PICTURE 1: WABEEK LAKE R/V BRODY LOADED WITH 50-F SEINE. NOTE GILL NET FLAGS IN BACKGROUND.

THE LIMNNOLOGY AND FISHERY OF WABEEK LAKE, OAKLAND CO, MI 18-19 JULY 2024

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INTRODUCTION

Jay Brody of Wabeek Lake contacted us for a comprehensive study to examine the limnology, fishes, and zooplankton of the lake during July 2024.

METHODS

STATION LOCATION AND SAMPLE COLLECTION

In any of our studies, we establish sites (stations) where water chemistry, zooplankton sampling, and fish sampling occurs. We also try to get a copy of a google map to put the lake or site into perspective. We try to provide GPS readings so others can go back to any spot and we list the times that gear are deployed . Details of each type of collection we make and how we collect them are found under its category in this report.

PHYSICAL PARAMETERS

Light Penetration

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

Water Temperature

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

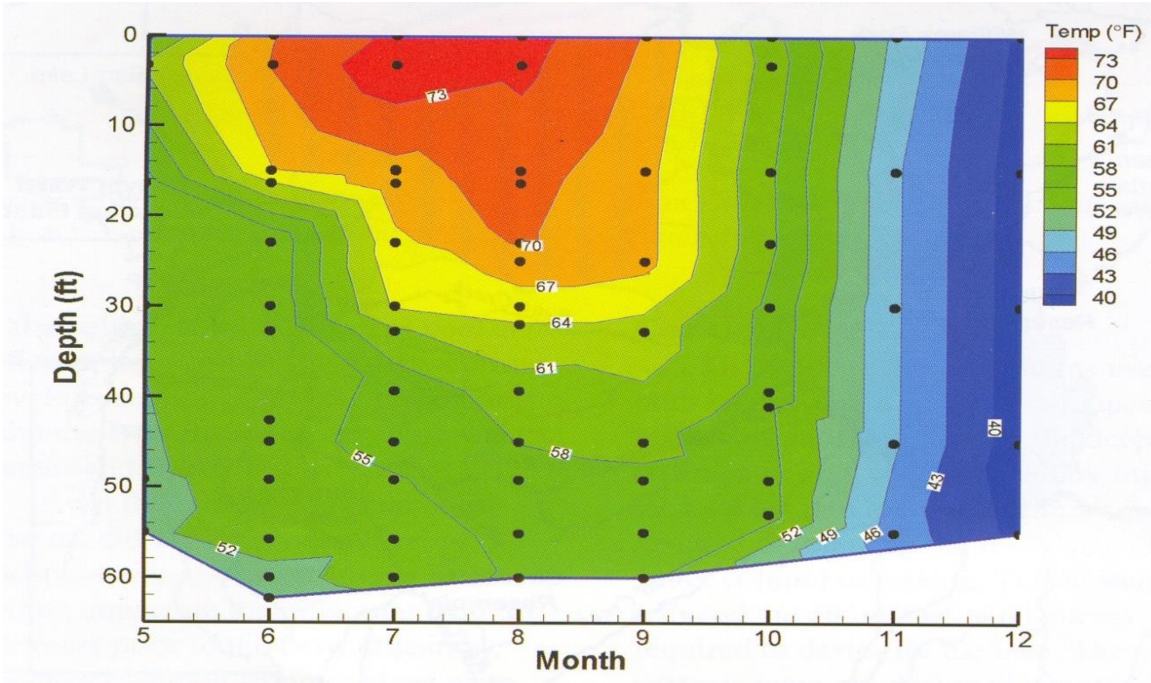

Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red, yellow, and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during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

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

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

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

Dissolved Oxygen

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

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

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

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

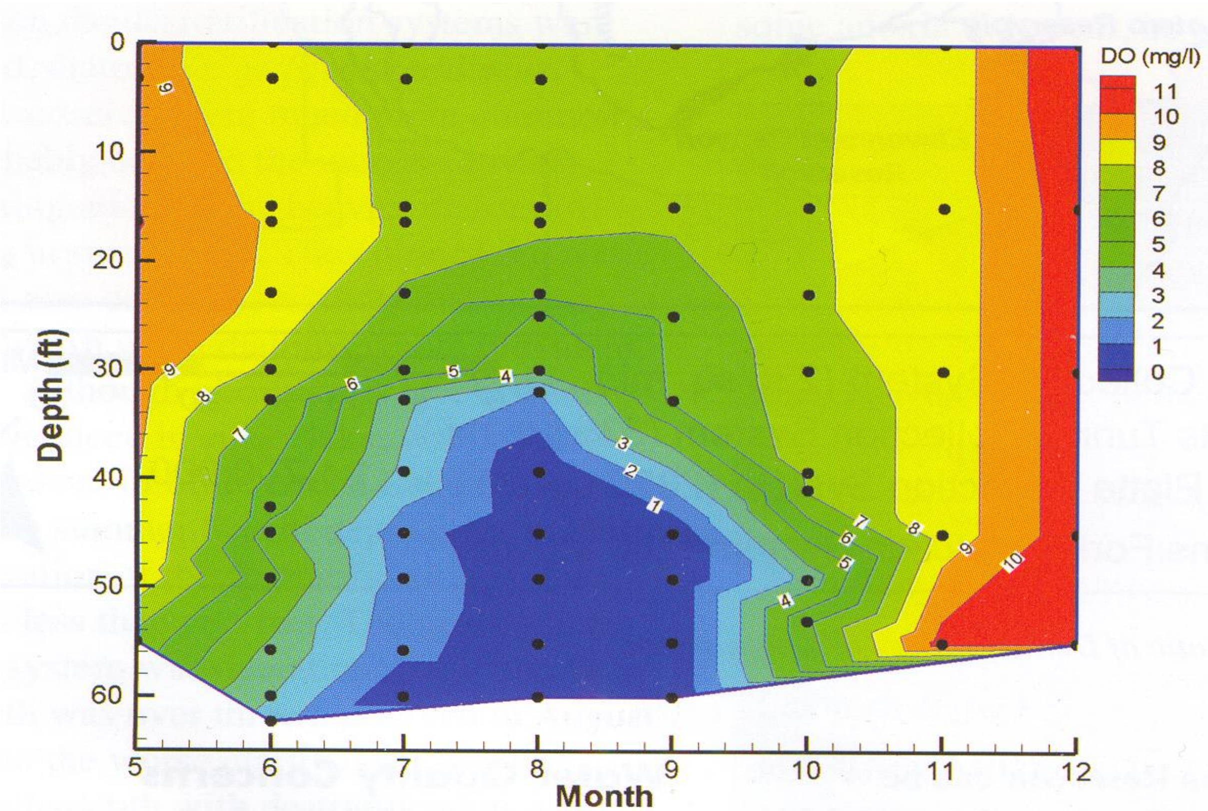

Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when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

depletion. Lack of oxygen in the lower waters (hypolimnion) prevents fish from living there and changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic). Stratification does not occur in all lakes. Shallow lakes are often well mixed throughout the year because of wind action. Some lakes or reservoirs have large flow-through so stratification never is established.

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

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

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 24-hour cycle. During the day in summer, plants photosynthesize and produce oxygen, while at night they join the animals in respiring (creating CO_2) and using up oxygen. This creates a diel cycle of high dissolved oxygen levels during the day and low levels at night. These dissolved oxygen sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

Conductivity

Conductivity (unit of measure is microSiemens/cm) is a measure of the ability of water to conduct current and is proportional to the dissolved solutes present. Some urban lakes with septic tanks and considerable amounts of road salt (inputs high concentrations of chlorides) will increase conductivity values.

Chlorides

Water chemistry parameters are extremely useful measurements and can reveal considerable information about the type of lake and how nutrients are fluxing through the system. They are important in classifying lakes and can give valuable information about the kind of organisms that can be expected to exist under a certain chemical regime. All chemical parameters are a measure of a certain ion or ion complex in water. The most important elements--carbon (C), hydrogen (H), and oxygen (O) are the basic units that comprise all life, so their importance is readily obvious. Other elements like phosphorus (P) and nitrogen (N) are extremely important because they are significant links in proteins and RNA/DNA chains. Since the latter two (P and N) are very important plant nutrients, and since phosphorus has been shown to be critical and often a limiting nutrient in some systems, great attention is given to these two variables. Most algae and macrophytes have a ratio of: 40 Carbon molecules; 7 Nitrogens; 1 Phosphorus. Therefore, P can become limiting before the others in some circumstances. 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.

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

Phosphorus

This element, as noted, is an important plant nutrient, which in most aquatic situations is the limiting factor in plant growth. Plant material is composed of 1 P molecule: 7 N molecules, and 40 C (carbons) molecules as noted above. 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 enough 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 EPA-approved standard methods. The most reduced form of nitrogen, ammonia (NH3), is usually formed in the sediments in the absence of dissolved oxygen and from the breakdown of proteins (organic matter). Thus, high concentrations are sometimes found on or near the bottom under stratified anoxic conditions. Ammonia is reported as mg/L as N and is toxic in high concentrations to fish and other sensitive invertebrates, particularly under high pHs. With turnover in the spring most ammonia is converted to nitrates (NO3=) when exposed to the oxidizing effects of oxygen. Nitrite (NO2-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured. Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. Nitrates, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about succession of algae species, which usually proceeds from diatoms, to green algae to blue-green algae. Blue-green algae (an undesirable species) can fix their own nitrogen (some members) and thus out-compete more desirable forms, when phosphorus becomes scarce in late summer.

BIOLOGICAL PARAMETERS

Algae

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

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

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

The types of algae found in a lake serve as good indicators of the water quality of the lake. The algae are usually microscopic, free-floating single and multicellular organisms, which are responsible many times for the green or brownish color of water in which they are blooming. The filamentous forms, such as *Spirogyra* and *Cladophora* are usually associated with aquatic macrophytes, but often occur in huge mats by themselves. The last type, *Chara*, a green alga, looks like an aquatic macrophyte and grows on the bottom in the littoral zone, sometimes in massive beds. Starry stonewort *Nitellopsis obtusa* is an exotic invasive alga that looks like *Chara*. It is important to identify it in lakes since it can dominate large areas of the lake and damage spawning sites and prevent boat access and fishing in areas where it is present. It is spread from lake to lake on boats and other equipment from infected lakes. Hence, it is important to prevent its spread by having good education of lake residents and signage at boat launch sites to prevent its spread. It is important to understand the different plant forms and how they interact, since plants and algae compete for nutrients present and can shade one another out depending on which has the competitive advantage. This knowledge is important in controlling them and formulating sensible management plans.

Macrophytes

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

Zooplankton

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

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

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

Fish

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

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

RESULTS

STATION LOCATION

Wabeek Lake is situated in a highly developed city with many roads, houses, apartments, and condominiums, but it also has a considerable number of trees and bushes in its watershed which can act as buffers and green belts in un-developed areas near and away from the lake (Fig. 3). The highly developed nature of the watershed will generate a much higher nutrient and salt load into the lake via runoff and culverts, because of the large amount of impervious surfaces which accelerates the runoff of rain during rain events. There is one outlet on the north end of the lake which passes water onto Upper Long Lake through a weir. Considering we are concerned about common carp coming into Wabeek Lake and efforts to control them in the lake, this outlet could act as a conduit for more common carp coming in from Upper Long Lake, but could also act as a collection device for them during spawning in the spring. One positive feature of the lake is its rule against any use of outboard motors on the lake, which will reduce the impact that motorized boats have on inland lakes without these rules, allowing large currents to be generated which can destroy sea walls, but more of concern, re-suspend flocculant sediments which contain nutrients that get re -suspended in the water column. However, residents should be aware that even large pontoon boats powered by electric motors can also disrupt sediments if they operate large engines too close to shore. We were assured that all boats on the lake were limited to 1 hp electric motors.

We established stations on Wabeek Lake to try to representatively sample all the different habitats present in the lake. We established a deep station A in 28 ft of water (Fig. 4, Tables 1, 2) where we sampled water quality from surface, mid-depth, and bottom and zooplankton (Z); and stations for sampling fish with seines (S), gill nets (G), and a trap net (T). Data on set times of fishing gear and GPS (Tables 1, 2) document times and places of fishing gear deployment.

Figure 3. Google map of Wabeek Lake showing the extensive development and roads circling the lake, docks, lawns, and tree growth. The lake is a no outboard motor lake.

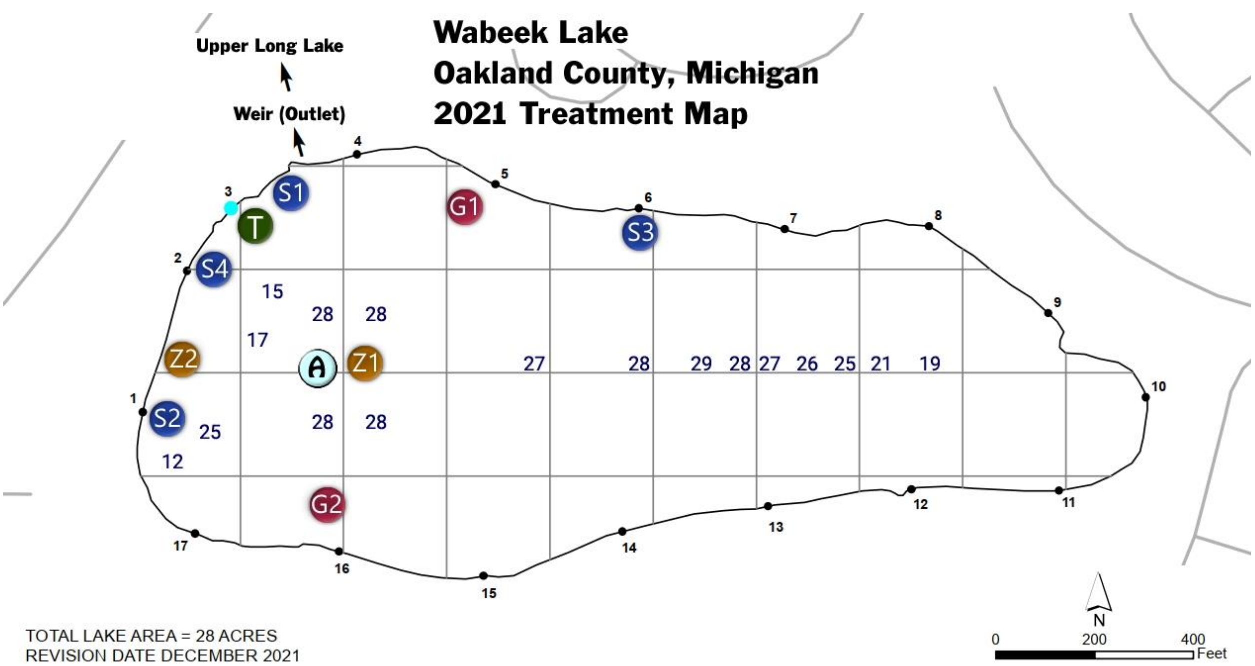

Figure 4. Station location map for Wabeek Lake, 18-19 July 2024. Shown is location where water samples (station A) and a zooplankton sample (Z1 and Z2) were collected, where seining was conducted (S1-S4), and where a trap net (T) and two gill nets were deployed (G1, G2). We placed several depth readings we gathered on the map for perspective. Also shown is the outlet from Wabeek Lake, protected by a weir, that connects to Upper Long Lake. Modified from a map provided by Progressive EngineeringAE.

Table 1. Listing of gear type and sample type, start and end times for fishing gear deployment, and fish species caught in various gear. BG=bluegill, CP=common carp, LB=largemouth bass, YP=yellow perch, YB=yellow bullhead, YOY=young-of-the-year, NP=northern pike, PS=pumpkinseed, ZZ=zero catch, G1-1=first setting of a gill net, G1-2=second set of same gill net, S1-S4=sites of seine hauls, TN=trap net. See Table 2 for GPS for the sites where gear were deployed.

	Start		End		Fish
Net type		**Time**	**Date**	**Time**	**Catch**
Water	18-Jul	1150	18-Jul	1222	NA
Zooplankton	18-Jul	1225	18-Jul	1245	NA
G1-1	18-Jul	1340	18-Jul	1725	BG,CP,LB,
G1-2	18-Jul	1745	19-Jul	1045	YB,YP,LB,BG,NP
G2-1	18-Jul	1400	19-Jul	1745	BG,LB,1
G2-2	18-Jul	1805	19-Jul	1000	CP,LB,BG,YB,NP
TN	18-Jul	1455	19-Jul	1015	ZZ
S1	18-Jul	1430	18-Jul	1455	BG, LB
S2	18-Jul	1515	18-Jul	1530	BG,LB,YP
S3	18-Jul	1615	18-Jul	1625	BG YOY
S4	18-Jul	1630	18-Jul	1645	BG,LB,PS,YP

Table 2. Depths and GPS coordinates for the various sites where water quality, zooplankton, and various fishery gear were deployed in Wabeek Lake, 18-19 July 2024.

		GPS	
STATION	**DESCRIPTION**	**N**	**W**
A	28 FT	42 35.144	83 19.079
Z2	DEEP-28 FT	42 35.160	83 19.125
S1	1-4 FT	42 35.222	83 19.078
S2	1-4 FT	42 35.150	83 19.150
S3	1-4 FT	42 35.197	83 18.912

S4	1-4 FT	42 35.200	83 19.103
T	1-3 FT	42 35.222	83 19.078
G1	5-8 FT	42 35.207	83 18.993
G2	6-12 FT	42 35.100	83 19.078

WATER QUALITY

Water clarity in Wabeek Lake was 5.9 ft on 18 July 2024, low for most Michigan lakes, and categorizes the lake as eutrophic (Secchi disk reading < 7.5 ft). Eutrophic is the lowest category of trophic status, which is typical of many Michigan lakes, and indicates that it is very productive, has an abundance of macrophytes, and algae blooms would be expected to be common. Mesotrophic lakes (Secchi disk value between 7.5 and 15 ft) are intermediate in productivity between eutrophic, and oligotrophic (think Lake Superior- Secchi disk values >15 ft). We suspect common carp may be part of the cause of the reduced water clarity in Wabeek Lake. Additional secchi disk measurements in Wabeek Lake showed that summer values were 8.5 ft in 2021, 3.5 ft in June and 6 ft in August 2023, and readings were 8 ft on 31 July 2024 (Table 3) only 2 weeks after our reading of 5.9 ft on 18 July 2024. This provides a range of values, all of which are below 7.5 ft except one at 8.5 ft (mesotrophic), designating the lake very productive with a mostly eutrophic status. The 3.5 ft in early June 2023 is particularly of concern, since this is a very low value and probably indicates a tendency for declining water clarity and a major algae bloom ongoing.

Table 3. Water chemistry parameters collected from a deep site in Wabeek Lake: Dissolved oxygen on the bottom, total phosphorus (TP) (mg/L) on the bottom, secchi disk measures, and chlorophyll a over various summer dates, 2021, 2023, and 2024. Data provided by ProgressiveAE.

DATE	DISS. OXY BOTTOM	TP BOTTOM	SECCHI FT	CHLOR A
28-Jul-21	0	0.127	8.5	4
8-Jun-23	0.4	0.202	3.5	4
21-Aug-23	0.2	0.177	6	3
31-Jul-24	0.2	0.061	8	36

The water quality of Wabeek Lake reflects the low water clarity and the anoxia (no dissolved oxygen on the bottom) (Fig. 5) during our study, which will become much worse later in the summer. There was anoxia on the bottom 3 m (9.8 ft) of water at the deep spot (station A – see Fig. 4), and the dissolved oxygen concentrations from 13 to 19.7 ft were too low for warm water fish which require a minimum of 3 mg/L, since dissolved oxygen was 0.26-1.03 mg/L; the thermocline was around 2 m, which is very unusual- it is usually much deeper. Water temperature was 26.6 C (almost 80 F) at the surface, which is stressful for the only cool-water fishes, the northern pike and yellow perch. As we will discuss further in the Fish section, northern pike are not a good fit for eutrophic lakes with anoxia on the bottom. As demonstrated, during the summer stratified period when anoxia develops on the bottom, cool water fish that require cool water find it is devoid of dissolved oxygen on the bottom, while at the surface it is very warm and stressful for these species (Fig. 6). Although this is the case for Wabeek and many other lakes in Michigan, northern pike do grow and prosper in these lakes despite the adverse summer conditions. They can feed and grow during the colder parts of the year. However, the real drawback is spawning habitat, which is lacking in most lakes, and appears to be the case in Wabeek as well.

The second problem for anoxia in Wabeek Lake is that there is a chemical reaction between iron and phosphate, that during oxygenated conditions creates an insoluble compound, iron phosphate. However, when anoxia arrives it reverses that reaction and under anaerobic conditions, creates a kind of phosphorous pump which produces large quantities of P along with ammonia, which of course fuels plant growth the following spring after being distributed lake wide during the fall and spring overturn (mixing) process. This is called “internal loading” and is one of the concerns we have for nutrient sources in Wabeek Lake. Interestingly, ProgressiveAE found dissolved oxygen to be much better during their studies with 0-0.4 mg/L found on the bottom during the 3 years of their studies (Table 3). Residents can help improve the trophic status of Wabeek Lake by not fertilizing their lawns, by planting greenbelts to retard runoff, by not burning leaves near the lake or in the watershed, and by not washing boats or vehicles using high phosphate detergents. Fortunately, the lake has an extensive area of trees and vegetation around the edges of the lake, which will help ameliorate the negative effects of these actions.

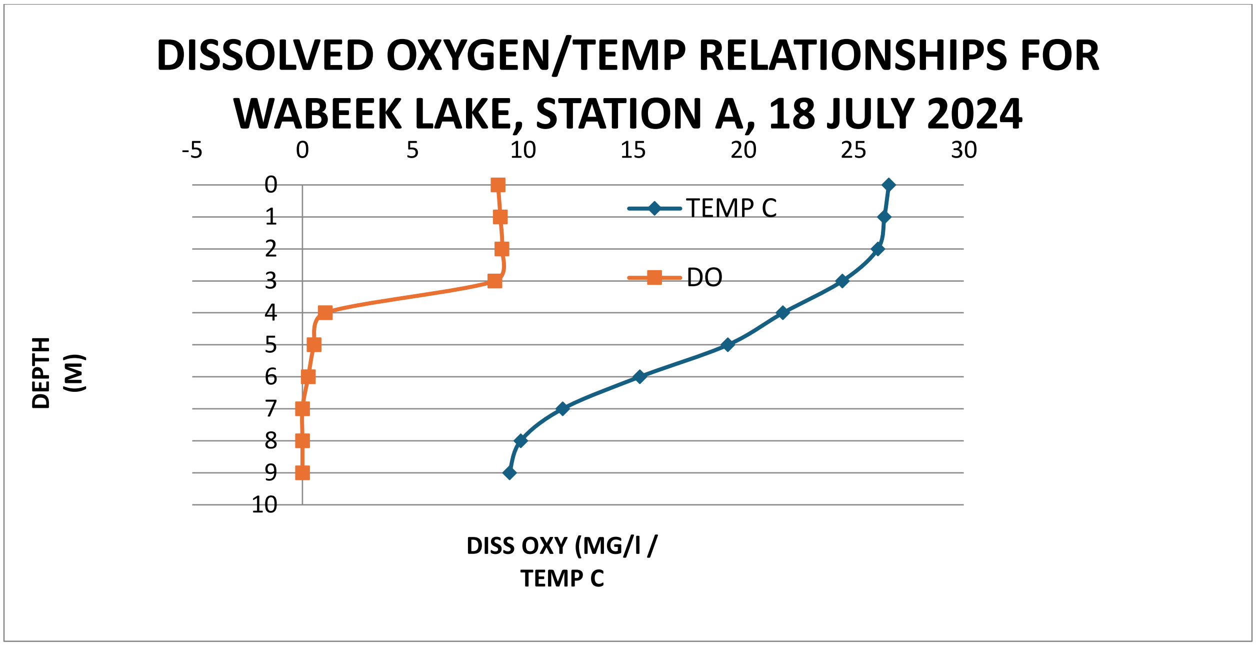

Figure 5. Temperature and dissolved oxygen profile of Wabeek Lake, 18 July 2024 at the deep spot in the lake.

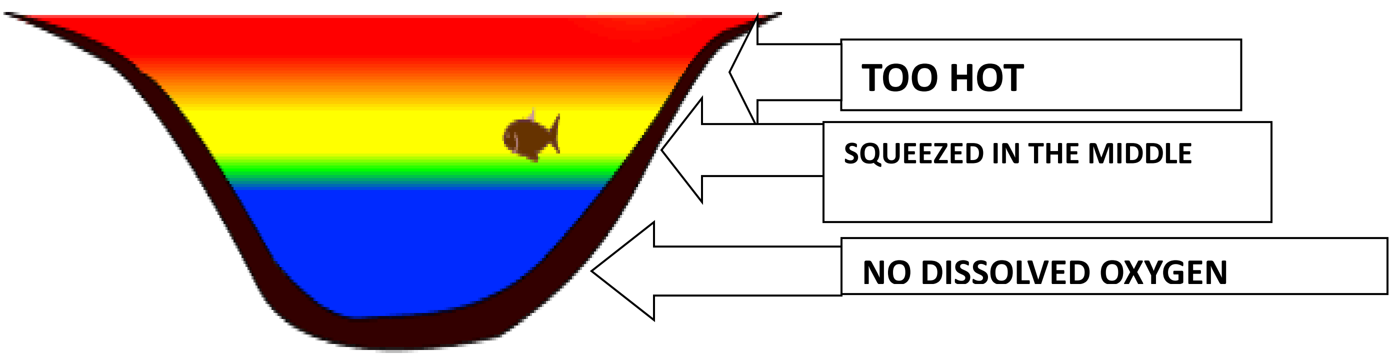

Figure 6. Depiction of the dissolved oxygen concentrations in a stratified lake during summer, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, but has no or very low dissolved oxygen present. Cool water fishes, such as northern pike and walleyes are "squeezed" between these two layers and undergo thermal stress during long periods of summer stratification.

We always try to document the fish habitat conditions in lakes we work on and did this for Wabeek Lake, producing water clarity, dissolved oxygen profiles, and water chemistry of selected parameters for assessing habitat suitability for cool and warmwater fishes. The pH for Wabeek Lake was low considering it was turbid, probably with algae which usually increases pH in lake surfaces. However, the pattern was as expected, surface waters were higher in pH (7.32-7.37), while pH was considerably lower on the bottom, because of decomposition processes there increasing acidity (Table 4).

Conductivity (measure of the ability of water to conduct electricity) was elevated with values of 894-849 uS in surface waters and as was found for pH, much higher conductivity on the bottom (958 uS), again elevated because of the products of decomposition on the bottom, which also produced other substances in high concentrations, such as ammonia and Total Phosphorus (Table 4).

Nitrates are usually low in lake waters during summer because they are taken up by plants in surface waters and because sediments decompose in oxygen-free water, the nitrogen product is ammonia-- not nitrates. This was also true in Wabeek Lake as nitrates were 0.07-0.09 mg/L (Table 4).

As noted above, when a lake becomes stratified, anoxia often settles in removing oxygen from bottom water and creating anaerobic conditions, which as noted, creates ammonia instead of nitrates (which require oxygen) as products of this activity. Sometimes some large concentrations are measured depending on how degraded the environment is. For Wabeek Lake, the typical pattern was apparent: ammonia was non-existent in the surface, somewhat higher at mid depths (0.14 mg/L), but very elevated on the bottom where it was 2.12 mg/L, extremely high concentrations (Table 4). This fertilizer is released into the water column and mixed throughout the lake during fall (and spring overturn) when the lake mixes (see explanation in Fig. 1). This is part of the "internal loading" referred to earlier and is a substantial source of nutrients for Wabeek Lake, which is greatly enlarged because of the expanded area of the bottom of Wabeek Lake (see depths in Fig. 4) which are deep and anoxic.

The concentrations of SRP (soluble reactive phosphorus) are usually uniformly low or trace in most lake samples, because it is the most "available" form of P and is quickly taken up by algae and macrophytes. This pattern was not quite the same in Wabeek Lake; concentrations were indeed at trace concentrations in surface and mid depth samples, but somewhat elevated (0.014 mg/L) in the bottom sample we collected (Table 4). Again, we attribute this to the intense decomposition ongoing on the bottom of Wabeek Lake and this is early in the season; conditions will get much worse later in the year.

Total phosphorus is all the P in a unit mass (usually 1 mL) of water and limnologists use the surface TP to characterize the trophic status of lakes. Wabeek Lake is mesotrophic (between 0.010 and 0.020 mg/L – value of 0.015 mg/L – Table 4), which is in between degraded eutrophic (>0.010 mg/L) and pristine (<0.010). The bottom TP is another indication of degraded water in the hypolimnion, since it had a really high concentration of 0.193 mg/L, a clear demonstration of the breakdown of organic matter on the bottom. Other studies (Table 3) have also shown very high concentrations on the bottom, from 0.061 mg/L on the bottom on 31 July 2024 to 0.202 mg/L during 8 June 2023. Note that 2 weeks earlier, we found 0.193 mg/L at a slightly different site on the lake. This is somewhat surprising, since we would not expect a lower concentration not far from our station and later in the hottest summer in existence, which should have accelerated the amount of TP on the bottom. Never-the-less, there is a considerable amount of TP on the bottom which will be released along with high levels of SRP (0.013 mg/L) to fuel plant growth the coming year.

Lastly, Chlorophyll a was measured in Wabeek Lake; it is a measure of the algae in the surface waters and in the summers of 2021 and 2023 it was modest, ranging from 3 to 4 ug/L (Table 3). These values are mesotrophic (2.2-6 ug/L), while the value of 36 ug/L recorded 31 July 2024 is way off the charts (eutrophic is >6 ug/L), indicating a massive algal bloom ongoing in Wabeek Lake at this time.

Table 4. Water chemistry parameters: pH, conductivity (uS/cm), and chlorides, nitrates, ammonia, soluble reactive phosphorus (SRP), and total phosphorus (TP) (mg/L) measured in Wabeek Lake at station A, 18 July 2024.

Depth - m	pH	Cond	Chlorides	Nitrates	Ammonia	SRP	TP
Surface	7.32	894	137	0.08	<0.01	<0.005	0.015
Mid-4 M	7.37	849	143	0.07	0.14	<0.005	
Bot-7.5 M	7.17	958	149	0.09	2.12	0.013	0.193

MACROPHYTES

The macrophytes of Wabeek Lake are of great interest to us, since they are such an important part of fish habitat in a lake. We do not want an overabundance of plants, such that small fish are not vulnerable to top predator predation, nor do we want them to be severely destroyed in the name of access to residents, who do deserve to have access, but it should be done mechanically and only to provide a place for a beach or to launch a boat. At the present time macrophytes and the alga *Chara*, are being controlled to some degree by the high turbidity in the lake and the nuisance plants are being controlled with herbicides. About 4.5 acres of Eurasian milfoil were treated and purple loosestrife and *Phragmites* were treated in areas along the shore to stop their proliferation. Fortunately, ProgressiveAE has provided their summer 2024 list of species and what percentage they occupy of the sites they surveyed (Table 5), showing that there were four invasive species present in Wabeek Lake with the percentage of sites they occupied being: Eurasian milfoil (65%), Curly-leaf pondweed (29%), Swamp loosestrife (71%), and *Phragmites (24%)*. Currently these invasive species are being targeted, and native species are being protected, which is an excellent philosophy we support. For fish, the lily pads were found in around 50% of the sites surveyed; these are great fish habitat, since they provide shade, cooling on those hot days of summer, refuges, fish-food organisms, and protection from wind-generated waves and currents that can re – suspend sediments containing nutrients. We noted some *Chara* in the areas where we seined, but they are relatively rare only found at 12% of the sites surveyed. They too are important algae since they occupy nearshore areas and protect them from invasive species encursions, provide fish habitat and food organisms, and are also responsible for sequestering phosphorus through shifts in the carbonate system precipitating P. As noted, the plants are a low diversity community with an overabundance of invasive species, but have some elements of structure that are critical to the fish community. More diversity and native plants should be a goal.

Table 5. List of the common and scientific names of aquatic plants found in Wabeek Lake and an indication of their abundance (what percentage of the sites they occupied). Study done in summer 2024.

Aquatic plants **Common name**	**Scientific name**	**% of sites where present**
Sago pondweed	*Stuckenia pectinata*	71
Illinois pondweed	*Potamogeton illinoensis*	71
Eurasian milfoil*	*Myriophyllum spicatum*	65
Coontail	*Ceratophyllum demersum*	41
Curly-leaf pondweed*	*Potamogeton crispus*	29
Chara	*Chara* sp.	12
Thin-leaf pondweed	*Potamogeton* sp.	6
Yellow waterlily	*Nuphar* sp.	53
White waterlily	*Nymphaea odorata*	47
Swamp loosestrife*	*Decodon verticillatus*	71
Cattail	*Typha* sp.	65
Purple loosestrife*	*Lythrum salicaria*	59
Phragmites*	*Phragmites australis*	24
Pickerelweed	*Pontederia cordata*	18

ZOOPLANKTON

As part of our "ecosystem approach" to lake management, we try to learn about all important components of the biological and physical entities, which includes humans, probably the most important. Zooplankton are important biological constituents of the communities that make up the lake's metabolism. They are critical food of newly hatched fishes and some juvenile and adult fishes eat them when other foods are less available. There are two major groups that are important: copepods (Picture 2) and cladocerans with the most prominent member being *Daphnia* (Picture 3). Fish planktivores target the largest individuals in the lake, which are usually cladocerans, especially *Daphnia*. In addition, *Daphnia* and other cladocerans are very important in that they eat algae (not the filamentous types, like some green and blue-green algae) and can lower the turbidity levels of a lake if they are abundant. Hence, we pay particular attention to how many there are in a lake to see if maybe their abundance may impact fish growth or improve water clarity.

We collected two samples of zooplankton, one from the deep spot and one from a shallower spot (10 ft). Something happened to the shallow sample, since no zooplankton were found in the sample. This could be severe fish predation or perhaps an error in sample preservation, most likely the latter. We collect samples at two depths to find out if predation by fishes nearshore is more intense than offshore, which we were sure we would see after we saw how abundant YOY (young-of-the-year) bluegills were in our nearshore seines and how many appeared in largemouth bass stomachs we examined (sometimes up to 28 in one stomach- see Table 8 below, Picture 5). In the deep sample, cladocerans composed 21.8% of the sample and *Daphnia* made up 16.9%, which is an acceptable number and will ensure that they will exert pressure on the algae helping to increase water clarity. Note that *Daphnia*, in order to escape fish predation, will do what is termed a diel vertical nocturnal migration: they descend into that anoxic water where fish do not go during the day, then rise at night to feed on algae and reduce fish predation. *Daphnia* in the nearshore zone use macrophytes for this purpose, but they are much less of a refuge than the anoxic water is. Copepods, *Diaptomus* and *Cyclops,* made up the remaining zooplankers present. This group is much faster than cladocerans, are fed on only when *Daphnia* is uncommon, but are poor feeders on algae, so do not have the effect on improving water quality that *Dapnhia* do. Sometimes, lake managers utilize a process called top down control which involves manipulating the fish populations by stocking more predators, which eat more prey, which reduces the pressure on *Daphnia*, and results in improved water clarity. A biological example of the butterfly flutter effect!! Bottom line conclusion for zooplankton is: There is a healthy population of *Daphnia* offshore that is probably stable because of the anoxic water providing refuge from fish predation during the day and there are probably less planktivores out deep than in shallow water.

Table 6. List of zooplankton groups collected from the deep basin (28 - ft station A) on18 July 2024. Samples were collected with a vertical tow of a 153-um, mesh nylon net deployed about 1 m off bottom. Imm. = immature, spp. = one or more species.

Zooplankton group	No.	%
Diaptomus Imm.	136	26.8
Diaptomus spp. ♂	19	3.7
Diaptomus spp. ♀	48	9.4
Cyclops imm.	144	28.3
Cyclops spp, ♂	32	6.3
Cyclops spp. ♀	18	3.5
Daphnia spp.	86	16.9
Bosmina spp.	20	3.9

Ceriodaphnia spp.	5	1.0
TOTALS	508	100.0

Picture 2. A copepod (zooplankter).

Picture 3. *Daphnia*, a large zooplankter, adept at eating algae (note green in intestine).

FISH

Fish diversity

We seined, set a gill net and a trap net. The fact that we used a two-man paddle boat added extra challenges to the activities. Wabeek Lake was difficult to seine, since the near shore is mucky in some areas and has some large beds of macrophytes in other areas (especially lily pads), but we did catch large numbers of bluegills (there were large numbers of small bluegills) and largemouth bass at some sites. We caught seven species of fishes (see Picture 4), with bluegills the dominant species followed by largemouth bass (Table 7). We also caught four common carp in our gill nets and they were seen stirring the water nearshore and jumping in the open water of the lake. We also collected one green sunfish, one northern pike (the largest of all the species), four yellow bullheads, and eight yellow perch. There were no minnows or black crappies found. The fact that there is a good size range of yellow perch present indicates that the northern pike population is probably small, because yellow perch are preferred prey by this predator. It is also a good sign that there are yellow bullheads in the lake, since they are great predators on bluegills, but so far the predators present are not making much of a dent in their populations, probably because of the high turbidity for the visual predators (northern pike and largemouth bass), and the dense macrophyte beds nearshore which provide good refuge for the small bluegills. We only got one pumpkinseed, which is strange; usually if present they are more prevalent. Black crappies and golden shiners do well in turbid water so would be great candidates for stocking to see if they would become established. This is low diversity compared with most eutrophic lakes in Michigan and the presence of common carp, a destructive species that stirs up the bottom and increases turbidity is a detriment to the lake's water clarity and fish populations. Regarding the abundant macrophytes and algae nearshore, we highly recommend that residents instead of relying on herbicides to control plants, that they should remove them mechanically if a beach or access through macrophyte beds is required. The old saying if you live on a lake get a rake applies here.

Table 7. Fish species, the number caught, and the size range from Wabeek Lake, 18-19 July 2024.

SPECIES	N	SIZE RANGE
Bluegill - BG	33+	1.2-8.2
Common carp - CP	4	23.3-25.3
Green sunfish - GN	1	7.3
Largemouth bass - LB	23	2.5-12.3
Northern pike - NP	1	26.9
Yellow bullhead - YB	4	5.8-10.5
Yellow perch - YP	8	2.1-10.3

Picture 4. Several fish species (northern pike, yellow perch, largemouth bass) collected during sampling in Wabeek Lake.

Fish Diets

Largemouth bass are the dominant predators, but northern pike, yellow bullheads, and yellow perch are effective predators that will help to control the proliferation of small bluegills in the lake. The largemouth bass were carnivorous, eating sometimes up to 27 young-of-the-year bluegills (Table 8); we seldom see this kind of predation on bluegills with so many YOY eaten. Even young bass 2.5- 3.3 in were eating YOY bluegills, while fish 8.1-12.3 in were eating almost exclusively YOY bluegills, with a maximum of 27 eaten by one fish (see Picture 5). The only other food consumed was caddisflies by one fish. Largemouth bass are the major predators on bluegills in Wabeek Lake.

Bluegills were strictly insect and invertebrate consumers. Smaller fish (1.2-5.4 in) ate zooplankton, chironomids, plants, algae, caddisflies, ants, isopods, damselflies, and fingernail clams (Table 8). Larger fish from 5.4 in to 8.2 in consumed similar items along with mayflies, Hydracarina (water mites), *Chaoborus* (phantom midges), but they usually had higher numbers in stomachs compared with smaller fish. The presence of caddisflies and mayflies is a good indication of conditions in the lake (sufficient dissolved oxygen) to support these fragile species. The food supply eaten by bluegills seems to be adequate, with high numbers of chironomids and a diverse number of other insects being eaten by bluegills. The one pumpkinseed we caught had an empty stomach; usually we see more pumpkinseeds in lakes where they are present. They are also molluskivores (snail and clam eaters) which taps into another food source seldom eaten by other species. Yellow bullheads, contrary to expectations, were eating insects chironomids and *Chaoborus* phantom midges. In most other lakes, this species usually feeds at night and eats many bluegills, so this species is important to the lake fish community helping to control bluegills. The small yellow perch were eating zooplankton, mayflies, and an invertebrate fairy shrimp *Hyalella*. The larger fish was eating one YOY bluegill (ca. 1 in). The northern pike is another good predator in the lake and they prefer yellow perch, but should also help control the bluegill population.

Table 8. Diets of fishes collected from Wabeek Lake, 18-19 July 2024. See Table 1 for species codes definitions. S=Seine, G=Gill net, sizes of fish eaten are in mm as are lists of the lengths of fish for bluegills and largemouth bass to show how abundant YOY (young-of-the-year) were in the nets. II=immature, F=female, M=male, CC=can't tell. For gonad condition (e.g., F1), the 1 refers to poorly developed gonads, a 2 is moderately developed, and a 5=spent.

SPECIES	GEAR	TL-IN	WT-OZ	SEX	DIET
		BLUEGILL			
BG	S3	1.2	0.01	II	ZOOP, PLANTS
BG	S1	1.2	0.01	II	ZOOP, CHIRONOMID
BG	S3	1.3	0.01	II	MT
BG	S4	2.0	0.07	II	PLANTS
BG	G2-2	2.7	0.16	II	ZOOP, ALGAE
BG	S2	2.9	0.19	F1	4 CADDISFLIES
BG	S2	3.2	0.32	F1	CADDISFLIES
BG	S4	3.3	0.32	II	INSECT PARTS
BG	S2	4.0	0.55	F1	5 CHIRONOMIDS
BG	S4	4.0	0.68	F1	ANTS, ISOPOD
BG	S2	4.6	0.94	F1	CHIRONOMID, FINGERNAIL CLAMS
BG	S1	4.8	1.08	F1	PLANTS, DETRITUS
BG	S1	4.8	0.99	F1	PLANTS
BG	S2	5.4	1.51	F1	DAMSELFLY
BG	S2	5.4	1.51	F1	11 CADISFLIES

BG	S4		5.6		F2	ANTS, MAYFLY
BG	S4		5.9	2.28	F1	ISOPOD, ANTS, PLANTS
BG	S4		6.0	2.46	F1	ISOPOD, PLANTS
BG	G1		6.2	2.44	M1	MT
BG	G2-2		6.4		F1	INSECT PARTS
BG	G2-2		6.6	3.00	F2	CHIRONOMID, FINGERNAIL CLAMS
BG	G2-2		6.8	3.50	M1	INSECT PARTS
BG	G2-2		7.0	4.20	M1	MT
BG	G1		7.1	3.60	F2	10 CHIRONOMID, FILAMENTOUS ALGAE
BG	G1		7.5	4.44	M2	
BG	G1		7.5	5.26	M2	MT
BG	G1		7.6	4.36	F3	FILAMENTOUS ALGAE
BG	G2-2		7.7	4.50	F2	15 CHIRONOMID, HYDRACHRARINA, CHAOBO
BG	G2-2		7.9	5.10	M2	CHAOBORUS, FINGERNAIL CLAMS, 25 CHIRON
BG	G1		7.9	5.01	F2	13 CHIRONOMID
BG	G2-2		7.9	5.18	M2	10 CHIRONOMID
BG	G2-2		8.2	5.74		INSECT PARTS
BG	G2-2		9.9		F1	MT
BG	S1	25,29,26,27,28,25,26				
BG	S1	25,,29,25,27,26,28,29,27,28,24,28,25,30,26,30				
BG	S4	32,53,49,52,46,50,49,43,51,50,24,59,31,53,42,53,34,50,27				
BG	S2	81,49,45,48,56,55,39,28,29,50,42,42,62,26,28,92,33,35,58,41				
		COMMON		**CARP**		
CP	G1-1		23.0		F2	DETRITUS
CP	G1-1		25.3		F2	OSTRACODS, PLANT MATERIAL
CP	G2-2		23.1		F1	DETRTUS, PLANT MATERIAL
CP	G2-2		24.5		F2	DETRTUS, PLANT MATERIAL
		GREEN		**SUNFISH**		
GN	S3		7.3	5.10	M1	MT
		LARGEMOUTH		**BASS**		
LB	S2		2.5	0.10	II	2 BG 29, 28 MM
LB	S4		2.6	0.12	II	MT
LB	S4		2.7	0.15	II	BG 24 MM
LB	S4		2.8	0.15	II	BG 26, 24 MM
LB	S4		2.8	0.16		
LB	S4		2.8		II	BG 28
LB	S1		2.9	0.16	II	MT
LB	S1		2.9	0.17	II	MT
LB	S1		3.0	0.17	II	MT
LB	S2		3.0		II	BG 28 MM
LB	S4		3.1	0.21	II	BG 26 MM
LB	S4		3.1	0.20	CC	MT

LB	S2		3.1	0.21	CC	MT
LB	S4		3.2	0.23		PLANTS
LB	S2		3.2	0.21	CC	CADDISFLY
LB	S2		3.3	0.27	CC	2 BG 29, 28 MM
LB	G2-2		8.1		F1	15 YOY BG
LB	G1		10.4		M1	12 YOY BG
LB	G2-2		11.2		M1	22 YOY BG
LB	G2-2		11.3		M1	20 YOY BG
LB	G1		11.6	11.63	F2	ABOUT 12 YOY BG ABOUT 26 MM
LB	G2-2		12.0			21 YOY BG, 1XX FISH 50 MM
LB	G1		12.3		F5	27 BG YOY
LB	S4	68,72,66,,73,71,70,68,67,72,68,67				
LB	S2	76,98,73,77,74,71,69,54,77				
		NORTHERN		**PIKE**		
NP	G1-2		26.9		F1	MT
		PUMPKINSEED				
PS	S4		3.0	0.24	CC	MT
		YELLOW		**BULLHEAD**		
YB	G1-2		9.5	5.57	F1	10 CHIRONOMID, 2 CHAOBORUS
YB	G2-2		5.8	1.25	II	15 CHIRONOMID, PLANTS
YB	G2-2		10.5		F1	60 CHIRONOMID
YB	G2-2		6.7	2.12	F1	SEED
		YELLOW		**PERCH**		
YP	S3		2.1	0.04	II	ZOOP, MAYFLY - *CAENIS*,
YP	S2		2.1	0.04	II	3 MAYFLIES
YP	S4		2.2	0.05	II	HYALELLA
YP	S4		2.2	0.05	II	MT
YP	S2		3.2	0.06	II	MAYFLY, 4 HYALELLA
YP	G1-2		8.4	3.56	F1	MT
YP	G1-2		9.5	5.43		
YP	G1-2		10.3	7.41	F5	1 YOY BG 20 MM

Picture 5. Some 21 YOY bluegills eaten by one largemouth bass, voracious predators.

Age and growth

We had great success in catching some species (bluegills and smaller largemouth bass) and less so for others. Largemouth bass large individuals are difficult to catch with the gear we use and we usually rely on resident fishers to provide us with scales from large individuals. Some species are rare (northern pike). Despite these drawbacks, we were able to garner enough specimens for most fish to document their relative abundance and growth in Wabeek Lake. Overall, all species were growing at MDNR's state averages. We caught most of our bluegills in nearshore seine hauls; most were YOY and they were very abundant. The larger individuals were caught in gill nets in deeper water. Most age groups were growing at state averages, but the 3 and 4-year olds were growing at higher rates than averages (Fig. 7). It appears that the nearshore vegetation is providing great shelter for high survival of YOY bluegills, because they were so abundant in our seines and because they were found in large numbers in the largemouth bass stomachs (Table 8, Fig. 7, Picture 5).

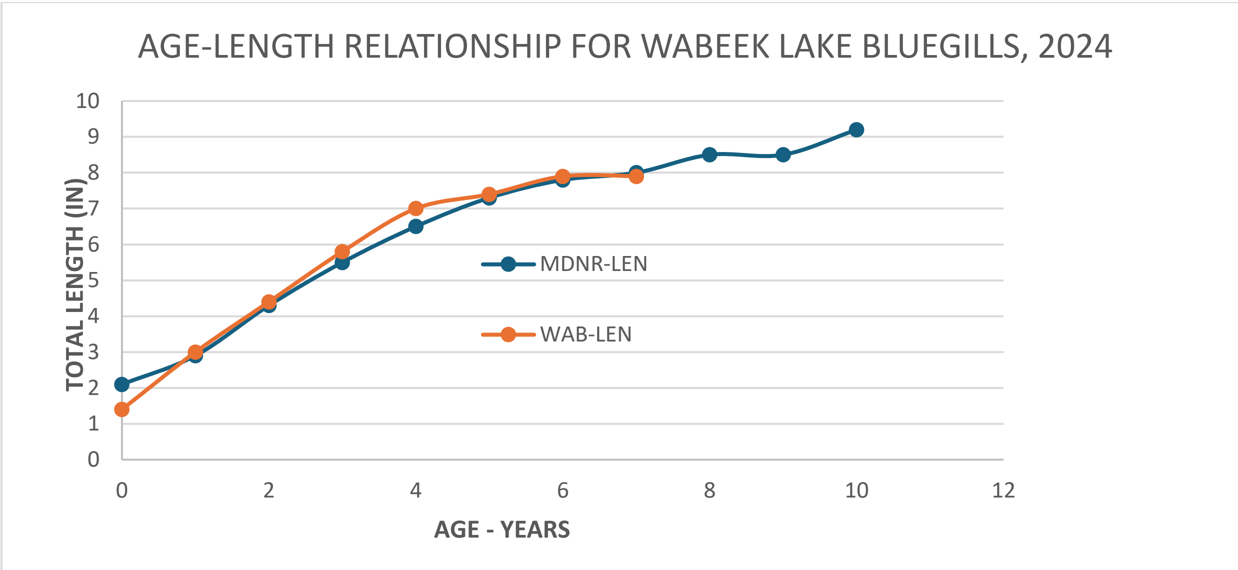

Figure 7. Age – length relationship for Wabeek Lake bluegills, 2024. N=33.

Largemouth bass were the second-most abundant fish caught in our Wabeek Lake sampling efforts. Fish were mostly small and were caught in nearshore seine hauls, while the larger individuals were caught in our gill nets. Fish were growing at state averages (Fig. 8), although we did not have any larger individuals, there are probably plenty in the lake. Like northern pike these large individuals should be released to reproduce although conditions for both species are probably limited – the most for northern pike, but largemouth like other sunfish require firm usually sandy substrate. There are some presumably man-made beaches that could fill this need, it might be a good effort to provide more rocky, sandy substrates to increase nesting success of the bluegills and largemouth bass in Wabeek Lake; however we did catch large numbers, so there was great year class success during 2024.

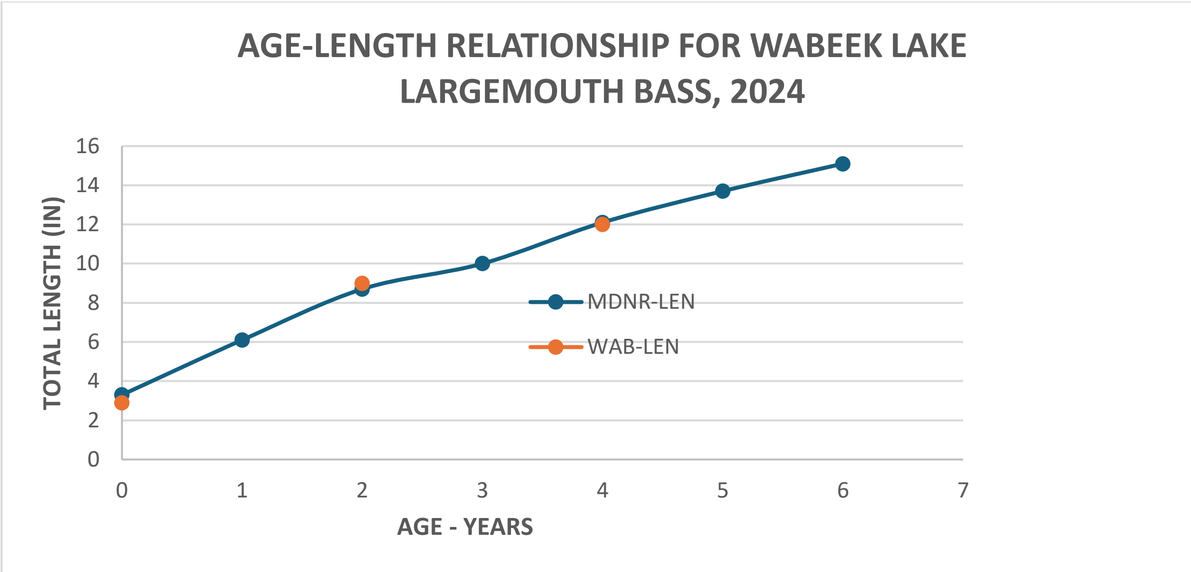

Figure 8. Age – length relationship for Wabeek Lake largemouth bass, 2024. N=24.

We only caught one large northern pike so they are unfortunately rare in the lake. It was a spent female growing at adequate state rates, despite stressful thermal conditions of the squeeze (Fig. 6). We usually do not advocate for stocking fish unless conditions demand it, but northern pike may be an exception based on having another top predator that can control the bluegills and yellow perch (preferred prey) and provide another large species for fishers.

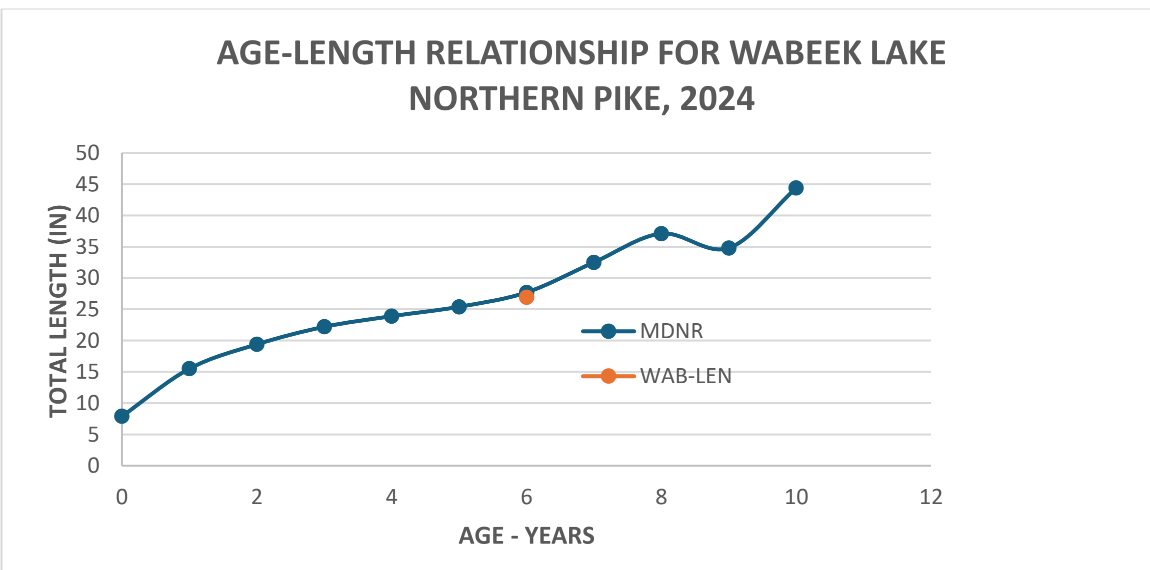

Figure 9. Age – length relationship for Wabeek Lake northern pike, 2024. N=1.

There were only eight yellow perch caught that ranged from 2.1-10.3 inches so they have an uncommon presence in the lake. They are favored prey of northern pike, so may be affected by their presence. They are a prized catch for fishers because of their taste and command high prices at grocery stores that sell fishes. The ones we sampled showed there was moderate reproduction based on the number of YOY we got. They were growing at MNDR average rates (Fig. 10) and probably have adequate spawning substrate.

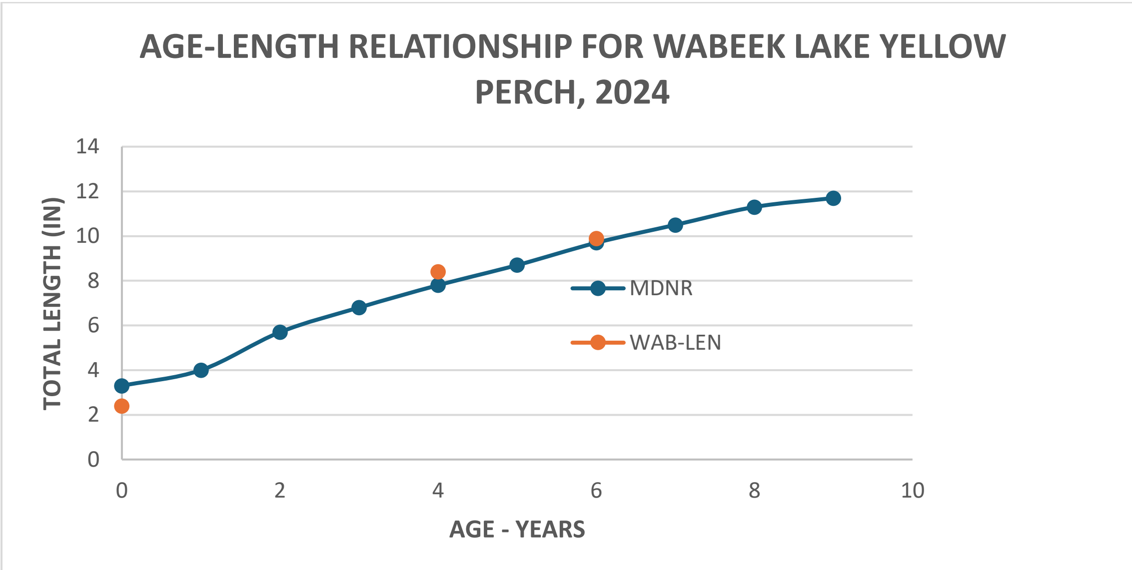

Figure 10. Age – length relationship for Wabeek Lake yellow perch, 2024. N=8.

There was one 6.9-in pumpkinseed sunfish caught which is odd, in that usually if present they can attain a common abundance in lakes. They are known molluskivores (eating clams, snails) and this one was growing at MDNR averages. It is unfortunate that there are not more in the lake to eat the snails and clams and they provide great fishing opportunities and eating.

PROBLEM AREAS: POSSIBLE SOLUTIONS

NUTRIENT ENRICHMENT

As limnologists, we are concerned about nutrient sources which fuel algae blooms and proliferation of macrophytes. We can speculate about those sources based on what we have found out from this study.

Anoxia

One of the major sources of nutrients that continue to fertilize Wabeek Lake every spring and fall is termed "internal loading". This is the decomposition of organic material on the bottom of Wabeek Lake when the lake is stratified during summer and loses it oxygen on the bottom (anoxia) and during winter with ice and snow cover. It is particularly problematic during summer because bottom waters warm up and become anaerobic generating large quantities of ammonia and phosphorus (phosphorus pump). Ammonia in our study was 2.12 mg/L and TP was 0.193 mg/L; ProgressiveAE had similar TP values during 2021-2024 when values ranged from 0.061 to 0.202 mg/L, very elevated levels and these nutrients will be re cycled into the lake during fall and spring turnover. **Recommendations**: There are three expensive solutions to this problem. One is hypolimnetic aeration where oxygen is pumped into a chamber in the hypolimnion (bottom waters), aerated, then discharged back into the hypolimnion. This is used in large reservoirs in California to improve drinking water and most times a two-tier fishery (warm water fish in surface and trout on the bottom is established). The second is dredging which would remove large quantities of the bottom material that is causing the problems. Access and spoils disposal would be a severe drawback. Lastly, there is Phosloc, a bentonite - lanthanum mixture, which ties up phosphates in a insoluble compound and is a treatment which we have been involved with in a Michigan 300 - acre lake that cost around 100K, but did have limited results: Increased water clarity by about 1.7 ft and decreased the total phosphorus by a small amount.

Runoff from Culverts and Riparians

There are five culverts that we are aware of (see Picture 6) that deposit runoff from a highly developed watershed plus runoff that originates from houses along the shoreline. We were unable to view any of these during the study but our experience from other studies (Pine Lake) would suggest that during rain events these culverts will deposit large amounts of road salt (measured by our chloride data – ca 150 mg/L, a moderately high value), but more importantly nutrients into Wabeek Lake. We know nothing about what is coming into the lake from these five sources. **Recommendations**: First, these five culverts should be monitored at least two-three times during rain events during 2025, especially during rains in early spring. We can write a proposal and provide costs for doing this study including 15 or more brown 1-l bottles or more if desired. They would be used to gather samples from each culvert and analyzed for chlorides, nitrates, ammonia, and soluble reactive phosphorus. Second, there is a new product called TimberChar, closely related to charcoal, which purports to be able to remove nutrients from water and has been deployed in front of culverts to reduce nutrient entry to lakes. We are still evaluating this product for efficacy and there is supposed to be a publication out soon describing the process and evaluating its usefulness in lakes.

Riparians need to participate in reducing nutrient inputs from their property by practicing good environmental activities. **Recommendations:** These would include: no lawn fertilization, herbicide or pesticide treatments (save the insects and birds who eat them), no leaf burning – dispose of leaves outside the watershed, no washing boats or cars in the driveway with high phosphate detergents, planting of green belts (see Michigan Shoreline Partnership website for guidance) to retard runoff (including fruit trees for the birds), and remember anything deposited in the watershed (oil, gas leaks, etc.) may end up in Wabeek Lake.

Picture 6. Map of Wabeek Lake showing the five outfalls that run into the lake. Map courtesy of ProgressiveAE.

FISH MANAGEMENT

We try to take a conservative approach to fish management and seldom recommend stocking of ill-adapted fish, such as walleyes or trout into eutrophic lakes. Wabeek Lake has a low diversity of fishes, degraded water quality environment, low diversity but high density of macrophytes in some places, and what looked like and has been documented in the past: extensive algal blooms. We did not analyze samples for algae (the high chlorophyll a reading of 36 ug/L on 31 July 2024 is stark evidence of an intense bloom), but it should be pointed out that these blooms were probably blue-greens which can proliferate under the conditions that exist in Wabeek Lake: shallow warm nearshore zone, over fertilization, and low diversity of macrophytes which lose dominance to algae. These algae can produce toxins which could be toxic to pets and cause intestinal problems with humans who ingest it, so care needs to be taken during summer if people swim in the lake. Avoid obvious areas with green paint-like scum.

The two major species of fishes we caught were bluegills and largemouth bass, so we assume they are maintaining their numbers (certainly for bluegills, but largemouth bass YOY were common as well). There are some yellow perch in the lake and we got samples of both YOY and adults indicating they are maintaining a low population status in the lake. There appear to be some yellow bullheads in the lake and they will contribute to controlling the bluegill populations. There were two rare species: pumpkinseed and green sunfish. **Recommendations**: There are six recommendations we think would improve the fishery of Wabeek Lake.

1. Consider stocking northern pike (usual recommendation is about 2/acre- get the largest possible; stock in spring or fall under cold water conditions). There appear to be very few in the lake, spawning habitat is limited, and they will help control the abundant bluegills. Two other species would be good candidates for stocking as well. The first is black crappies; they are voracious consumers of YOY bluegills and the water is turbid which is also to their favor. Lastly, golden shiners, if you can find them would be a great addition: they do well in turbid conditions and grow up to 12 inches and are great prey for your top predators.
2. Practice catch and release of northern pike and large largemouth bass; keep all panfish.
3. Common carp (Picture 7) are a big problem in Wabeek Lake since they appear to be numerous and they are known to eat eggs of nesting fish like bluegills and largemouth bass and they dig and root up the bottom sediments searching for food items, which results in increased turbidity in the water and releases nutrients into the water column where they fuel algae blooms.
    A. <u>Solution 1</u>: Common carp are important "sport" fish in England and there are niche groups all around the US that fish for them – usually using fly rods and flies or imitation crayfish. Residents, if they are interested in catching a big fish, should embrace this endeavor and fish for common carp in Wabeek Lake off their dock or from a boat using nightcrawlers and some say kernels of corn after "chumming a bit" first. They are fantastic fighters and you will be contributing to removing them from the lake. If you have any bow fishers, they should also be encouraged to shoot as many as possible. One lake I worked on had a bounty on common carp which proved useful.
    B. <u>Solution 2</u>: Common carp are very active in May when the water warms to their spawning temperatures. If we can get permission from the MDNR, we could exploit this behavior at the outgoing weir. Fish will go to this site to spawn and one can then put a V-shaped weir usually made with willows but steel fence posts or some other device that would allow water through would work as well. Fish approach the open side of the V and there is a small gap at the bottom part of the V that fish can squeeze through into the "pot" which is then formed by placing a net or solid fence in the back of the pot to keep the fish in one place. Fish can then be harvested from this site and removed.
    C. <u>Solution 3</u>: There is a company in Minnesota that removes common carp from lakes there and they also worked on a lake here in Michigan - Hess Lake near Newago. They captured five or six fish, tag them with GPS units so they can track them, then when they find where they congregate, they install what could

best be described as elevators that hoist the fish up into waiting trucks. This may be a bit impractical and costly, but we wanted to include it, in case someone might want to look into what and how they do it. We have another alternative however. Before the Hess Lake people brought in the Minnesota group, we were hired to remove as many as we could from the lake. We bought two long 100-yd nets specifically designed for catching common carp: a net called a trammel net and another one was a gill net with 4-in bar mesh. We still have them and if you are interested, we can prepare a proposal to set these nets in Wabeek Lake and remove as many common carp as possible, say in a 2-day effort. We would dispose of the common carp as part of the proposal, unless the board has other suggestions. MDNR approval obviously would be necessary, but they granted it in our previous work.

PICTURE 7. Large common carp *Cyprinus carpio* from Wabeek Lake, 2024.

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LITERATURE CITED

ProgressiveAE. 2024. Wabeek Lake Program Report, 2024. Prepared for: Wabeek Lake Improvement Board, Oakland Co., MI; 8 pp.