PICTURE 1: INDIANWOOD LAKE WITH TRAP NET IN BACKGROUND

THE LIMNOLOGY AND FISHERY OF INDIANWOOD LAKE, OAKLAND CO, MI 11-12 JULY 2024

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INTRODUCTION

William Colvett, riparian member of the Indianwood Improvement Board contacted us for a comprehensive study to examine the limnology, fishes, and zooplankton of the lake during 11-12 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).

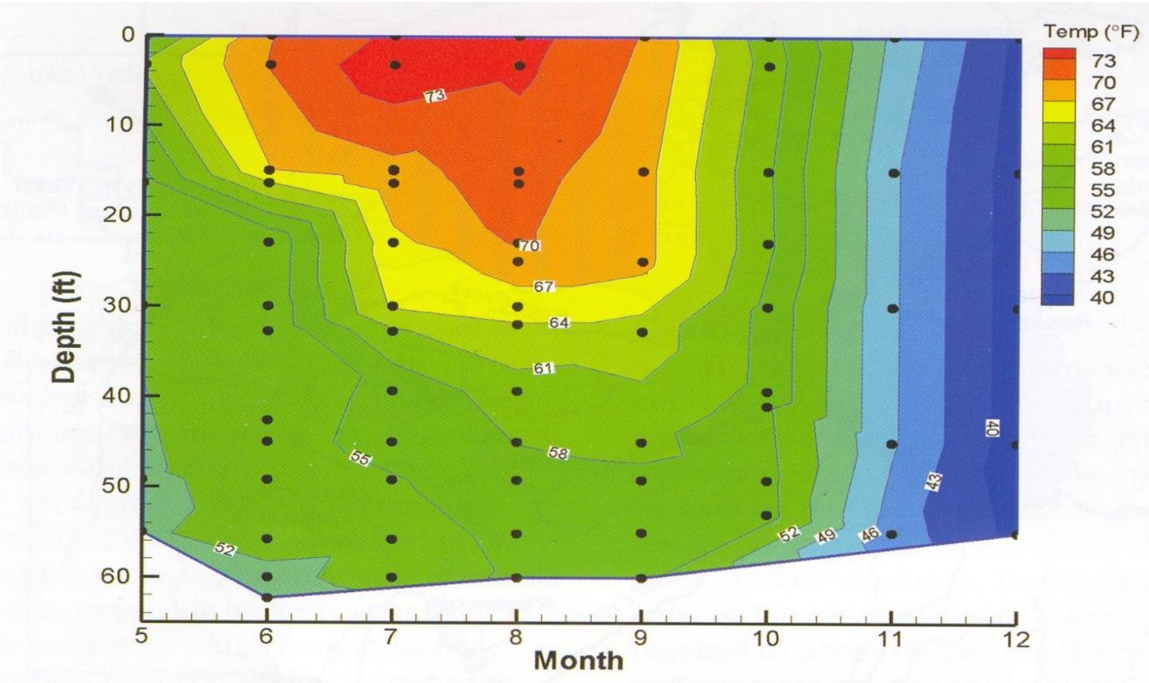


Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red, yellow, and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during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

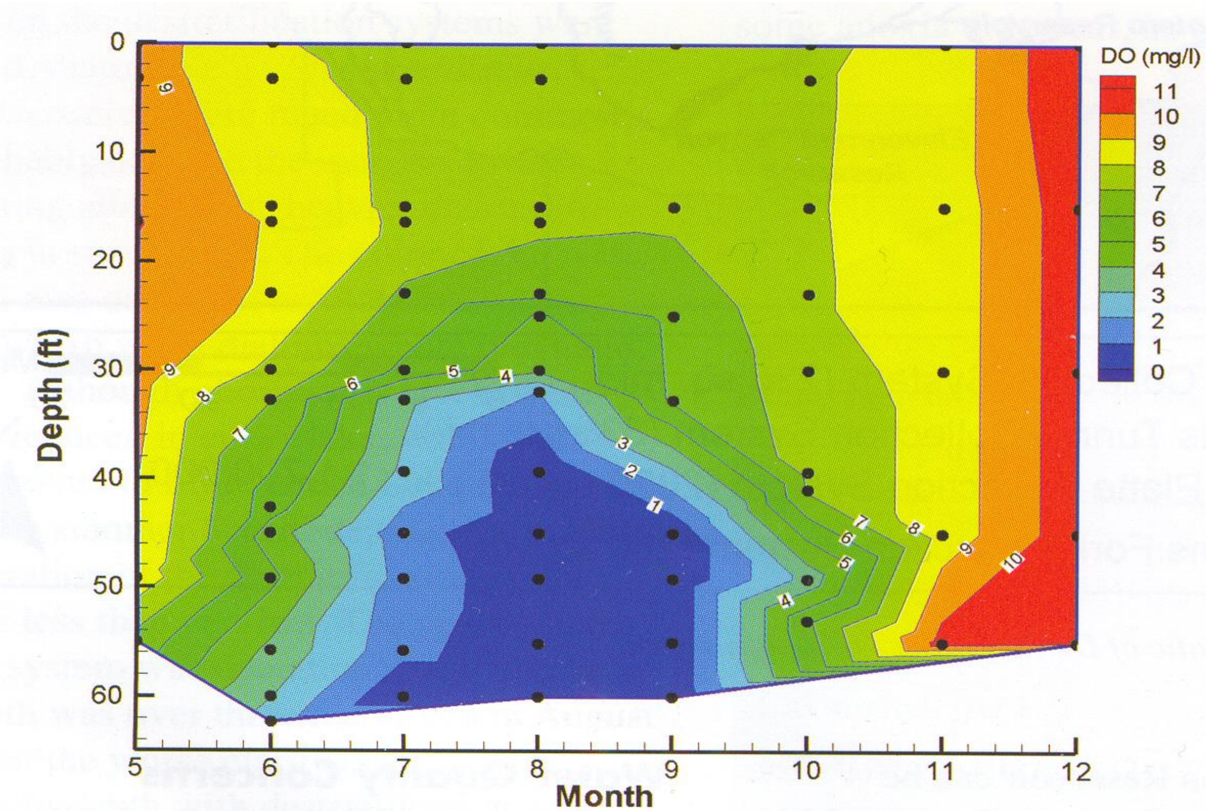


Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when 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 because of its rarity. 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 (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 (NO3=) 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 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. 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

Indianwood Lake is in an area replete with other water bodies, is well developed with many houses in the nearshore zone and roads leading to them (Fig. 3). It has one deep basin (40 ft or 12 m – station A- Fig. 4) and two other smaller basins of 20 and 10 ft; the remainder of the lake is shallow, and therefore very productive. The fact that there is a deep basin in the lake is a positive feature, since this area can assimilate nutrient insults better and it can also provide optimal habitat for cool water fish (in the deep chlorophyll zone where the temperature and dissolved oxygen were both around 11 (to be discussed in dissolved oxygen section). It has an abundance of aquatic plants along the shoreline, including Eurasian milfoil, and is being actively treated to control invasive species. During the time were sampling on 11 July 2024, there was a large "slick" on the water, which could have been an algae bloom. The secchi disk reading during our sampling was 3.8 m or 12.5 ft, which is good and categorizes Indianwood Lake as mesotrophic, since it has a measure >7.5 ft, but way short of oligotrophic (>20 ft).

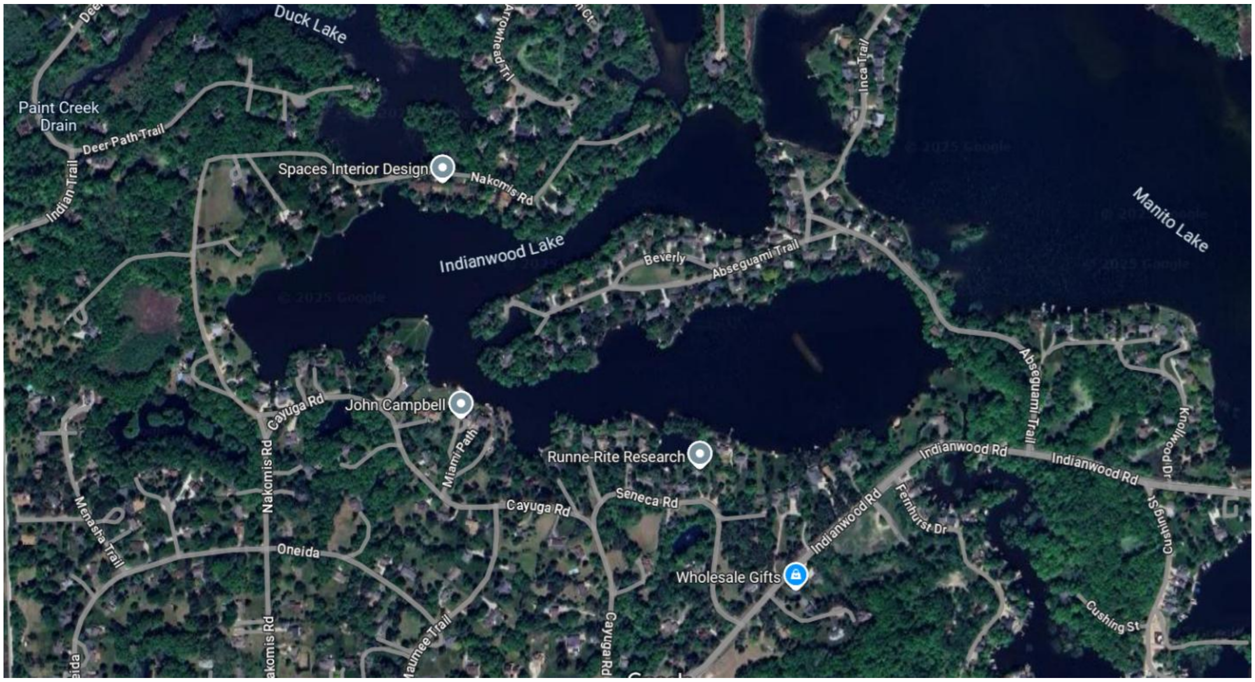


Figure 3. Google map of Indianwood Lake showing the extensive development and roads circling the lake, docks, lawns, and tree growth.

We established several types of stations in Indianwood Lake to sample the water (station A), zooplankton (stations Z1 and Z2), and fish (T for trap net, G for gill net, and S for seine) (Fig. 4). The times of deployment and pick up of gear for sampling water, zooplankton, and fish, as well as their GPS, and what fish were captured are also shown (Table 1). We tried to sample all types of different habitats, but usually have trouble catching large largemouth bass; however, not this time. We caught a few large ones which were critical for the age and growth section of the report.

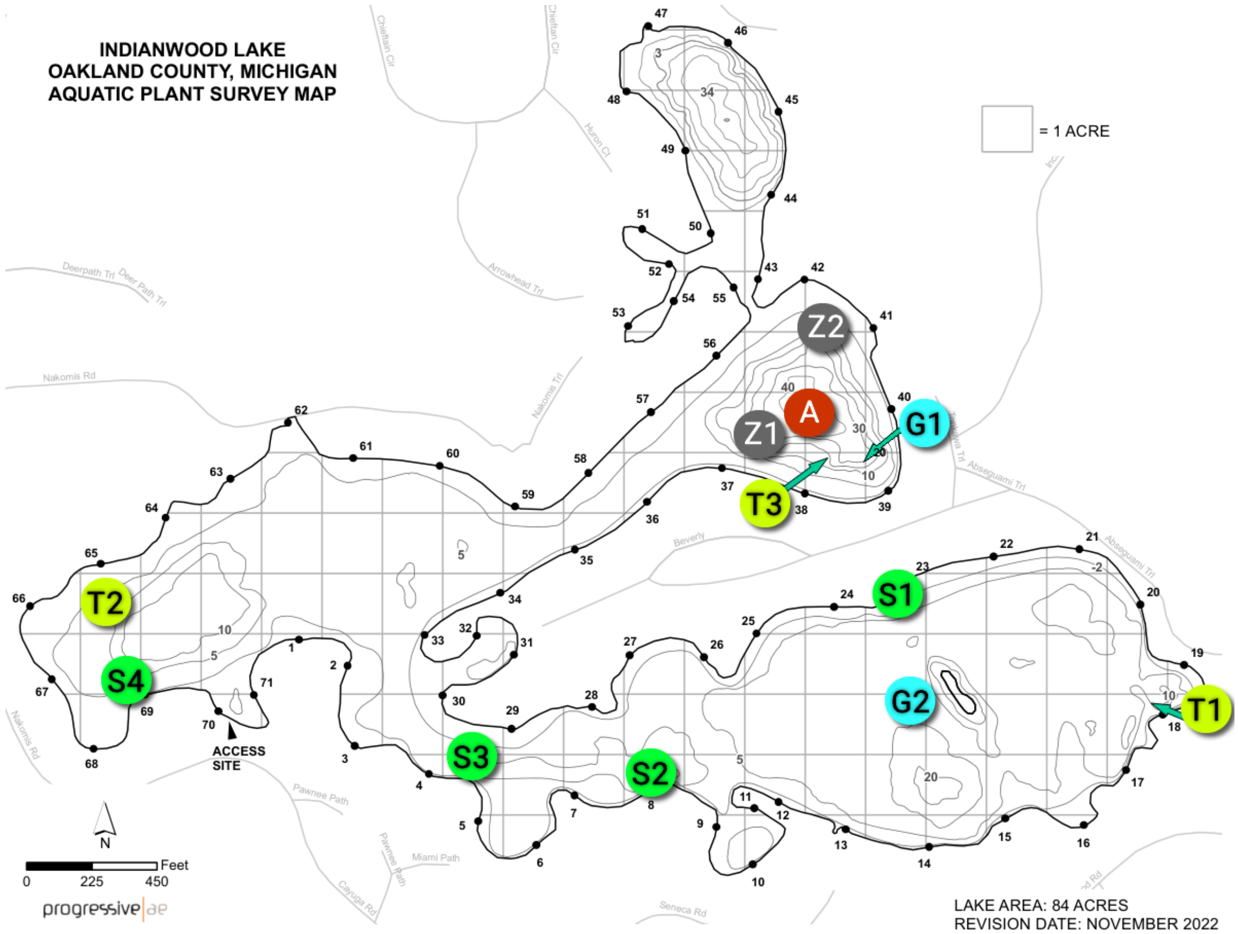


Figure 4. Station location map for Indianwood Lake, 11 July 2024. Shown is location where water samples (station A) and a zooplankton samples (Z1 and Z2) were collected, where seining was conducted (S1-S4), and trap nets (T) and two gill nets were deployed (G1, G2). Map modified from Progressive Companies (2024).

Table 1. Listing of station (gear type and sample type), start and end times for fishing gear deployment, GPS, and fish species caught in various gear. BG=bluegill, CP=common carp, LB=largemouth bass, YP=yellow perch, YOY=young-of-the-year, NP=northern pike, PS=pumpkinseed, RB=rock bass, ZZ=zero catch, G=gill net, S1-S4=sites of seine hauls, T=trap net.

TIME	STATION	GPS	FISH CATCH
1045	A	N42 47.785 W83 15.975	WATER SAMPLE
1520	S1	N42 47.685 W83 15.843	BG,BN,LB,PS,YP
1530	S2	N42 47.566 W83 16.088	BG,LB,PS
1540	S3	N42 47.597 W83 16.317	BG,BN,LB,NP (1),YP
1635	S4	N42 47.609 W83 16.527	NONE KEPT

1315-1220	T1	N42 47.611	W83 15.718	1 RB
1350-1120	T2	N42 47.650	W83 16.520	BC,PS
1410-1100	T3	N42 47.802	W83 16.943	BG, LB
1135-1045	G1	N42 47.805	W83.15.966	BG,LB,NP,PS,RB
1225-1200	G2	N42 47.605	W83 15.925	BG,LB,NP,PS

WATER QUALITY

We collected water samples from the deep spot (station A – Fig. 4) in Indianwood Lake during 11 July 2024 at the surface, mid depth, and bottom; this station is deep 12.2 m or 40 ft. Water clarity in Indianwood Lake was 3.8 m or 12.5 ft., a good reading classifying Indianwood Lake as mesotrophic (Secchi disk reading between 7.5 and 15 ft). Eutrophic is the lowest category of trophic status (Secchi disk value <7.5 ft), 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 Indianwood Lake, since we saw them spawning nearshore and they are known to stir up bottom sediments in lakes in which they are abundant (see Picture 6).

There was anoxia (no dissolved oxygen) on the bottom 12-14 m at station A (Fig. 5). The dissolved oxygen concentrations from 8 m (26 ft) to the bottom were too low for warm water fish which require a minimum of 3 mg/L, since dissolved oxygen was <0.8 mg/L; the thermocline was around 3-4 m, which is unusual- it is usually much deeper. In addition, there is a condition called the deep chlorophyll layer (DCL) which is shown in Fig. 5 as a substantial increase in dissolved oxygen over surface values at 5 m; this increased dissolved oxygen is caused by light inhibition of algae at the surface, making optimal conditions for survival deeper in the water column where they produce more dissolved oxygen. In addition, zooplankton and fish feeding on them often congregate at this layer. We are concerned about the dissolved oxygen temperature relationships, since the two cool-water species in the lake, northern pike and yellow perch, need optimal conditions: cool water temperatures in the thermocline and bottom area and adequate dissolved oxygen. The optimal layers with these conditions are often detrimental to cool-water species because it can be too hot in surface waters with anoxia on the bottom, squeezing fish in the middle (Fig. 6). From the data we collected it appears that there is adequate space for cool-water fish to exist and flourish in Indianwood Lake at this basin, which often does not happen in eutrophic lakes. Because of better conditions for northern pike and yellow perch, we expect that growth will be good for these two species (or at least those that utilize the optimal conditions near station A).

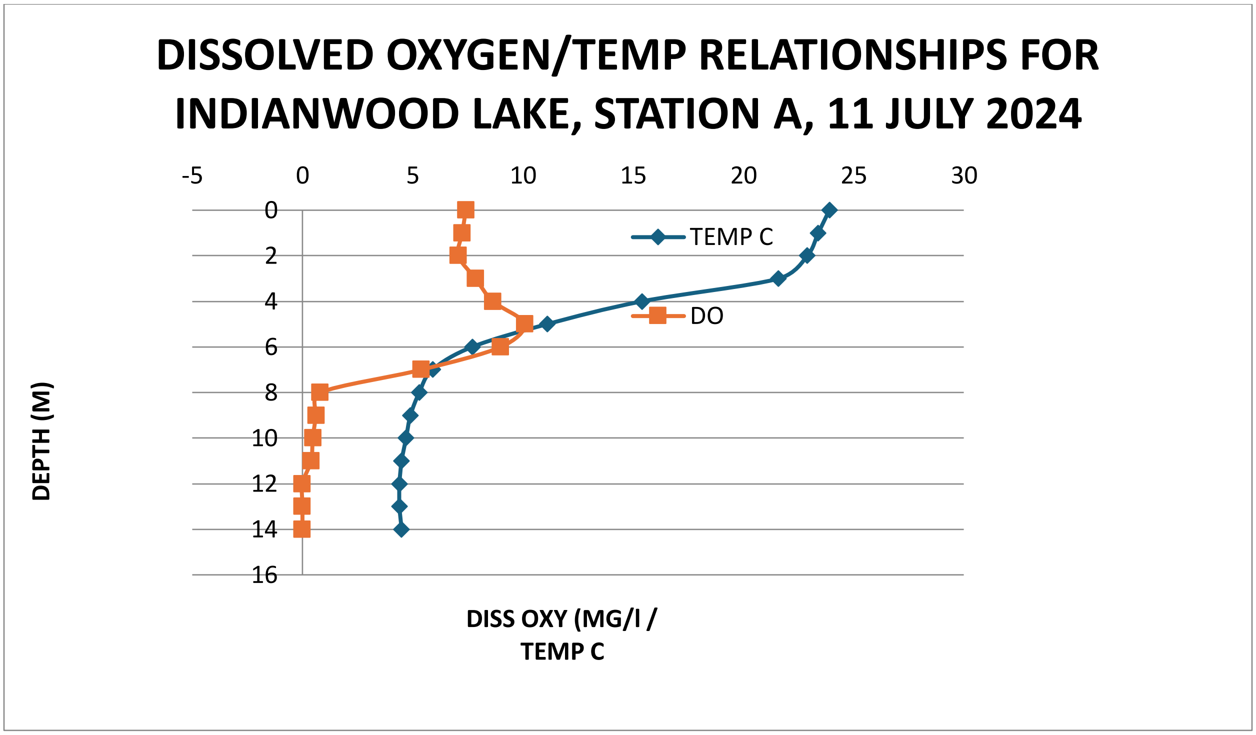


Figure 5. Temperature and dissolved oxygen profile of Indianwood Lake, 11 July 2024 at the deep spot in the lake station A (see Fig. 4 for location of station A).

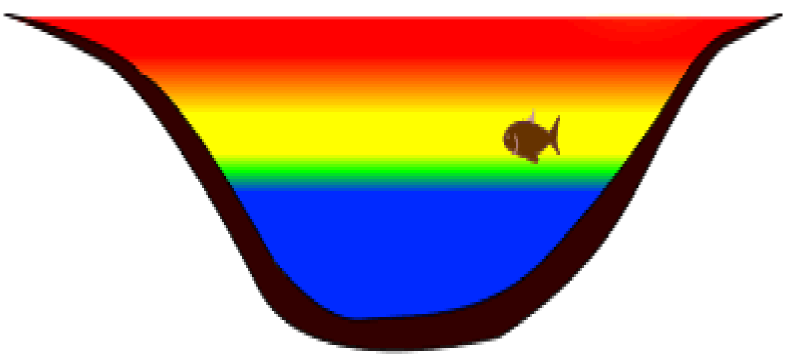


Figure 6. Depiction of the dissolved oxygen concentrations in a stratified lake during summer, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, 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.

The presence of anoxia on the bottom results in two negative aspects: First, fish will not go into an anoxic zone, which because of the presence of hydrogen sulfide and ammonia would be toxic to fish. However, as a side note, which we will discuss in the zooplankton section, This anoxic zone provides a safe refuge from fish predation during the day when predation is heavy. Second, there is a chemical reaction involving phosphate and iron, which under oxygenated conditions, forms an insoluble compound iron phosphate, but under anaerobic conditions switches this reaction and results in release of phosphorus (a phosphorus pump) into the overlying sediment. In addition, large quantities of ammonia are also produced. These nutrients are released into the water column and then mixed into the water column during the fall turnover when the temperature is isothermal from top to bottom. These nutrients then fuel the macrophyte and algae crop in the following year. Residents can help improve the trophic status of Indianwood Lake by not fertilizing their lawns, especially those like shown in the frontispiece (Picture 1), which depicts a steep hill, lawn all the way down to the lake, and no greenbelts to retard runoff of fertilized lawns. In addition, riparians, as noted, should plant greenbelts to retard runoff (see the Michigan Shoreline Partnership website for guidance on what plant to use and where to place them), by not burning leaves near the lake or in the watershed, and by not washing boats or vehicles using high phosphate detergents near the lake. Fortunately, the lake has an extensive area of trees and vegetation around the edges of the lake in between some houses, which will help ameliorate the negative effects of these actions.

The pH was low in surface waters (7.57-7.60) and even lower on the bottom (7.38) (Table 2). The surface conductivity (ability of water to conduct electricity) ranged from 822-825 uS, but was much higher on the bottom, 923 uS, an elevated value, suggesting large qualities of negative ions (especially chlorides) in the lake (Table 2). Bottom values are expected to be higher, because decomposition on the bottom produces ions that conduct electricity.

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. Sometimes some large concentrations are measured depending on how degraded the environment is. This was also true in Indianwood Lake, as nitrates were 0.07-0.09 mg/L in surface water, but 2.12 mg/L (Table 2) on the bottom, extremely high concentrations. 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" and is a substantial source of nutrients for Indianwood Lake in the deep basin we sampled.

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 Indianwood Lake; concentrations were indeed at trace concentrations in surface and mid depth samples, but somewhat elevated (0.041 mg/L) in the bottom sample we collected at station A (Table 2). Again, we attribute this to the intense decomposition ongoing on the bottom of Indianwood Lake in this area and this was early in the season; conditions undoubtedly got 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. Indianwood Lake is eutrophic (> 0.020

mg/L – value of 0.022 mg/L – Table 2), which is the lowest designation, while an oligotrophic status would have TP <0.010 mg/L. The bottom TP is another indication of degraded water in the hypolimnion, since it had a really high concentration of 0.173 mg/L, a clear demonstration of the breakdown and accumulation of organic matter on the bottom. There is a considerable amount of TP on the bottom at station A, which will be released along with high levels of SRP (0.041 mg/L) to fuel plant growth the coming year.

Table 2. Water chemistry parameters: pH, conductivity (uS/cm), and chlorides, nitrates, ammonia, soluble reactive phosphorus (SRP), and total phosphorus (TP) (mg/L) measured in Indianwood Lake at station A, 11 July 2024.

Depth-m	pH	Conductivity	Chlorides	Nitrates	Ammonia	SRP	TP
0	7.57	825	100	0.09	0.06	<0.005	0.022
6	7.6	822	96	0.12	0.08	<0.005	
12	7.38	923	104	0.09	2.12	0.041	0.173

MACROPHYTES

The macrophytes of Indianwood 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. Fortunately, ProgressiveAE has provided their summer 2024 list of plant species and what percentage they occupy of the sites they surveyed (Table 3), showing that there were five invasive species (their frequency of occurrence in parentheses) in the lake: Eurasian milfoil (2%), Curley-leaf pondweed (2%), Phragmites (7%), Purple loose strife (16%), and starry stonewort (48%). Currently these invasive species are being targeted, and native species are being protected, which is an excellent philosophy we support. During 2024, 85 acres were treated with herbicides with targets of Eurasian milfoil and Curley-leaf pondweed. These are potentially damaging for fish since they can be so dense it provides too much cover for juvenile fishes resulting in stunting of panfish. They can also grow large, dense beds overtaking native plant species. It appears they have gotten good control since their occurrence for both groups is low, 2%. Starry stonewort is also a dangerous alga, since it can produce huge tumbleweed-like growths that overtake the nearshore zone and completely cover important spawning grounds for panfish and largemouth bass. They have had less success depleting this species since starry stonewort still occupies 48% of the sites they examined. To control this species, they have treated it and other nuisance algae with copper compounds and through harvesting (93 acres were treated during 2024). Since the lake is composed of 84 acres, this effort has exceeded the total area of the whole lake, so battling exotic species is a large problem in Indianwood Lake but this is the correct way of dealing with reducing exotic species and improving the habitat in the lake for man and fish.

We also want to note the importance of some native species. Lily pads (white – 81% and yellow – 10%) were found throughout the lake and these plants 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; they were common (50% occurrence). This species is an important alga, since they occupy nearshore areas and protect them from invasive species incursions, provide fish habitat and fish-food organisms, and are also responsible for sequestering phosphorus through shifts in the carbonate system precipitating P. Overall, it appeared that there was a healthy aquatic plant population, although threatened by invasive species, with a high diversity of species, which should provide great habitat for the fish community, provide fish – food organisms, provide spawning substrate, and stabilize the nearshore bottom so as to protect it from waves generated by wind. The fact that the lake is a non-outboard motor lake is a great asset for the lake; never-the-less, boats should stay away from the nearshore zone or slow down when they need to access this area to prevent re-suspension of flocculant sediments nearshore.

Table 3. List of the common and scientific names of aquatic plants found in Indianwood Lake and an indication of their abundance (what percentage of the sites sampled they occupied). Study done in summer 2024 by Progressive Companies - used with permission. * = Invasive species.

Aquatic plants **Common name**	**Scientific name**	**% of sites where present**
Sago pondweed	*Stuckenia pectinata*	12
Illinois pondweed	*Potamogeton illinoensis*	17
Flatstem pondweed	*Potamogeton zositerformis*	3
Eurasian milfoil*	*Myriophyllum spicatum*	2
Curly-leaf pondweed*	*Potamogeton crispus*	2
Whitestem pondweed	*Potamogeton praelongus*	88
Chara	*Chara* sp.	50
mini bladderwort	*Utricularia minor*	79
Bladderwort	*Utricularia vulgaris*	47
Starry stonewort*	*Nitellopsis obtusa*	48
Thin-leaf pondweed	*Potamogeton* sp.	2
Wild celery	*Valliseneria americana*	41
Yellow waterlily	*Nuphar* sp.	10
White waterlily	*Nymphaea odorata*	81
Swamp loosestrife	*Decodon verticillatus*	10
Cattail	*Typha* sp.	17
Purple loosestrife*	*Lythrum salicaria*	16
Phragmites*	*Phragmites australis*	7
Iris	*Iris sp.*	41

Watermeal	*Wolfia punctata*	5
Bulrush	*Schoenoplectus sp.*	2

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 (40 ft) and one from a shallower spot (10 ft) (Fig.4). We collect samples at two depths to find out if predation by fishes nearshore is more intense than offshore. In the deep sample, cladocerans composed 57.4% of the sample and *Daphnia* made up 22%, which is a good 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 on the bottom 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 and there are more small planktivorous fish nearshore. *Daphnia* in the nearshore zone composed 14.1% of the sample, considerably less common than offshore, validating our hypothesis that there is more predation nearshore. However, 14% is still a good number of large cladocerans for fish, suggesting they should have a good supply of zooplankton as prey. The copepods, *Diaptomus*, *Cyclops,* etc. 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 fish 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 and nearshore that is probably stable because of the anoxic water and macrophytes providing refuge from fish predation during the day and there are probably less planktivores out deep than in shallow water. This is a good outcome for one of the important food web components in the Indianwood ecosystem.

Table 4. List of zooplankton groups collected from the shallow (10 – ft, station Z2) and deep basin (40 - ft - station Z1) on11 July 2024. Samples were collected with a vertical tow of a 153-um, mesh nylon net deployed about 1 m off bottom and pulled to the surface. Imm. = immature, spp. = one or more species.

	Deep		Shallow	
Zooplankton group	No.	%	No.	%
Diaptomus Imm.	23	16.3	106	24.5
Diaptomus spp. ♂	3	2.1	5	1.2
Diaptomus spp. ♀	1	0.7	25	5.8
Cyclops imm.	23	16.3	127	29.3
Cyclops spp. ♂	4	2.8	8	1.8
Cyclops spp. ♀	1	0.7	23	5.3
Daphnia spp.	31	22.0	61	14.1
Bosmina spp.	47	33.3	61	14.1
Eubosmina		0.0	9	2.1
Ceriodaphnia spp.	3	2.1	4	0.9
Diaphanosoma	3	2.1	3	0.7
Trophocyclops ♂	2	1.4	1	0.2
TOTALS	141	100.0	433	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 four sites, set two gill nets, and three trap nets. Indianwood Lake is a long, dammed lake (reservoir), so we were able to set nets and seine in a diverse set of habitats in wide-spread areas of the lake. The near shore is mucky in some areas, but sandy in others and has some large beds of macrophytes in some areas (especially lily pads). The sandy areas provide optimal spawning sites for panfish (bluegills, pumpkinseeds, largemouth bass, black crappies). We caught eight species of fishes, with bluegills the dominant followed by pumpkinseeds and largemouth bass (qualitative estimates). We noted common carp at one site, but never caught any. A group of spawning individuals was seen stirring up the water in nearshore zone. We also collected five northern pike including one YOY (young-of-the-year) fish. In addition, a largemouth bass had eaten a northern pike (about 3 in) which is an outstanding finding, suggesting that all the inlets and bays full of shoreline vegetation are providing good substrate for spawning. The ideal situation would be a stream they could migrate up and spawn in or a shallow bay that has few predators. The example of the largemouth bass preying on a YOY northern pike is ample evidence of their vulnerability to these predators in an open lake environment before they grow large enough to escape this type of predation. We also caught nine yellow perch, two black crappies, three bluntnose minnows, and two rock bass. This is moderate diversity compared to 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. People who are bow fishers should be encouraged to shoot as many as they can, especially during the spawning season, when they are most vulnerable. Any caught should be removed. It was good to see a wide range of species, including rock bass, which increases diversity and provides for a well balanced fish community. There were only three bluntnose minnows collected (some were released), so they are not abundant, but are present and will provide another good prey fish for young predators and older ones as well. We were surprised that we did not catch any bullheads; we suspect they are in the lake but just did not catch any. They are good predators and will help control the panfish 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. We saw evidence that most riparians were practicing this on their property. The old saying if you live on a lake get a rake applies here.

Table 5. Fish species, the number caught, and the size range (inches) from Indianwood Lake, 11-12 July 2024. Many fishes we did not need for samples were released. Common carp were observed spawning nearshore.

Species	N	Size Range (in)
Bluegill	36	1.8-8
Pumpkinseed	32	2.5-8
Largemouth Bass	23	1.6-18.9
Yellow Perch	9	4-6.5
Northern Pike	5	5-29.7
Bluntnose Minnow	3	1-2
Black Crappie	2	6.9-10
Rock Bass	2	9.1-10.4

Picture 4. Several fish species (northern pike, bluegill, pumpkinseed, rock bass, largemouth bass) collected during sampling in Indianwood Lake.

Fish Diets

We caught two large black crappies (6-10 in) that were surprisingly eating insects (chironomids) and zooplankton (Table 6). Small black crappies are known to eat zooplankton but larger ones, although they will eat zooplankton, usually eat fish, especially small bluegills. This is a good species to have in the lake to provide another nice-sized fish for anglers.

Bluegills 1.8-8 in – great size range- were eating insects and invertebrates, including chironomids, caddisflies, mayflies *Caenis*, and water mites Hydracarina (Table 6). They also ate zooplankton, snails, terrestrial insects, ostracods, and the invertebrate shrimp *Hyalella*. There did not appear to be much difference between small and larger fish diets, although there was a tendency for the larger ones to eat terrestrial insects, plants, and one had eaten fish eggs. One genus of mayflies and caddisflies was found which is a good sign of ecological health. These insects are sensitive insects and require high concentrations of dissolved oxygen all year long on the bottom to survive.

Largemouth bass caught ranged from 1.7 to 18.9 inches (Table 6) and are the dominant predators, but northern pike, bullheads (assuming they are in the lake), rock bass, and yellow perch are effective predators that will help to control the proliferation of small bluegills in the lake. The small largemouth bass (1-5 in) were insectivorous and ate invertebrates (mayfly *Caenis*, and chironomids (Fly family), and *Hyalella*, the fairy shrimp); larger ones were carnivorous, eating young-of-the-year bluegills (Table 6). Fish 5-19 in were eating almost exclusively crayfish and YOY fish, including their own largemouth bass young, bluegill, and a surprising YOY 2.8-in northern pike eaten by a 6-in largemouth bass (Picture 5), something we had not seen before. Largemouth bass are the major predators on bluegills in Indianwood Lake, but they also eat other small prey that are available in the nearshore zone.

The pumpkinseeds we caught like the bluegills had a good size range (2.5-8 in) represented in our catches (Table 6). Small fish 2-4 in long had eaten insects and invertebrates, including *Hyalella*, chironomids, mayflies *Caenis*, ants, snails, and a surprise addition: zebra mussels. Pumpkinseeds are known to be molluscivorous (snail and clam eaters) which taps into another food source seldom eaten by other species and explains why they had zebra mussels in their stomach. Fish 5-8 in were eating somewhat different food, including *Hyalella*, snails, mayflies *Caenis*, up to 300 chironomids, fish larvae in two specimens, and another unusual food item fingernail clams (Sphaeriidae – miniature clams) that can be common to abundant on the bottom depending on substrate (preference for sand). Like bluegills, this species appears to be finding a diverse and abundant food supply among the aquatic plants and substrates of Indianwood Lake, which suggests this part of the fish community is healthy and doing well.

The yellow perch were eating zooplankton, mayflies, caddisflies, damselflies, snails, chironomids, and an invertebrate fairy shrimp *Hyalella*, while the largest one had eaten a crayfish. The rock bass were eating crayfish, and an unknown fish and small bluegills.

The northern pike is another great predator in the lake and they prefer yellow perch, but should also help control the bluegill population. The ones we collected were eating fish (unknown and bluegill). As we noted above, we had one largemouth bass that ate a YOY northern pike (Picture 5) and we seined another one (5 in), which was released. This is concrete evidence of successful spawning by the northern pike population and there are many places where they could spawn along shores, in coves with abundant macrophytes and possibly in any inlets that enter Indianwood Lake.

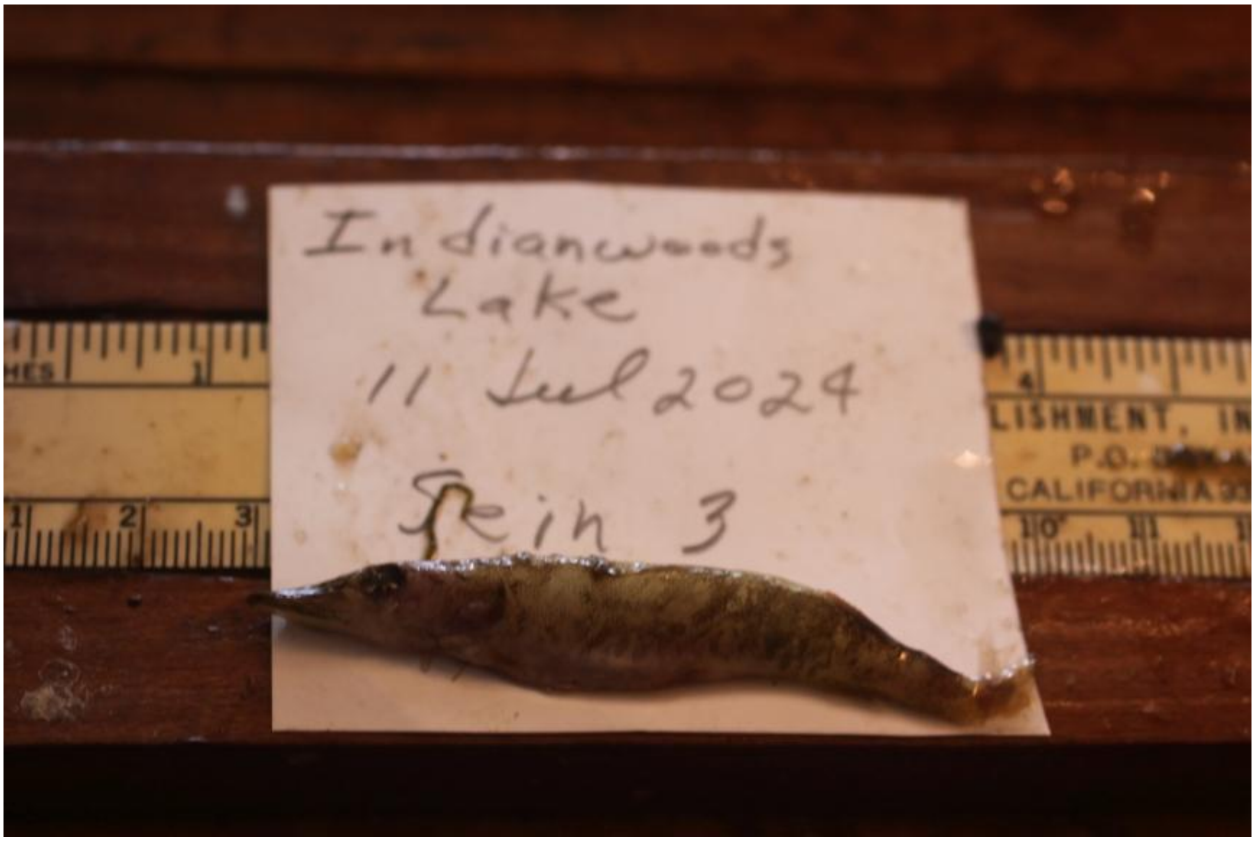
Table 6. Diets of fishes collected from Indianwood Lake, 11-12 July 2024. See Table 1 for species codes definitions. S=Seine, G=Gill net, sizes of fish eaten are in mm as are lists of the lengths of fish for bluegills and largemouth bass to show how abundant YOY (young-of-the-year) were in the nets. 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. XM=unknown minnow, XX=empty; MT=empty, TL=total length, T=trap net. *Hyalella* = shrimp-like invertebrate.

SPECIES	GEAR	TL-INCH	WT-OZ	SEX	DIET
	BLACK	**CRAPPIE**			
BC	T2	10.0	6.8	F2	CHIRONOMIDS, DETRITUS
BC	T2	6.9	2.7	F2	6 CHIRONOMIDS, ZOOPLANKTON-ABUNDANT
	BLUEGILL				
BG	S3	1.8	0.1	II	ZOOPLANKTON
BG	T2	1.9	0.0		HYALELLA
BG	T2	2.0	0.1		HYALELLA
BG	T2	2.0	0.1		HYALELLA
BG	T2	2.4	0.1		HYALELLA, CADDIDFLIES
BG	T2	2.5	0.2	II	
BG	T2	2.5	0.1		CADDISFLY
BG	T2	2.6	0.2	II	3 CADDISFLIES
BG	T2	3.0	0.2	II	HYALELLA
BG	T3	3.0	0.2	II	HYDRACHARINA, 10 HYALELLA, CAENIS
BG	T2	3.2	0.3		TERRESTRIAL INSECTS
BG	S3	3.4	0.3		CHIRONOMIDS, SNAILS
BG	T2	3.6	0.4	M1	MT
BG	T3	3.6	0.4	F1	2 CAENIS, HYDRACHARINA, 500 OSTRACODS
BG	S3	4.0	0.5		PLANTS, INSECT PARTS
BG	T2	4.3	0.7		ND
BG	T2	4.4	0.7	F1	HYALELLA, TERRESTRIAL INSECTS
BG	T2	4.7	1.0	M1	ANTS
BG	T2	4.7	1.0	M1	ND
BG	T2	4.8	1.0	F2	MT
BG	T2	5.0	1.1		
BG	S3	5.1	1.3		
BG	S3	5.1	1.3		CHIRONOMIDS, HYALELLA
BG	S3	5.2	1.4	F1	12 HYALELLA, 10 CHIRONOMIDS
BG	G2	5.3	1.2	II	SMALL ZOOPLANKTON
BG	T2	5.4	16.0	M1	30 ANTS , 9 HYALELLA
BG	T2	5.4	1.2		ND
BG	T2	5.6	1.6	M1	ANTS, SNAIL,HYALELLA
BG	T2	5.6	1.6	M1	PLANTS, ANTS,3 HYALELLA

BG	T2	5.7	1.9	M1	ANTS
BG	S3	5.9	2.0	M2	GRAVEL. FISH EGGS
BG	G1	5.9	2.2	M2	CHIRONOMIDS PUPAE, SNAIL,SAND GRAINS
BG	T2	5.9	2.0	M1	5 ANTS
BG	S3	6.0	1.9		20 HYALELLA
BG	G1	8.0	4.0	F1	60 CHIRONOMIDS
BG	S2	5.0			
BG	S2	48,50,56,52,54,48,28,25,29,30,26,30,31			
	BLUNTNOSE		**MINNOW**		
BM	T2	2.0			
BM	T2	1.7			
	LARGEMOUTH		**BASS**		
LB	T2	1.7		II	4 HYALELLA, 6 CAENIS,8 CHIRONOMIDS
LB	S3	1.9			4 CAENIS (MAYFLY), 5 HYALELLA
LB	T2	1.9	0.0	F1	HYALELLA, MAYFLY
LB	T3	1.9	0.0	II	MT
LB	S3	2.0	0.0		MT
LB	S3	2.0	0.1		5 CAENIS, 4 HYALELLA
LB	T3	3.2	0.1	CC	CAENIS, 2 XX FISH (?XM)
LB	T2	3.3	0.1	F1	HYALELLA
LB	T2	3.7	0.2	F1	MT
LB	T2	4.5	0.3	II	XX FISH 35 MM
LB	T2	4.5	0.4	II	MT
LB	S3	4.6	0.6	F1	XX FISH
LB	G1	6.1	0.6	F1	LB 48 MM
LB	G1	6.1	0.6	M1	LB 45 MM, BG 36, 45 MM
LB	S3	6.4	1.6	F1	NP 71 MM, ROCK
LB	G1	7.1	1.5	F1	LB 45 MM, BG 36, 43 MM
LB	G1	8.5	2.3	F1	CRAYFISH
LB	G1	8.9	2.7	F1	BG 51 MM
LB	T2	10.6	4.7	F1	XX FISH, BG 65 MM
LB	G2	13.8	4.9	F1	2 CRAYFISH
LB	G1	14.6	5.4	F1	MT
LB	G1	17.5		F1	CRAYFISH
LB	G2	18.9		F1	MT
	NORTHERN	**PIKE**			
NP	G1	29.7		F1	MT
NP	G1	24.3		M1	XX FISH
NP	G2	19.7		F1	BG 151 MM
NP	G2	17.8		F1	MT
NP	S3	5.0	ND		RELEASED

	PUMPKINSEED				
PS	T2	2.5		II	6 HYALELLA
PS	T2	2.7		F2	10 CHR, 8 HYALELLA
PS	T2	2.8		M1	HYALELLA, CAENIS
PS	T2	2.8	0.2	F1	10 HYALELLA, CAENIS
PS	S3	2.8	0.2	F2	INSECT PARTS
PS	T2	3.3	0.3	F2	CHIRONOMIDS, HYALELLA
PS	T2	3.3	0.3	M1	INSECT PARTS
PS	T2	3.5	0.3	M2	ANTS, 2 HYALELLA
PS	T2	4.0	0.4	II	SNAILS
PS	T2	4.5	0.5	F1	ZEBRA MUSSEL, SNAIL, HYALELLA
PS	G2	4.8	0.5	F2	MT
PS	T2	5.2	0.7	F1	
PS	S3	5.2	1.1	F1	HYALELLA, SNAILS, FISH LARVA
PS	T2	5.3	1.1	F2	4 CAENIS (MAYFLY), 6 HYALELLA
PS	T2	5.5	1.4	F2	SNAILS, CHIRONOMIDS
PS	S3	5.7	1.5	M1	SNAILS
PS	T2	5.8	1.7	F1	SNAILS, HYALELLA, ANTS
PS	S3	5.9	2.3	M1	300 CHIRONOMIDS,MAYFIY
PS	G1	6.0	2.3	M1	200 CHIRONOMIDS
PS	S3	6.1	2.5	M1	HYALELLA, SNAILS, FISH LARVA
PS	T2	6.7	2.4	M1	FINGERNAIL CLAMS
PS	G2	6.7		F2	SNAILS
PS	G1	6.9	0.3	M1	MT
PS	G2	6.9	3.2	M1	MT
PS	G1	6.9	3.6	F3	MT
PS	T2	6.9	3.6	F2	MT
PS	G1	7.0	4.3	M1	MT
PS	G1	7.2	3.7	M1	MT
PS	G1	7.7	3.9	M1	MT
PS	G1	7.7	4.0	F1	GRAVEL
PS	G1	8.0	4.4	F2	MT
PS	S2	7.2	5.5		
PS	S2	6.4	5.3		
PS	S2	3.6	4.1		
	ROCK BASS				
RB	G1	10.4		F1	CRAYFISH
RB	TN1	9.1		M1	CRAYFISH, XX FISH, ?BG 35, 38 MM
	YELLOW PERCH				
YP	T2	4.0	0.4	F1	9 CAENIS, 3 HYALELLA
YP	T2	4.4	0.5	F1	5 HYALELLA, MAYFLY, ZOOP
YP	S3	4.5	0.6	F1	CADDISFLIES,MAYFLIES
YP	S3	4.5	0.5	F1	DAMSELFIES,MAYFLIES, HYALELLA, SNAILS

YP	S3	4.6	0.6	F1	SNAILS, CHIRONOMIDS
YP	T2	4.7	0.6	F1	6 SNAILS
YP	S3	5.3	0.9	F1	SNAIL, MAYFLIES,CHIRONOMIDS
YP	S3	6.0	1.4	F1	DRAGONFLY NAIAD
YP	T2	6.5	1.4	F1	CRAYFISH



Picture 5. A 70 mm (2.8 in) YOY northern pike eaten by a 6-in largemouth bass.

Age and Growth

We had great success in catching most species, but 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, but despite this we managed to land a few larger fish to provide good data for our growth analysis. Overall, all species were growing mostly 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 (Fig. 7-13). It appears that the nearshore vegetation is providing great shelter for high survival of YOY bluegills and the many habitat types are providing a high diversity of food items ensuring good growth of the small fishes.

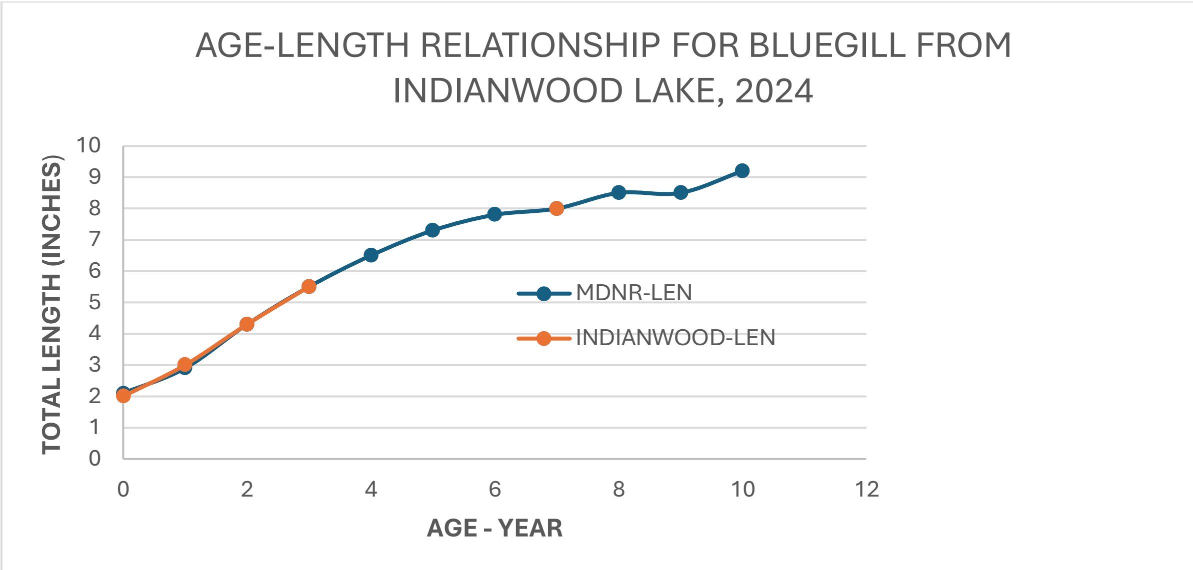


Figure 7. Age – length relationship for Indianwood Lake bluegills, 2024. N=34.

Largemouth bass were the third-most abundant fish caught in our samples. Many YOY fish were caught in nearshore seine hauls, while larger individuals were caught in gill nets. Fish were growing at state averages (Fig. 8), although sample sizes for larger individuals were small, they too were growing well. Like northern pike, these large individuals should be released to reproduce and be caught again. Largemouth bass like other sunfish require firm, usually sandy substrate to build nests, and it appears there is abundant areas that serve this purpose.

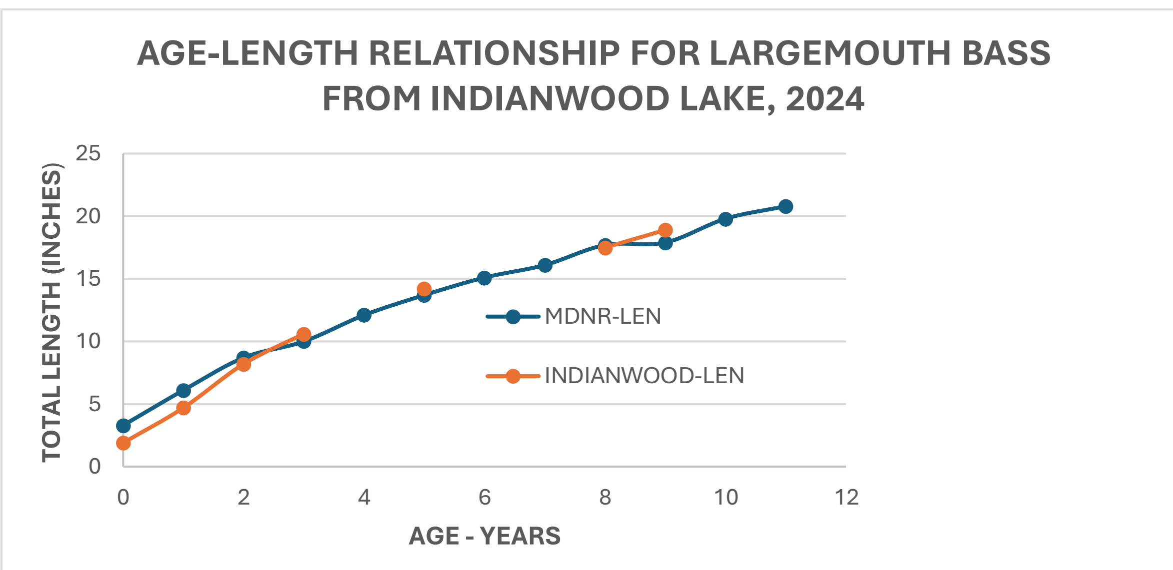


Figure 8. Age – length relationship for Indianwood Lake largemouth bass, 2024. N=24.

We caught six northern pike so they are rare-to-common in the lake. Interestingly, there was poor growth at both ends of the size spectrum (Fig. 9): The YOY was composed of two specimens, one was in the gut of a largemouth bass and was small (2.8 in) and the other was a estimated 5 in that we released from a seine haul. It was also early in the year and these YOY would have grown a lot more if we had gotten them later in the year. The other size group (7-year-olds) have a state average of 32 in at 7 years, while the two we aged as 7 averaged 27 in. As we have noted northern pike and yellow perch are cool water fishes, which require cool water on the bottom and adequate dissolved oxygen, because at the surface water is too warm and stresses them during summer, squeezing them in a layer of water that has the best available cool temperatures and dissolved oxygen (see Fig. 6, 7). However, Indianwood Lake is somewhat unique at the deep basin, because it has a deep chlorophyll layer at around 5 m and the dissolved oxygen there was 10 mg/L and the water temperature was 11 C. Unlike most eutrophic lakes in Michigan, the cool water layers (cool water fish need at least 5 mg/L and cool temperatures) in Indianwood Lake has double the required dissolved oxygen so would be ideal for high survival of this species. They would be stressed in other places in the more shallow basins in the lake because of the high water temperatures.

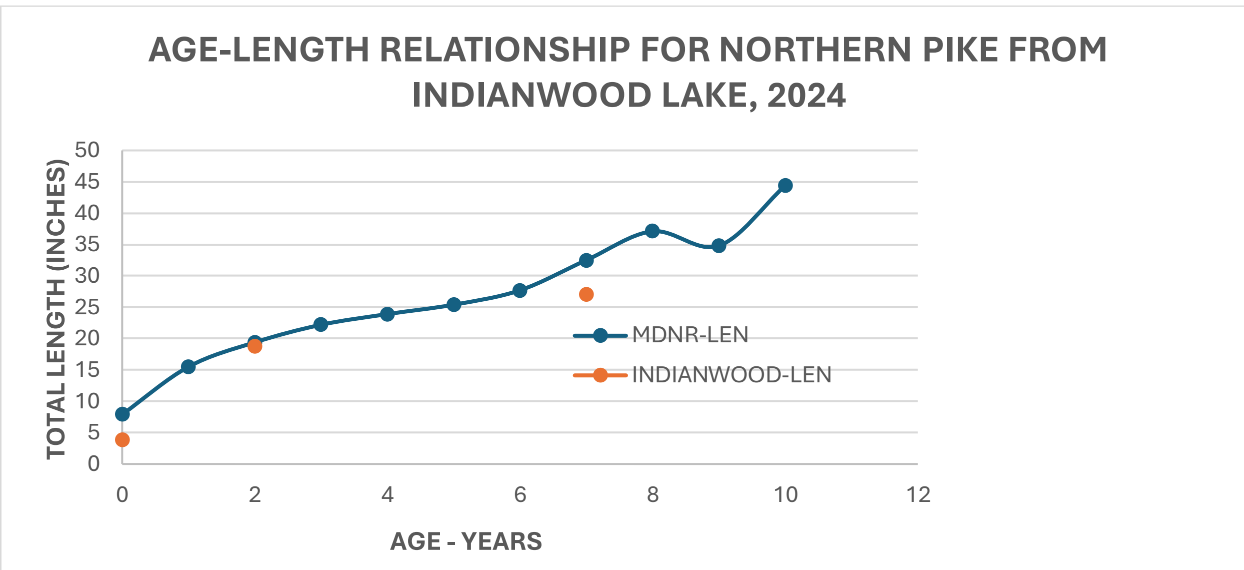


Figure 9. Age – length relationship for Indianwood Lake northern pike, 2024. N=6.

There were only nine yellow perch caught that ranged from 4 to 6.5 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 some reproduction based on the number of YOY we collected. They were growing at MNDR average rates (Fig. 10) and probably have adequate spawning substrate, since we ran into many sticks and logs while seining, optimal spawning habitat. This species is not a candidate for stocking since they have good spawning substrates present already and are probably being selectively preyed on by northern pike.

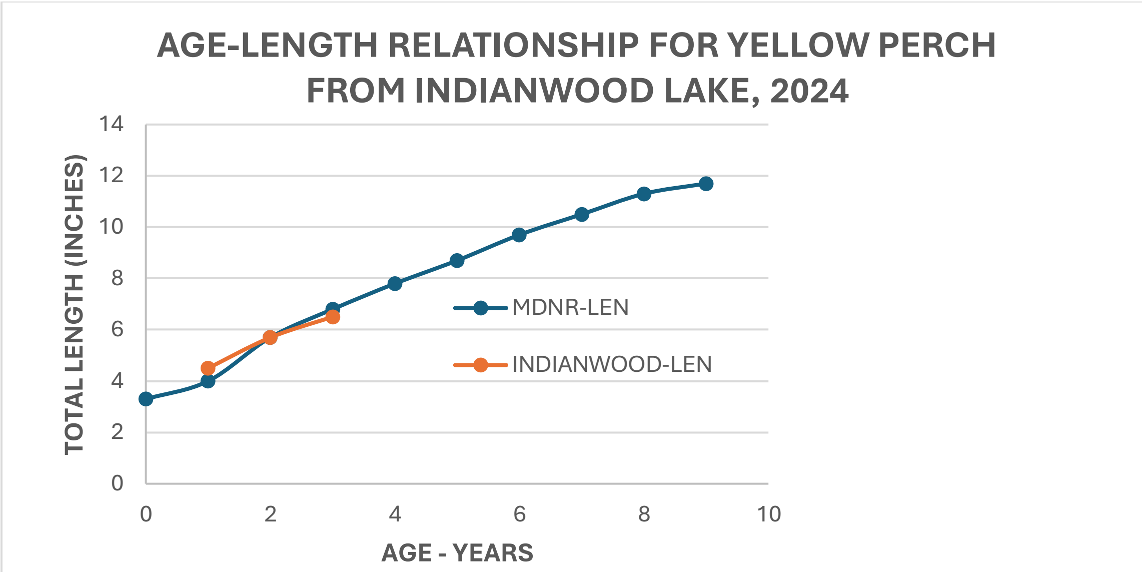


Figure 10. Age – length relationship for Indianwood Lake yellow perch, 2024. N=8.

We caught two rock bass, another great species to have in the lake, which enhances diversity, provides another predator to control bluegills, and provides more opportunities for fishers. Both fish were large (9-10 in) and were growing at state average rates (Fig. 11).

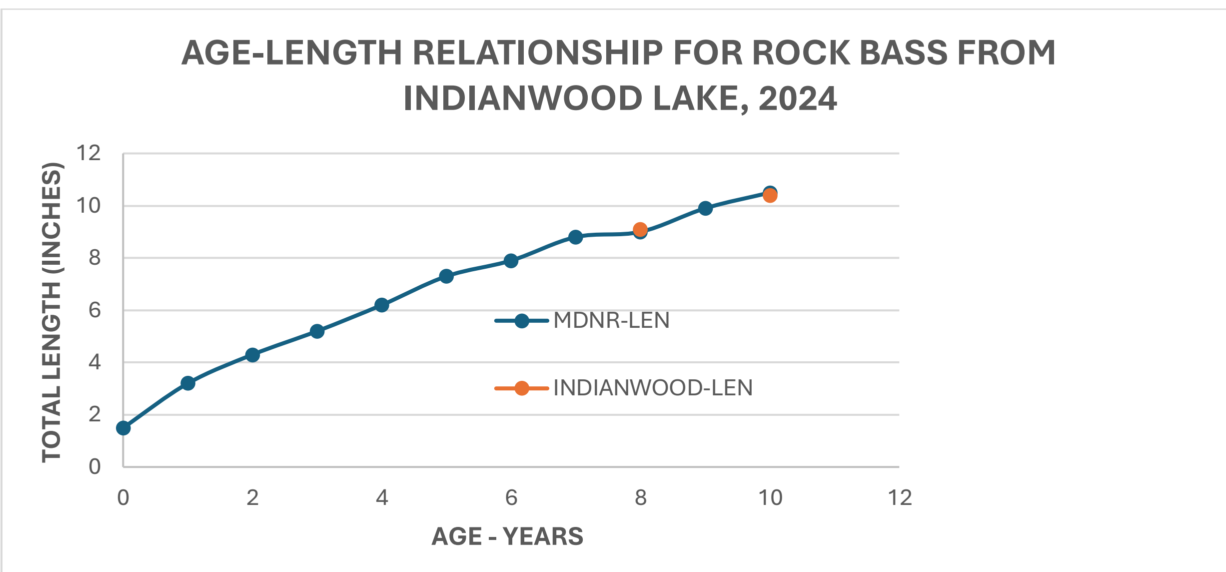


Figure 11. Age – length relationship for Indianwood Lake rock bass. N = 2.

We estimate that pumpkinseeds (2.5-8 in), might be the second-most abundant fish in the lake. They are known molluskivores (eating clams, snails) and all sizes were growing at MDNR averages (Fig. 12). There were many 6-8 in fish and they provide great fishing opportunities and eating. They are also probably utilizing the snails and fingernail clams that many other species do not eat and they were found to have zebra mussels in their diet, so are doing some good removing an invasive species.

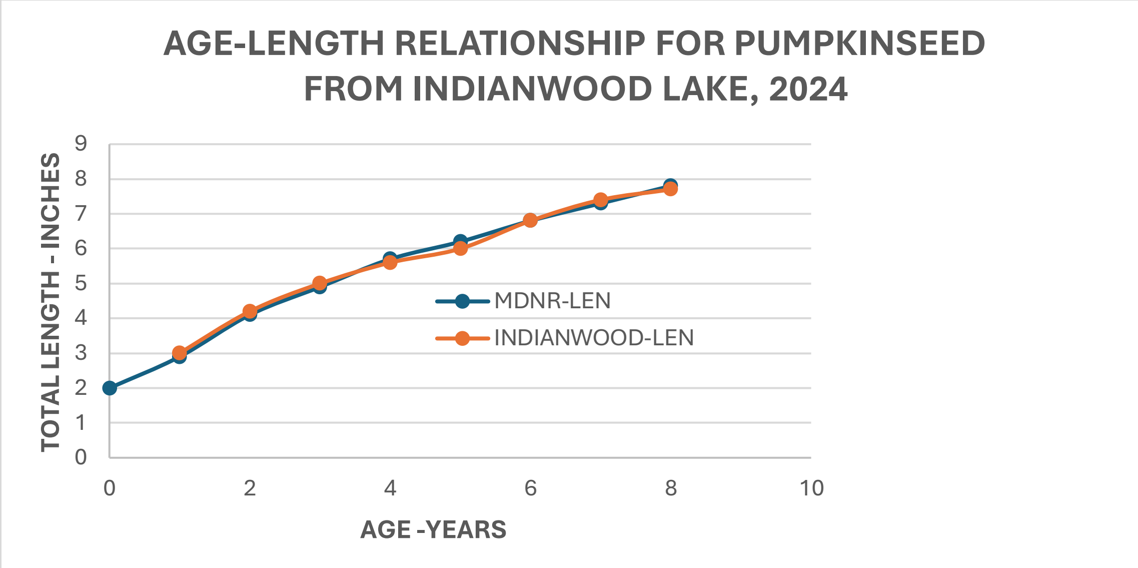


Figure 12. Age – length relationship for Indianwood Lake pumpkinseed. N = 31.

We only caught two black crappies, so they appear to be rare in the lake although there appears to be adequate habitat , spawning substrate, and prey (zooplankton and bluegill YOY) to support more. One of the fish (3-yr-old) was growing below state averages and one was at state averages.

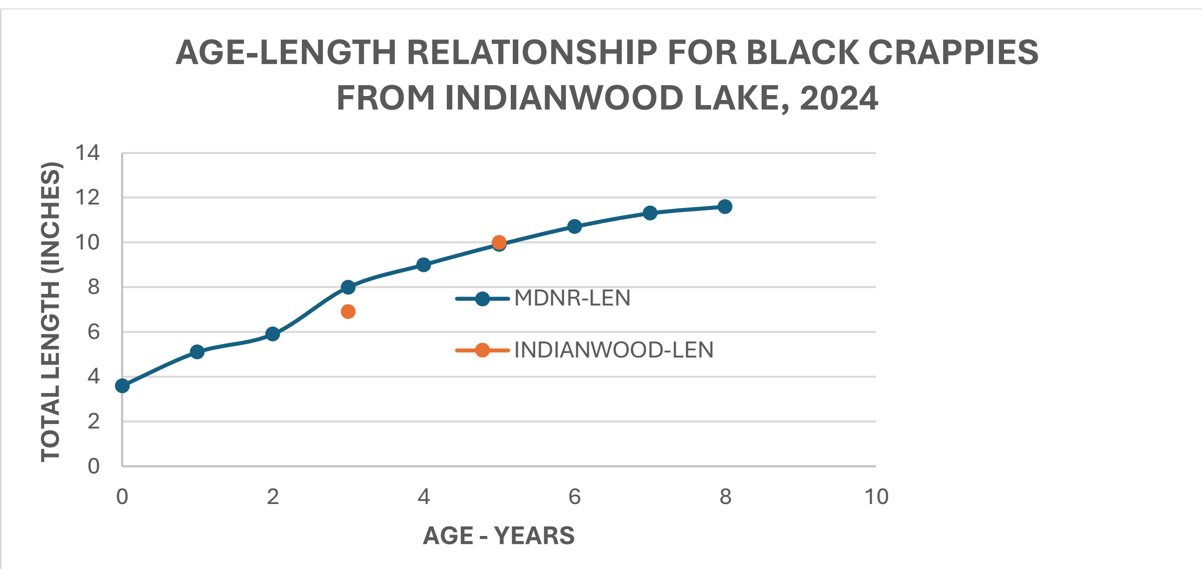


Figure 13. Age – length relationship for Indianwood Lake black crappies. N = 2.

PROBLEM AREAS: POSSIBLE SOLUTIONS

INTRODUCTION

Indianwood Lake is way above average among the lakes we work on. The water clarity is very good (mesotrophic), the dissolved oxygen-temperature profile has an uncommon characteristic- a deep chlorophyll layer (a layer with elevated dissolved oxygen and cool temperatures ideal for cool water fishes), a diversity of habitats, from highly vegetated nearshore zones to sandy, man-made beaches, to one deep basin (40 ft) and islands and very shallow environments. It is a large, reservoir lake, has a large proportion of its watershed in trees and brush, and therefore has an isolated cast to it. It has a good zooplankton population with plenty of *Daphnia* that will help control algae and enhance water clarity, and a moderately diverse fish population with an excellent largemouth bass fishery and a good northern pike population as well. There is moderate reproduction by northern pike which we seldom see, and there is one minnow we found. The bluegills and pumpkinseeds are growing at state averages and we got plenty of large individuals, ensuring good reproduction and good fishing for panfish. The diet information we gathered showed fishes were eating a wide variety of insects and invertebrates, including caddisflies and mayflies, crayfish, and a number of other insects. Pumpkinseeds were also found with zebra mussels in their stomachs. We assume, like we have seen in many other lakes infested with zebra mussels that they do not appear to be abundant enough to cause problems with either increasing the water clarity or sticking to boats and docks, causing trouble.

Therefore, areas of concern are small, and we will address problems that involve nutrient input to Indianwood Lake, the dead zone in the deep basin that generates nutrients that are eventually mixed into the lake, and fish management objectives to maintain the good quality fishery that is present in Indianwood Lake.

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 Indianwood Lake every spring and fall is termed "internal loading". This is the decomposition of organic material on the bottom of Indianwood 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 at the bottom of station A was 2.12 mg/L (toxic to fish), TP was 0.173 mg/L, and SRP was 0.041 mg/L, very elevated levels and these nutrients will be re-cycled into the lake during fall and spring turnover. The one positive feature is that there is only one deep basin of 40 ft in the lake, so most of the effects of internal loading will be confined to that end of the lake. **Recommendations**: There are three expensive solutions to this problem if there is interest in curtailing its effects. 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 drawback. Lastly, there is Phosloc, a bentonite - lanthanum mixture, which ties up phosphates in an 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 Riparian land

Indianwood Lake is a dammed lake and receives input from upstream and undoubtedly streams and culverts along its shoreline. We did not look for any of these, but they may be of importance during rain events. There is also runoff from houses on the lake. During rain events these culverts and streams as well as runoff from dwellings will deposit large amounts of road salt (measured by our chloride data – ca. 100 mg/L, a moderately high value- a pristine lake would have 5 mg/L or less), but more importantly, nutrients into Indianwood Lake. **Recommendations**: First, runoff from substantial sources of input of water should be identified and monitored at least two-three times during rain events during 2025, especially during rains in early spring. Samples from each source should be analyzed for chlorides, nitrates, ammonia, and soluble reactive phosphorus.

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 Indianwood Lake. The front Picture 1 depicts the kind of lawn that we would like to suggest could be more ecologically friendly by eliminating fertilizing the lawn and planting green belts to slow and stop the flow of runoff during rain events which carry high loads of nutrients into the lake. Riparians need to be part of the solution, not the problem.

AQUATIC PLANTS

Aquatic plants, algae and macrophytes, are the primary producers (the grass if you will) of the aquatic ecosystem. They provide the energy for the next food-web components (zooplankton and some fish), provide habitat for insects, invertebrates, and fishes, help stabilize the nearshore bottom sediments from boat and wave-induced currents, and remove carbon dioxide and generate dissolved oxygen that allows other residents of the lake, including humans, to survive. Besides being critical members of the ecosystem, they can also over produce, create dense beds of plants, generate algae blooms that can increase turbidity and produce toxins, that can kill pets and make humans sick, cover important fish habitat, provide too much shelter for small fishes, inducing stunting. Often this leads to management efforts to control exotic species that can damage ecosystem services and make recreational activities stressful. Progressive Companies are currently managing the algae and macrophyte populations with a program that focuses on invasive species using herbicide and copper -based treatments along with harvesting to try to control species like starry stonewort that can proliferate into vast beds of algae filaments that are not rooted to the bottom. **Recommendations:** Our study was done on 11 July 2024 and we observed plants first hand with our seining activities at four sites and in bringing up gill and trap nets in deeper areas. We saw many of the plants that are the focus of management activities, especially in the nearshore zone during seining. There are many nearshore sites that had too much vegetation to seine and many other areas that had a nice combination of lily pads, *Chara, Potamogeton* spp., wild celery, and bulrushes, a good diversity of plants. Many of the invasive plants would have been reduced later in the year. We agree with the multifaceted methods used to attack these invasive species with an effort to preserve native species and enhance their ability to grow in the areas where exotics were controlled.

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. Indianwood Lake has a moderate diversity of native fishes (including one invasive, the common carp), degraded water quality environment in the deep hole on the bottom, but high density of macrophytes in some places, and what looked like and has been documented in the past: extensive algal blooms.

The three major species of fishes we caught were bluegills, pumpkinseeds, and largemouth bass, so we assume they are maintaining their numbers (certainly for bluegills and pumpkinseeds, but largemouth bass YOY were common as well). We caught some large largemouth bass and reports from riparians we talked with suggest there is an abundance of large largemouth in the lake that are regularly caught and probably released (one of our recommendations). There are some yellow perch, black crappies, and rock bass in the lake and we think they are maintaining a low population status in the lake. There is a minnow, bluntnose, in the lake but we collected very few probably as a result of intense predation by largemouth bass. **Recommendations**: There are two recommendations we think would improve the fishery of Indianwood Lake.

Practice catch and release of northern pike and large largemouth bass; keep all small panfish.

1. Common carp (Picture 7) are a problem in Indianwood Lake since they appear to be numerous, 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 of nutrients into the water column where they fuel algae blooms.
    A. Solution 1: 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 Indianwood 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.
    B. Solution 2: If you have any bow fishers, they should also be encouraged to shoot as many as possible. One lake we worked on had a bounty on common carp which proved useful.

PICTURE 7. Large common carp *Cyprinus carpio*.

ACKNOWLEDGEMENTS

We want to thank Bill Colvett of the Indianwood Improvement Board for hiring us and coordinating the study. Larry Sak was an outstanding partner, in addition to being an excellent long-distance runner, he provided advice and guidance about the lake, was our guardian angel when we were on the lake, he helped bring equipment to the lake using a four-wheeler, making our trip to the lake much more efficient. He also provided captainship and use of his pontoon boat and dock for launching the study. The study would have been much more difficult without his help. Paul Hausler and Jared Laughlin graciously provided aquatic plant survey data and plant management methods. Jason Jude provided assistance with the maps and very important help with computer problems. Tim Miller, my able-bodied assistant, was a critical part of the study and I am thankful for his dedication and excellent help with the nets and for being the chief recorder. Residents should be thankful that there are people in their midst who have the best interests of Indianwood Lake in mind and dedicate their time and equipment to help improve the ecological health of the lake. Residents can help maintain and improve the ecological integrity of the lake by following some of the suggestions noted in the recommendations section.

LITERATURE CITED

Progressive Companies. 2024. Indianwood Lake plant survey, Oakland Co., MI. Progressive Companies report, 8 pp.