2017. Fishes were collected in seines and trap nets, scales removed, aged, and mean total lengths at various ages compared with Michigan state mean lengths for various fishes at those same ages (see Latta 1958; Laarman 1963). Shown is the age (years) of the fish, its total length (inches) based on MDNR state of Michigan mean lengths, and the mean length-at-age of Ogemaw Lake fishes along with sample size (n) in parentheses. Total no. fish aged given at top as n. See Figs. 7-12 for graphical display of these same data.

MDNR Age (yr)	MDNR Len (in)	Ogemaw Len (in)
BLUEGILL		n=47
AGE	**MDNR**	**OGEMAW**
0	2.1	1.7(12)
1	2.9	3.2(7)
2	4.3	4.3(14)
3	5.5	5.1(8)
4	6.5	6.1(3)
5	7.3	6.6(3)
6	7.8	
7	8	
8	8.5	
9	8.5	
10	9.2	
LARGEMOUTH BASS		n=59
AGE	**MDNR**	**OGEMAW**
0	3.3	2.1(52)
1	6.1	5.1(5)
2	8.7	7.8(1)
3	10	
4	12.1	
5	13.7	
6	15.1	
7	16.1	
8	17.7	18(1)
9	18.8	
10	19.8	
11	20.8	
YELLOW PERCH		n=30
AGE	**MDNR**	**OGEMAW**

0	3.3	3.7(8)
1	4	4.2(19)
2	5.7	5.4(1)
3	6.8	
4	7.8	6.8(2)
5	8.7	
6	9.7	
7	10.5	
8	11.3	
9	11.7	

BLACK CRAPPIE n=1

AGE	MDNR	OGEMAW
0	3.6	
1	5.1	
2	5.9	
3	8	
4	9	
5	9.9	
6	10.7	
7	11.3	7(1)
8	11.6	

PUMPKINSEED n=47

AGE	MDNR	OGEMAW
0	2	2.2(2)
1	2.9	3.1(2)
2	4.1	4(7)
3	4.9	4.8(6)
4	5.7	5.4(7)
5	6.2	6.1(11)
6	6.8	6.8(7)
7	7.3	7.1(3)
8	7.8	8.2(2)

NORTHERN PIKE n=1

AGE	MDNR	OGEMAW
0	7.9	
1	15.5	
2	19.4	
3	22.2	
4	23.9	21(1)
5	25.4	
6	27.7	
7	32.5	
8	37.1	

9	34.8
10	44.4

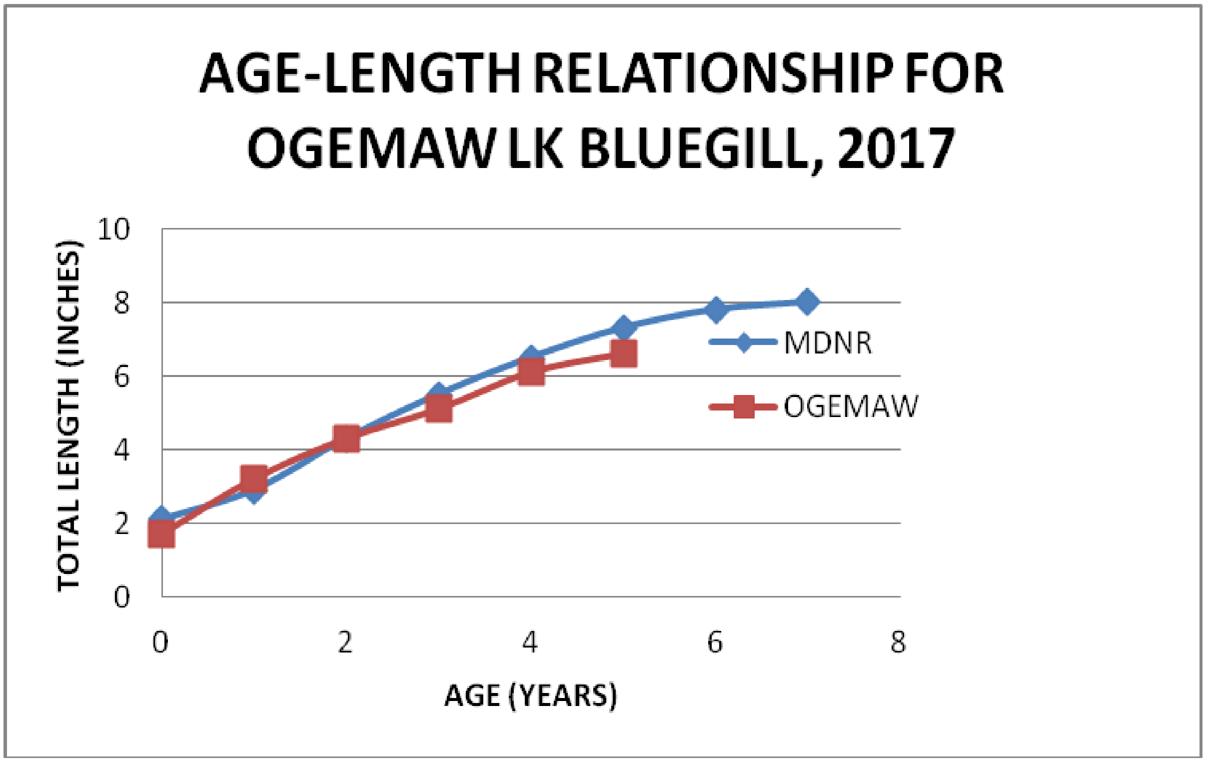


Figure 7. Growth of bluegills in Ogemaw Lake (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 15-17 August 2017. See Table 7 for raw data. n=47.

Largemouth bass were also common in Ogemaw Lake, especially YOY, but we never saw very many intermediate or very large fish. Fish collected ranged from 1.7 to 18 inches (Table 5). The age-length relationship for Ogemaw Lake bass (Fig. 8, Table 7) based on ageing 59 fish was for ages 0-3 mostly slightly below growth rates of Michigan DNR's fish with the large 18-in fish growing at state averages. There appears to be some reduced growth in the age 0-3 fish, perhaps because these groups are numerous in the lake. This species is one of the keystone predators in your lake and responsible for keeping the bluegills in check and probably for decimating the minnows as well, so the big fish should be left in the lake to the degree possible (catch and release unless hooking leads to death). The other reason, as noted elsewhere, is that large individuals are probably contaminated with mercury and should not be eaten very often anyway. We concluded the following: first, the one large fish was generally growing at state averages, and second, based on our findings of large numbers of young-of-the-year fish caught (personal observations in seine hauls; Table 6), we think that largemouth bass are reproducing adequately in the lake. We explored the near shore zone in the lake, and there definitely was considerable gravel and sand substrates along shore that is good spawning substrate for sunfish family members, including largemouth bass. In fact, we observed many old nests during our travels on the lake and Crawford (2009) has a map with where the most important ones are. This finding also has implications for fish management recommendations. There obviously were large numbers of YOY fish in the lake indicating good reproduction; hence there should be no stocking of this species.

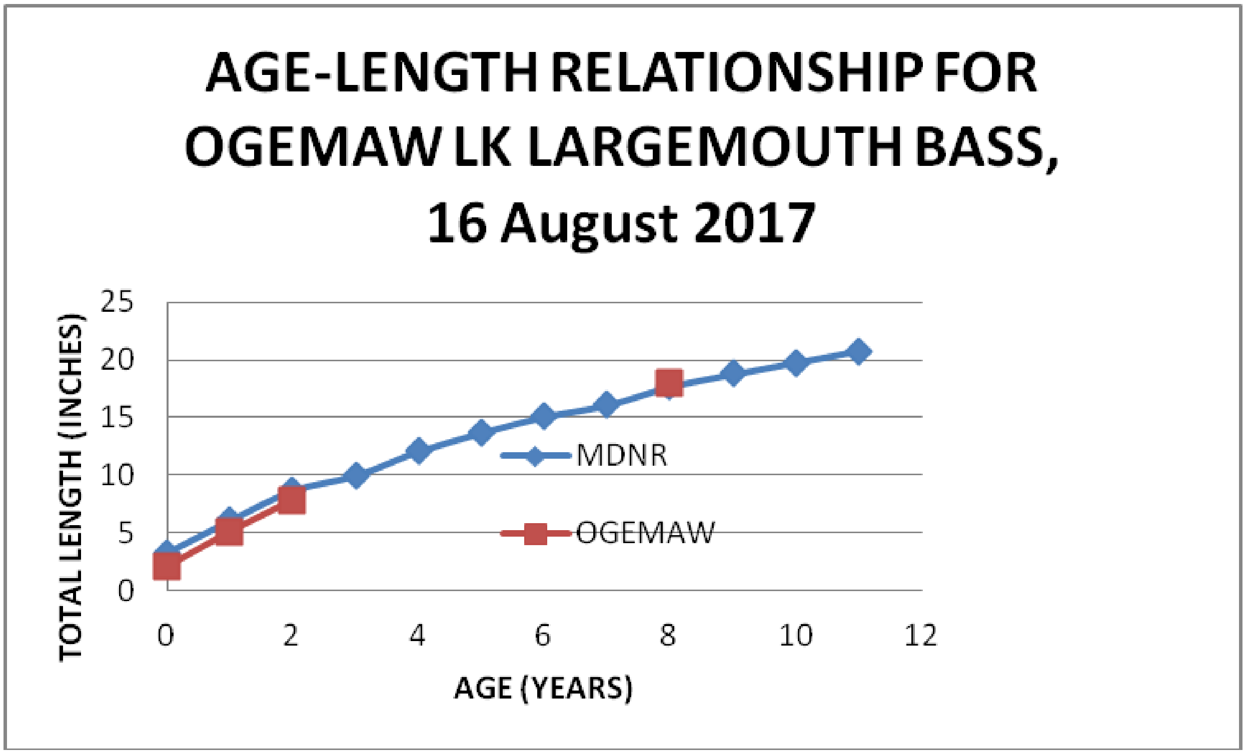


Figure 8. Growth of largemouth bass in Ogemaw Lake (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 15-17 August 2017. See Table 7 for raw data. n=59.

Yellow perch in Ogemaw Lake showed moderate numbers of YOY in seine hauls suggesting good reproduction during 2017. However, the fish we collected (n=30) ranged from 3 to 5.7 inches, indicating a truncated population, since we expected to catch more larger individuals. Part of this is due to not having gill nets set and some may be due to severe predation by top predators, especially northern pike and channel catfish, assuming there are enough in the lake to effect severe predation. It is typical in lakes with abundant northern pike populations to have reduced yellow perch populations, but those that survive usually grow very fast and to large sizes. We need more information to solve this conundrum. Those we caught were growing at state means for 0 to 2-yr-old fish, but slightly below state averages for the 4-yr old fish (Table 7, Fig. 9). Yellow perch are important prey fish that are usually not too susceptible to predation (however one 3-in perch was eaten by a largemouth bass and one 3.8-in fish was eaten by a yellow bullhead), and are outstanding table fare for people. Hence, we would like to have seen more of them, especially larger individuals, in the lake.

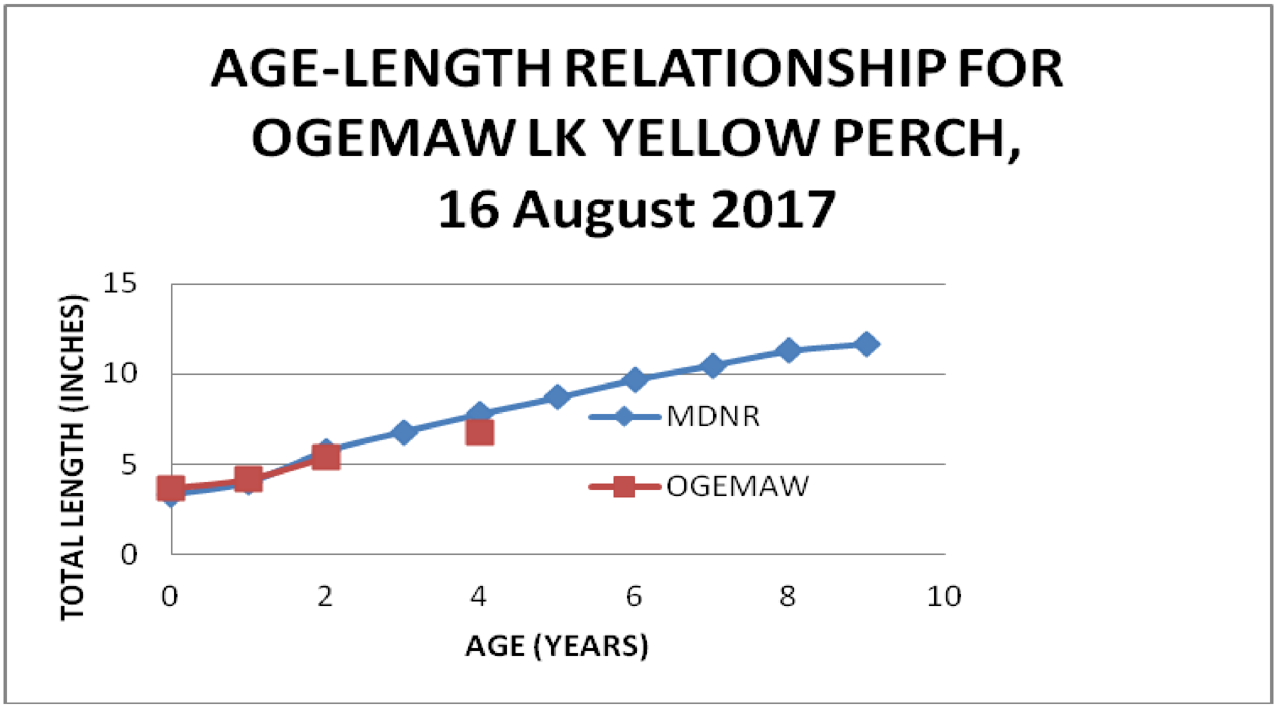


Figure 9. Growth of yellow perch in Ogemaw Lake (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 15-17 August 2017. See Table 7 for raw data. n=30.

One large black crappie (11.5 in) we collected was growing at approximately state averages (Table 7, Fig. 10).

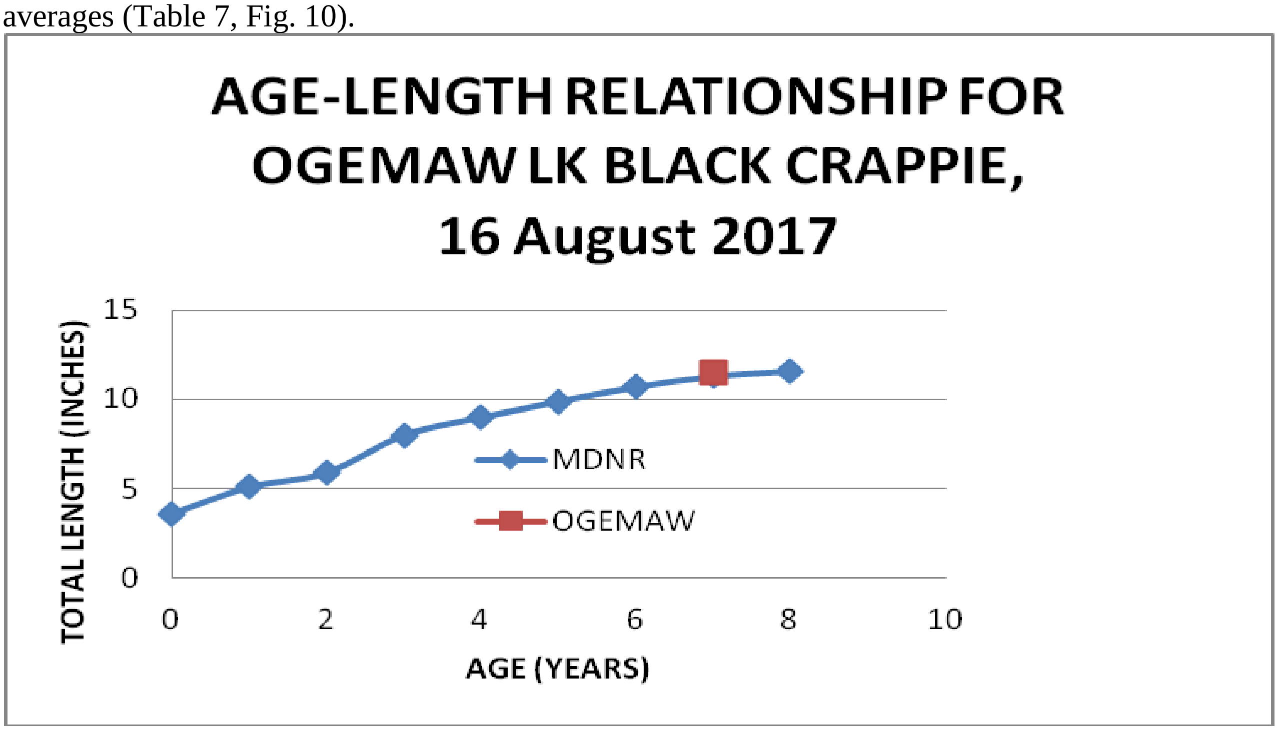


Figure 10. Growth of black crappies in Ogemaw Lake (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 16 August 2017. See Table 7 for raw data. n=1.

Black crappies appear to be rare in the lake, despite stocking of 4,325 in the past (and 500 during 2017 after our sampling). Black crappies are commonly caught in trap nets so we are reasonably assured of their low abundance. We saw no impediments to successful spawning, since black crappies spawn in similar areas as bluegills, building nests and guarding them.

Pumpkinseeds represented a wider range of sizes (2.2-8.2 in; n=47) than did bluegills. As we pointed out, pumpkinseeds are unique in that they are molluskivores (consumers of snails, clams). It appeared in our sampling of Ogemaw Lake that there was an abundance of snails on the vast beds of vegetation, including the newly introduced mystery banded snail, which was common in many areas of the lake and accumulated on the shoreline. They represent an abundant food source and apparently the pumpkinseeds are responding by eating them and growing at MDNR standards for this fish for all the groups we aged (0-8). As noted this species is a known molluskivore and therefore feeds on a food supply that is not usually consumed by other sunfish species. In addition, in lakes with zebra mussels present, we usually observed large numbers of them in stomachs; their lack of appearance in Ogemaw Lake black crappies and the fact we did not observe any, suggest zebra mussels are absent or rare in the lake. Keep it that way by following recommendations on invasive species.

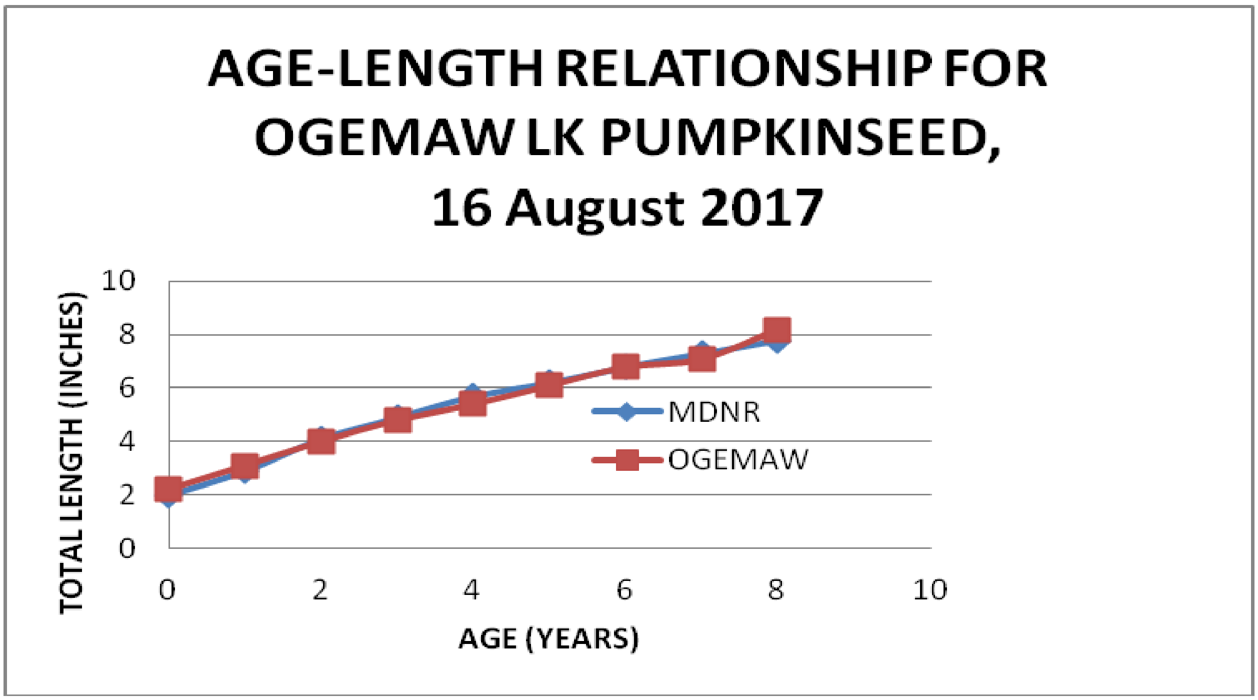


Figure 11. Growth of pumpkinseeds in Ogemaw Lake (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958), 15-17 August 2017. See Table 7 for raw data. n=47.

We collected two northern pike: one 21-in specimen from a trap net (which is unusual) and another 6-in individual from a seine. The small fish was undoubtedly a YOY (which we released) and a great sign, since it indicates that reproduction by this species has occurred during 2017. We discuss this issue later, but one of the objectives of a management plan will be to investigate possible spawning sites for northern pike and ensuring that access to them in spring is not impeded. Petersen Creek comes to mind and any other similar creek should also be under scrutiny for improvement. Since neither of these fish were stocked (100 were stocked in 1998), both are naturally produced in Ogemaw Lake. As we have said, northern pike are native species, even though they are stressed being a cool-water species like walleye during summer in eutrophic and mesotrophic lakes. The YOY fish was around 6 inches (estimated length) and is much smaller than the 10 inches that YOY reach at the end of their first year of life. However, our specimen was collected in early summer and has the rest of the year, which is cooler and during which they may grow faster, to catch up with MDNR averages. The 21-in northern pike was 4 years old and growing slightly below MDNR means.

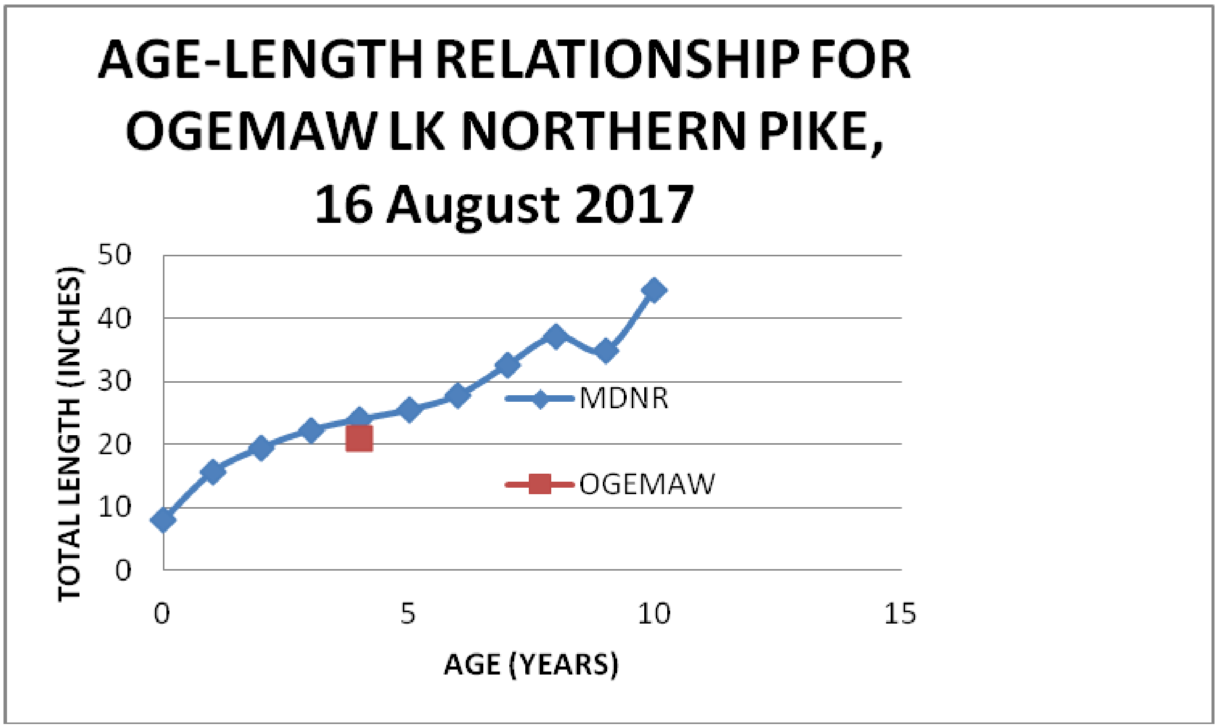


Figure 12. Growth of northern pike in Ogemaw Lake (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 15-17 August 2017. See Table 7 for raw data. N=1.

At least 215,880 walleyes have been stocked into Ogemaw Lake over the period 1980 and 1996-2017 (Appendix 2). Of these, 500 were stocked during November 2017 after our study. We believe that stocking walleyes (and other non-native species) into an established fish community that has evolved as a warm-water fish ecosystem is controversial. They do provide another top predator and are a popular fish with fishers, even though they are notoriously difficult to catch. We believe stocking walleyes is an activity that runs contrary to fish management principles for three reasons: first, walleyes are not native to this population and are not expected to reproduce, and will consume prey that other native species would eat. In fact they are extremely efficient predators, feeding at night or under low-light conditions. MDNR recommends them to help control lakes with stunted bluegill and yellow perch populations (Schneider and Lockwood 1997).

Second, stocking is only acceptable under a number of conditions that must be clearly documented. This includes a situation where the species is native and some catastrophe (e.g., winterkill, fish disease) reduces numbers to very low levels and stocking can assist recovery of the native species. In some cases, we have seen stunted bluegill populations reduce the number of largemouth bass surviving by eating eggs and larvae from nests, justifying stocking more predators. Winterkill can also eliminate susceptible species and re stocking may be the only alternative to restore populations.

Third, Ogemaw Lake is a classic example of a lake which puts the squeeze (see Fig. 6) on cool water species, such as walleye and also northern pike. These species require cool water with high dissolved oxygen. These conditions are met in Ogemaw Lake during fall, winter, and early spring. However, during summer stratification, water warms in surface waters to unacceptable levels, while the cool water required for survival is devoid of or has low dissolved oxygen concentrations. During this time, cool water species are stressed, some probably die (we had reports of walleye die offs in the past from residents), and growth is restricted until other times of the year when water quality was optimal. Therefore, for these reasons, we recommend against stocking any more walleyes into Lake Ogemaw, but recognize that some do survive and provide a small fishery for Ogemaw Lake fishers. Therefore, we could accept some low numbers of stocked fish provided: 1. decision makers realize these fish are not well adapted to conditions in mesotrophic lakes, and 2. there is a strong desire on the part of sport fishers to have some in the lake and accept the consequences of slower growth of other top predators and severe predation on near shore prey fish (e.g., minnows, yellow perch).

MANAGEMENT RECOMMENDATIONS

There are two overarching concerns we have for Ogemaw Lake that bear directly on fish management recommendations. All water bodies have an innate carrying capacity (pounds of fish/acre) and increasing that carrying capacity involves activities such as fertilization, increasing valuable macrophyte fish habitat (and hence fish-food organisms), or perhaps stocking a native species that could utilize more fully an underutilized food resource such as mollusks (pumpkinseed currently fulfill this niche in Ogemaw Lake). Our other possibilities usually involve shifting of resources and fish species within this food web complex, for example by stocking walleyes, which will consume prey items that native species, like largemouth bass would eat. There are other techniques, such as creation of artificial structure (brush piles) that do nothing to increase productivity, but are just fish attractors that concentrate fish so they are easier to catch. There may be some algal growth on these structures that would foster aquatic insect production and hence lead to some increases in fish production.

Considering this background, our first concern is the overall productivity of Ogemaw Lake. Based on our 2017 water clarity - good, the dissolved oxygen profile - good, and nutrient data –low in nutrients, Ogemaw Lake is a mesotrophic lake which develops hypoxia (low dissolved oxygen) on the bottom during summer stratification. Mesotrophic lakes are generally not as productive as is Ogemaw Lake; however, we believe that Ogemaw Lake is way more productive than a comparable mesotrophic lake because it is almost 82% littoral zone, which is the most productive part of a lake. Ogemaw Lake also has extensive beds of vegetation which have been documented by Pullman (2009) and Progressive AE (2016). Efforts are underway to control Eurasian milfoil and starry stonewort, yet foster as many native macrophytes as possible to supplement fish habitat, which would benefit the entire Ogemaw Lake ecosystem, especially the fish. Mechanical means (a rake) can take care of most problem beach accumulations and are more healthy alternatives to herbicides (e.g., copper), which can also kill lots of snails and other mollusks, which as we have documented, are important fish food for fish such as pumpkinseeds. Simply put, try to balance the needs of the recreationalists with those of the fish resource.

Water quality in Lake Ogemaw is generally very good. There is moderate conductivity, low chlorides in bottom waters, low nitrates, ammonia, SRP, and TP is low in the surface, but somewhat elevated on the bottom. In addition, the critical dissolved oxygen curve showed that there was still dissolved oxygen on the bottom during summer stratification, which will allow fish quick access to these places, while being a firewall to P release, which occurs during anoxic conditions. However, we need to keep Lake Ogemaw as a mesotrophic lake and not let it drift into becoming a eutrophic one. As we have noted, the dissolved oxygen profile shows it is right on the edge of shifting from meso to eutrophic (anoxia – no dissolved oxygen on the bottom). If this occurs, two detrimental things will happen: there will be "internal loading" of nutrients from the decomposition of organic matter in the deep hole, because of chemical changes that allow phosphorus and other nutrients and toxic substances such as hydrogen sulfide and carbon di oxide, to be re generated from bottom sediments. These are mixed into the lake during fall and spring over turn and will fuel macrophyte and algal growth. Second, fish will be prevented from accessing the bottom and its benthos and cool water fishes will be stressed as the dissolved oxygen concentrations in their optimal thermal habitat is reduced. The preventive cure for this is to retard nutrient input to the lake. This is summarized in Appendix 1, but includes septic tank pumping at least every 2 yr and every year if the home gets lots of use (nutrients are not removed by septic fields but eventually leach into the groundwater and then into the lake and your substrate is sand which will not slow down leaching at all), no lawn fertilization, no burning of leaves in the watershed, greenbelts to retard runoff, and less paving of driveways, tennis courts, etc..

Fish management strategies emanating from these data include the following. First, regarding largemouth bass, we believe it is the most abundant top predator in the lake. As we argued above, there is a surfeit of YOY fish but few >15 inches, which may be related to our ability to sample large predators effectively. Small largemouth bass grew slightly below state averages, while the one large one was at MDNR mean length for that age. Although we would like to have had more data, what we do have suggests that there is good reproduction by largemouth (expected because of good availability of spawning substrates) based on many captured during seining and they appear to be growing adequately. Since this is a native species adapted to lake environments and there appear to be no problems with stunted bluegills eating eggs and fry off nests, there is no need for any stocking of this species. Yellow perch release a long gelatinous mass of eggs near sticks, logs, rocks, or vegetation. There is a good availability of vegetation and debris (e.g., fallen trees, logs, branches), which we observed during seining and which are required for successful perch spawning and should be encouraged to be left in the lake. Hence, there is no need for stocking yellow perch and because they are severely preyed on by top predators; any stocked would probably be eaten anyway.

Second, we recommend catch and release of the bigger largemouth bass and other top predators, say those > 20 inches, so they can control prey fish populations, especially bluegills and so they can be caught again. Note that the 21-in northern pike we sampled and released was

4 years old and the 18-in largemouth bass was 8 years old. It takes a long time to grow big fish and they should be cherished and released to be caught again. It may seem counter intuitive to recommend saving predators when they are having such a dramatic impact on minnows, but we believe the better outcome is to protect top predators so they can continue to utilize the prey that are flourishing in Ogemaw Lake. We do not have a good indication of abundance of walleyes or channel catfish since we caught none, but we did collect two northern pike, one of which was a YOY. Northern pike spawning is an issue, as it is in most inland lakes without tributary-pond systems attached which promote good reproduction. They can spawn in flooded vegetation and near shore but creeks are optimal habitats since they provide safety for young northern pike. Hence as we have noted before, efforts should be undertaken to make sure there are no obstacles to northern pike ascending creeks, such as Petersen Creek, in the spring to spawn. Finally, a catch-and-release policy is also supported by the fact that larger individuals of many sport fishes in many Michigan inland lakes are contaminated with mercury, limiting their consumption by humans to small fish or long intervals between meals (see M*ercury in Fish* for a discussion).

Third, as we pointed out, stocked walleyes are stressed in Ogemaw Lake during summer stratification by too warm water at the surface and no dissolved oxygen on the bottom where cooler waters reside (see the Fish Squeeze – Fig. 6). This situation of warming surface water may be exacerbated with increased warming due to climate change. These conditions usually result in poor growth during summer and probably some fish die as a result. Schneider et al. (2007) and Laarman (1980) compiled data for walleye yields and catch rates and found that for the Midwest and North America, the walleye yield was 0.6 walleyes/acre and catch rate was 0.01 walleye/hr. Michigan data were similar: yield was 1.1/acre and catch rate was 0.06/acre. Mortality rates were also high, with 20% due to natural deaths and 30% due to fishing. We believe stocking walleyes into a lake with a well balanced fish community is an activity that requires careful scrutiny before enacting. Stocking is only acceptable under a number of conditions that must be clearly documented (see Dexter and O'Neal (2004) for MDNR's guidelines). This includes a situation where the species is native and some catastrophe reduces numbers to very low levels and stocking can assist recovery of the species (e.g.., winterkill). It is justified in some cases when we have stunted bluegill populations that for example, reduce the number of largemouth bass surviving by eating eggs and larvae from nests, justifying stocking more predators (Schneider 1995, Dexter and O'Neal 2004). Stocking walleyes into Ogemaw Lake violates at least four principles of fishery science: 1. The fish is not native and most likely will not spawn, 2. The existing fish community is a co – evolved, warm-water fish community and should not be de-stabilized by introduction of another keystone predator, 3. Water quality conditions, warm surface water and low dissolved oxygen in cool bottom waters, are not conducive nor optimal for a cool water fish, 4. You are playing ecological roulette with stocking, since you could introduce diseases (VHS see below), parasites, or non-indigenous species through stocking of fish, especially if done by non-professionals. A case in point is another lake we worked on: channel catfish were stocked into the lake and somehow gizzard shad were introduced about the same time. This fish is now a prominent part of the fish community and has had severe detrimental effects on P inputs to the lake causing turbid water clarity, blue-green algae blooms, and fish community shifts and degradations to the top predator functioning in the lake. We therefore recommend against stocking any more walleyes into Ogemaw Lake and suggest if fishers want walleyes (they are difficult to catch anyway) they go to Saginaw Bay or Lake Erie where a world-class fishery exists. Despite these concerns, we are aware that that there is great interest in walleyes and that 500 were stocked in November 2017.

If a majority of fishers still want to stock walleyes, despite all these warnings and caveats, they should be obtained from a reputable source, few and large individuals should be stocked, and obviously they should be stocked during the cooler periods of the year, spring or fall. The cautionary tale we experienced in another lake was the elimination of a cool-water species called lake herring or cisco which co occurred in the lake with northern pike. A large number of walleyes were stocked and because of the "squeeze" noted above, the northern pike, walleyes, and ciscos all co occurred in a narrow band of water during summer, apparently resulting in the complete elimination of this prey species, the cisco, which only occurs in some 153 lakes in Michigan.

Fourth, there is a lack of minnows in the lake (two other species noted by Crawford (2009) brook silversides and rock bass) were also not found during our study). There is some controversy whether minnows were ever present in the lake in recent times, since a lake resident and fisher suggested that he had not seen any minnows near shore while living on the lake. We certainly did not collect any which is clear evidence they are certainly not present or present in very low density during 2017. In addition, 2,511 pounds of fathead minnows were stocked into Ogemaw Lake through 2002 and they never established a self-sustaining population. We believe this to be for two reasons: severe predation by largemouth bass and other predators and the fact that fathead minnows are not usually found in inland lakes in any numbers; other species such as bluntnose minnows, spotfin shiners, golden shiners, and sometimes emerald shiners are more common. Although we would desire that minnows be flourishing in the lake, since they occupy different niches than most other species, contribute to fish community diversity, and add another prey fish for predators, it appears that the conditions now extant in Lake Ogemaw do not allow for establishment of a self-sustaining population of minnows. The only suggestion we would have is to try other species of minnows, especially golden shiners, to see if they can establish a self-sustaining population.

Fifth is our concern about introducing more invasive species, besides the at least four you now have: Eurasian milfoil, starry stonewort, curly-leaf pondweed, and the mystery banded snail. Live bait use (minnows, crayfish) should be discouraged or banned because of the threat of introduction of exotic species (e.g., goldfish) and VHS (viral hemorrhagic septicemia) which killed many muskies and other species in many lakes, including Lake St. Clair. As noted above, any stocking should be done with a guarantee from the stocker that the fish are VHS-free. Any stocking by individuals should be banned for this very reason: introduction of fish from other water bodies or launching of contaminated boats may bring in parasites and diseases or non – indigenous species (e.g., quagga mussels), including VHS, that could have a devastating effect on the fish community of Ogemaw Lake.

DISCUSSION AND RECOMMENDATIONS

To summarize, Ogemaw Lake is a mesotrophic lake with a small deep hole of only 24 ft. It has many islands and canals, an outlet to the Rifle River on the west side near the public access, and a small creek on the NE side. Residents are on septic systems. It has a forested watershed with sandy soils. It has good water clarity, and generally low nutrient concentrations on the bottom. That deep area during summer stratification generates an area of low dissolved oxygen but not anoxic (dead zone) conditions near bottom. Interestingly, chlorides, an indicator of septic tank leakage and road salt runoff was low, a sign of good water quality in the lake.

Riparians also contribute to the lakes enrichment through septic tank leakage and lawn fertilization runoff of nutrient-rich water from their property. To reduce the footprint of residents, no lawn fertilization should be done, but if necessary only nitrogen-based fertilizer should be used. See Appendix 1 for other suggestions to reduce nutrient input. The lake has a vast area of littoral zone (>80%) which is shallow with extensive plant beds, including invasive Eurasian milfoil and starry stonewort. There are extensive areas of sandy bottom, which presumably act as good spawning substrate for sunfish, especially largemouth bass. Our zooplankton (small invertebrates in the water column) sample showed that a large species, *Daphnia*, composed 6% of the zooplankton, *Bosmina* 14% (the species most eaten by small fishes) present in the sample. This indicates that there is rather severe predation on the largest zooplankters, which have the most impact on eating algae. Copepods dominated the remaining species.

We collected only 9 species of fishes and another two, with two other stocked species, walleye and channel catfish probable members of the fish community, bringing the count to 11. Members of the sunfish family (Centrachidae) dominated the species collected; the top predator is largemouth bass along with contributions from northern pike, channel catfish, and walleyes. Other species that preyed on forage fish included yellow bullheads (common), yellow perch, and probably black crappies. No minnows were found in the lake. Crawford (2009) reported the presence of rock bass and brook silversides, which we were unable to confirm. Diets of fishes reflected the species, life stage, and feeding strategy of the fish. Small fishes were feeding on zooplankton and benthos, while the large specimens of predaceous fishes were feeding on fishes and sometimes crayfishes. They ate a wide variety of forage, including the young of yellow perch, largemouth bass, sunfish, and Iowa darters (members of the perch family). We believe that the dearth of northern pike has had a favorable effect on yellow perch survival, since they are preferred prey of this predator after minnows. Growth of the fishes we examined generally was at MDNR state averages for a given age; for bluegills, growth of big fish was below averages, while for largemouth bass, small fish were below state averages. Yellow perch, black crappie, pumpkinseed all grew at MDNR state averages.

From the data we collected we made the following management recommendations, which are discussed in detail above.

Water quality

The overall water quality of Ogemaw Lake is very good and anchored by presence of some dissolved oxygen on the bottom at the deep hole. This dissolved oxygen makes the lake mesotrophic (along with low nutrients and moderate water clarity) and acts as a firewall to further deterioration: release of large quantities of phosphorus and nitrates and prevention of fish from utilizing the benthos that lives on the bottom. Preventing further deterioration rests with the riparians, who must retard nutrient input into Ogemaw Lake by reducing runoff (greenbelts), eliminating or reducing lawn fertilization, and having septic tanks pumped every year if possible to reduce nutrient input from septic seepage into groundwater from the sandy soil around the lake (see Appendix 1).

Largemouth bass/Yellow perch

Largemouth bass and yellow perch are native species, with the bass being the major predator in Ogemaw Lake. YOY of both species were common to abundant in seine hauls, indicating good reproduction during 2017 and suggesting that spawning substrate (gravel/sand) for the sunfish family that builds nests is widespread (see Crawford (2009) study) and logs, sticks, and vegetation needed by yellow perch are also prevalent in the lake. We did not catch many large individuals of either species, which may be due to lack of gill netting, since many large bass were reported during fishing contests. In addition, we saw no evidence that stunted bluegills were adversely affecting largemouth bass reproduction, hence our conclusion of no need for stocking of either of these species.

Top predators

There are several top predators in the lake, with largemouth bass the most abundant followed by northern pike, walleye, and channel catfish. We caught many largemouth bass, two northern pike, and no walleyes or channel catfish. First, we suggest that spawning habitat for these species be investigated. Largemouth bass have adequate substrate, but northern pike, even though we caught one YOY from 2017, suggests that attention be given to ensure that any tributary creek that might be suitable for spawning by northern pike be made accessible if that is a problem. Walleyes will not spawn in Ogemaw Lake in our opinion, while channel catfish should and they can be encouraged by placement of spawning structures in the lake. Some designs (old milk cans) are available on the internet. Lastly, fishers should practice catch and release for these fish, since they are so important for maintaining stable fish communities and for repeat catching by the public. Since most large individuals are contaminated with mercury anyway, it is additional incentive to release these fishes. In the same vein, it should be noted that recent research has indicated that the presence of large bluegills and pumpkinseeds in the community can promote better survival and growth of these species. Therefore, because of the sheer number of possible fishers on Ogemaw Lake and the modern boats and ability to zero in on susceptible fish populations, we recommend that fishers only take enough fish for a meal rather than catching a limit every time they go out.

Stocking of walleyes

Apparently around 215,880 walleyes have been stocked into Ogemaw Lake, 1980 and 1996-2017. During our study, we caught no walleyes (gill nets would have been better gear). Although they provide another highly desired top predator for fishers, they are not recommended for more stocking because the fish is not native, will not spawn, and the existing fish community is a co – evolved, warm-water fish community and should not be de-stabilized by introduction of another keystone predator. In addition, water quality conditions are not conducive for a cool water fish, and you could introduce diseases, parasites, or non-indigenous species through stocking fish. Recognizing the importance of this fish to fishers and if managers are aware of these caveats, we could support some stocking of walleyes, despite the difficulty in catching them and their poor survival in the lake

Lack of minnows

Despite great effort with a 50-ft seine at five sites on the lake, we collected no minnows. Crawford (2009) indicated he observed some, but a lake resident reported he had seen none during his many years on the lake, which aligns with our findings. We believe the lack of minnows is due to severe predation by the largemouth bass, which are notorious for decimating most species, except bluegills from a lake. The fact that we caught some mudminnows in this type of environment is surprising, since they are usually absent from lakes with abundant predators. Many other predators, including walleyes, would also prey heavily on minnows. We note that over 2,511 pounds of fathead minnows were stocked into the lake over the years, but that species has failed to establish a viable population. Fatheads are not the best species to stock and we suggest if future introductions are contemplated that a different species, such as bluntnose minnow (common in lakes we sample) and perhaps golden shiner be considered instead of fathead minnows.

Invasive species

Someone brought you at least four exotic species, probably in boats or bait buckets dumped into the lake. Riparians and visitors to the lake need to be reminded to clean and treat ballast water in boats or gear with chlorine or drying out in the sun to prevent introduction of other invasive species or diseases. You should consider banning bait from outside the lake (live fish, crayfish) from being used by fishers to avoid getting viral hemorrhagic septicemia (VHS), exotic crayfish, exotic fishes like the gizzard shad problem we highlighted, and/or introduction of other non-indigenous species, such as zebra and quagga mussels, coming into the lake from outside sources. Stocked fish should come with a certificate of VHS-free fish.

SUMMARY OF RECOMMENDATIONS

Recommendations are summarized more concisely below:

1. Water Quality

   Water quality is good in Ogemaw Lake but dissolved oxygen, although present on the bottom during summer, it was in low concentration. It may be near a tipping point, which would release large amounts of nutrients into Ogemaw Lake. Riparians need to adhere to recommendations suggested in Appendix 1: pump septic tanks often, eliminate lawn fertilization, plant green belts, and no leaf burning in the watershed.

2. Largemouth Bass/Yellow Perch

   Largemouth bass and yellow perch YOY were common to abundant in seine hauls; reproduction is good. Spawning substrate is common for both species. There is no stunted bluegill population preying heavily on bass eggs. The upshot is these populations are stable and need no stocking as a native species that is reproducing adequately.

3. Top Predators

There are many top predators in Ogemaw Lake, with largemouth bass being the most abundant. Northern pike, walleyes, and channel catfish, although apparently rare, could be important as well. These predators are keystone species and should be released to promote stable prey fish communities and because they probably have high mercury concentrations as well. In addition, their spawning habitat should be improved if possible. Largemouth bass have adequate spawning substrate, while northern pike potential creeks may need scrutiny to ensure access during the spring spawning run. Channel catfish spawn in holes in logs, under rocks in excavated spaces, and many potential designs for spawning structures are available on the web. Walleyes are not expected to successfully spawn in the lake. None of these species are recommended for stocking, except northern pike, since they appear to have limited reproduction.

4, Walleyes

Walleyes have been stocked into Ogemaw Lake in large numbers. Some have apparently survived, providing a small fishery. We caught none during our sampling (nor any channel catfish). We oppose further stocking, because they are not native, they are difficult to catch, they will not spawn, stocking may introduce diseases or exotic species, and most importantly, they will be severely stressed during summer stratification. We would not oppose stocking some walleyes provided managers and fishers are aware of drawbacks and there is intense demand for these fishes.

5. Lack of Minnows

We collected no minnows and residents report none seen around their docks. We attributed this to severe predation by the top predators, especially largemouth bass. Fathead minnows were stocked in the past and we believe these are the wrong species to try to get established. We also believe that with the current crop of predators that it will be difficult to get a minnow established, however, mudminnows, which are usually absent from lakes with predators were collected, suggesting that the dense macrophytes present allowed them to survive predation. A similar conclusion is advanced for Iowa darters, which were found in largemouth bass stomachs, but attest to their presence. We suggest that if future stocking is considered, that other minnow species, such as bluntnose minnows or golden shiners, be tried.

6. Invasive species

Invasive species are the scourge of our times and although Ogemaw Lake has a least four now, there are many others that could wreak havoc with the food web. To prevent invasive species from entering, you need to put up signs at the private access asking people putting in boats that came from other lakes potentially contaminated, especially if from a Great Lake, to decontaminate their ballast water or other sources of exotic species by using chlorine or drying the boat for a long period of time. Consider banning bait from outside the lake and be careful to ensure that stocked fish come with a certificate that fish are VHS-free.

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

Condition Documented	Qualitative assessment	Problem Potential	Action to Take
Physical			
Water Clarity	+	High water clarity	Reduce nutrients
Water Depth	-/+	Shallow; sediment buildup	Reduce nutrients
Water Temp.	0	Warms up in summer	None now
Sediments	+/-	Sandy, muck, organic	May increase internal loading
Chemical			
pH	0	None	None
Dissolved oxygen	-	Reduced DO on bottom	Monitor, reduce nutrients
Chlorides	+	Very low	None
Nitrates	0	Good; monitor	See Guidelines; reduce N&P
Ammonia	0	Good; monitor	See Guidelines; reduce P
SRPhosphorus/TP	0	Good; monitor	See Guidelines; reduce P
Hydrogen sulfide	+	Not present in August	Monitor
Biological			
Macrophytes/Algae	-	Eurasian milfoil; S. stonewort	Continue treatment;save natives
Zooplankton	+	Few *Daphnia* present	None
Benthos	+	*NA*	NA
Fish			
Largemouth bass	+	Plenty YOY; few big adults	C @ R
Bluegill	+	Adequate	Maintain predator balance
Yellow perch	-	Plenty YOY; few adults	Monitor top predators
Minnows	-	Absent	Monitor; try other species
Northern pike	-	Rare	C @ R; spawning site improvement
Walleye	-	Stocked	Cease stocking
Pumpkinseed	+	Adults/YOY growing well	monitor
Channel catfish	+	Stocked; rare	Improve spawning sites

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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. In other areas use as little liquid fertilizer as possible; instead use the granular or pellet inorganic type. Do not burn leaves near the lake.

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

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

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

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

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

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

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

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

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

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

APPENDIX 2. Stocking records for Ogemaw Lake (from Crawford (2009) plus more recent records.

LAKE OGEMAW FISH STOCKING

County	Site	Date	Species	Number	Avg. Length (in.)
Ogemaw	Lake Ogemaw	1980	Walleye	20,000	0
Ogemaw	Lake Ogemaw	1996	Bluegill (hybrid)	500	5-7
			Fathead minnow	161 lbs	N.A.
			Largemouth Bass	335	6-8
			Walleye	1000	5-7
			Yellow Perch	1000	5-7
Ogemaw	Lake Ogemaw	1997	Fathead minnow	300 lbs	N.A.
			Channel Catfish	300	10-12
			Walleye	1500	5-7
Ogemaw	Lake Ogemaw	1998	Fathead minnow	300 lbs	N.A.
			Redear Sunfish/Bluegill Sunfish Hybrid	200	4-6
			Walleye	1000	5-7
			Yellow Perch	200	4-7
Ogemaw	Lake Ogemaw	1999	Black Crappie	50	5-7
			Fathead minnow	400 lbs	N.A.
			Largemouth Bass	125	6-8
			Trout	250	12
Ogemaw	Lake Ogemaw	2000	Black Crappie	200	5-6
			Fathead minnow	400 lbs	N.A.
			Trout	200	12
			Walleye	1000	5-7
			Yellow Perch	300	6-8
Ogemaw	Lake Ogemaw	2001	Fathead minnow	400 lbs	N.A.
			Trout	200	12
			Walleye	1000	5-6
			Yellow Perch	300	5-6
Ogemaw	Lake Ogemaw	2002	Fathead minnow	400 lbs	N.A.
			Yellow Perch	400	6-8
Ogemaw	Lake Ogemaw	2003	Walleye	550	6-8
Ogemaw	Lake Ogemaw	2004	Black Crappie	275	6-8
			Walleye	1500	7-9
Ogemaw	Lake Ogemaw	2005	Largemouth Bass	630	6-8
			Walleye	1000	7-9
Ogemaw	Lake Ogemaw	2006	Largemouth Bass	630	6-8
			Walleye	1000	7-9
Ogemaw	Lake Ogemaw	2007	Black Crappie	500	4-6
			Walleye	750	7-9
Ogemaw	Lake Ogemaw	2008	Largemouth Bass	800	6-8
			Black Crappie	300	5-6

Fish Plant Record for Lake Ogemaw

1996 500 Bluegill (hybrid) 5" to 7”

1000 Perch 6" to 8"

335 Largemouth Bass 6" to 8"

1000 Walleye 5" to 7"

160 lbs, of fathead minnows

1997 300 lbs. of fathead minnows

1500 Walleye 5" to 7"

300 Channel Catfish 10"to 12"

1998 100 Northern Pike 12"to 15"

300 lbs. of fathead minnows

200 Southern Red-ear SunfishlBluegill (hybrids) 4" to 6"

200 Perch 4" to 6"

1000 Walleye 5" to 7"

1999 250 Adult Trout 12"

125 Largemouth Bass 6" to 8"

50 Black Crappies 5" to 7"

400 lbs, of fathead minnows

2000 1000 Walleye 5" to 7"

300 Perch 6" to 8"

200 Adult Trout (3 yrs.old) 12"

200 Black Crappies 5" to 6"

400 lbs of fathead minnows

2001 1000 Walleye 5" to 6"

300 Perch 6" to 8"

200 Adult Trout (3 yrs, old) 12"

400 lbs of fathead minnows

2002 400 Perch 6" to 8"

400 lbs of fathead minnows

2003 550 Walleye 7" to 9"

2004 1500 Walleye 7 "to 9"

275 Black Crappies 6" to 8"

2005 1000 Walleye 7" to 9"

630 Largemouth Bass 6" to 8"

2006 1700 Walleye 6" to 8"

500 Crappies 4" to 6"

2007

1000 Walleye 7" to 9"

750 Crappies 5" to 7"

-;

2008 800 Largemouth Bass 6" to 8"

300 Crappies 5" to 6"

NO Walleye planted

2009 1500 Walleye 5" to 8"

225 Largemouth Bass 6" to 7"

200 Channel Catfish 6" to 8"

2010 1700 Largemouth Bass 6" to 8"

280 Walleye 6" to 8"

300 Crappies 5"

2011 200 Red-eared Sunfish (shell crackers) 4" to 5"

1400 Largemouth Bass 5" to 7"

200 Walleye 6" to 8"

2012 1200 Largemouth Bass 6" to 8"

250 Walleye 6" to 8"

200 Red-eared Sunfish (shell crackers) 4" to 5"

2013 1000 Largemouth Bass 6 in. to 7 in.

800 Crappies 4 in. to 5 in.

500 Walleye 6 in. to 8 in.

2014 900 Largemouth Bass 6 " to 8"

300 Walleye 5" to 7"

300 Crappie 3" to 4"

2015 1000 Walleye

650 Largemouth Bass

200 Channel Catfish

2016 200 Walleye ** reduced by 100 due to shortage from supplier.

500 Largemouth Bass

600 Crappies ** 100 larger crappies (7") in lieu of 100 walleye

2017 60,000 fat head minnows in May 2017

500 Walleye Nov. 2017

500 L/M Bass Nov. 2017

500 Crappies Nov. 2017