Picture 1. Loch Erin, 29 July 2015

A FISHERIES SURVEY OF

LOCH ERIN

WITH RECOMMENDATIONS AND A MANAGEMENT PLAN

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INTRODUCTION

We were asked to perform a fishery investigation of Loch Erin located near Onsted, MI in Lenawee County, and to develop short-term and long-term fish management plans for the lake. Loch Erin was formed during the 1970s by damming swamp and farmland, which has resulted in a very productive lake. Loch Erin is a eutrophic, shallow lake (mostly 10 ft deep: maximum 12 ft) with the entire lake littoral zone, which is unusual among eutrophic lakes in Michigan. It has several islands of brush and trees and some rocky shoals which provide diverse habitat and spawning substrate. We observed extensive shorelines of sand which is good for spawning panfish and largemouth bass. The lake is ringed with houses and has considerable boat traffic based on what we observed while working on the lake. It is an all sports lake. We did not observe many macrophytes, with the exception of the lily pads near the access site. There is extensive plant treatment program for Sago pondweed and curly leaf pondweed that were reported common in the lake prior to treatment efforts and an effort to control blue-green algae in late summer (see Pullman 2014). Leopold (2005) reported substantial amounts of aquatic vegetation in several shallow coves, mostly on the western sides of the lake. The lake is a 622-acre lake. It apparently was stocked with walleyes, channel catfish, and smallmouth bass in the past (Leopold 2005). The activities on the lake appear to be dominated by boating activities (pontoon boats, water skiing, skidoos) with fishing relegated to many dedicated individuals. Most houses are sewered with very few on septic tanks. No zebra mussels have been reported by residents, nor did we observe any on rocks or in the diet of fish.

METHODS

Our study involves physical, chemical, and biological measurements and observations by professional aquatic biologists who have conducted lake management studies since 1972; we incorporated in 1974. We use specialized samplers and equipment designed to thoroughly examine all components of an aquatic ecosystem. Shallow water, deep water, sediments, animal and plant life as well as inlet and outlet streams are intensively sampled and analyzed at several key stations (sites on the lake). Some samples are analyzed in the field, while the balance is transported to our laboratory for measurements and/or identification of organisms found in samples.

After the field study, we compile, analyze, summarize, and interpret data. We utilize a comprehensive library of limnological studies, and review all the latest management practices in constructing a management plan. All methods used are standard limnological procedures, and most chemical analyses are according to Standard Methods for the Examination of Water and Wastewater. Water analyses were performed by Grand Valley State University.

STATION LOCATIONS

During any study we choose a number of places (stations) where we do our sampling for each of the desired parameters. One of these areas is always the deepest part of the lake which was only 10 ft deep. Here we check on the degree of thermal and chemical stratification, which is extremely important in characterizing the stage of eutrophication (nutrient enrichment), and possible threats to fish due to production of toxic substances due to decomposition of bottom sediments. The number and location of these stations for this study are noted in that section.

PHYSICAL PARAMETERS

Depth

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

Acreage

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

Hydrographic Map

A map of the depth contours of the lake was adapted from Leopold (2005). Stations for fish sampling were appended to another map provided to us.

Light Penetration

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

Temperature

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

CHEMICAL PARAMETERS

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

Temperature Stratification

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

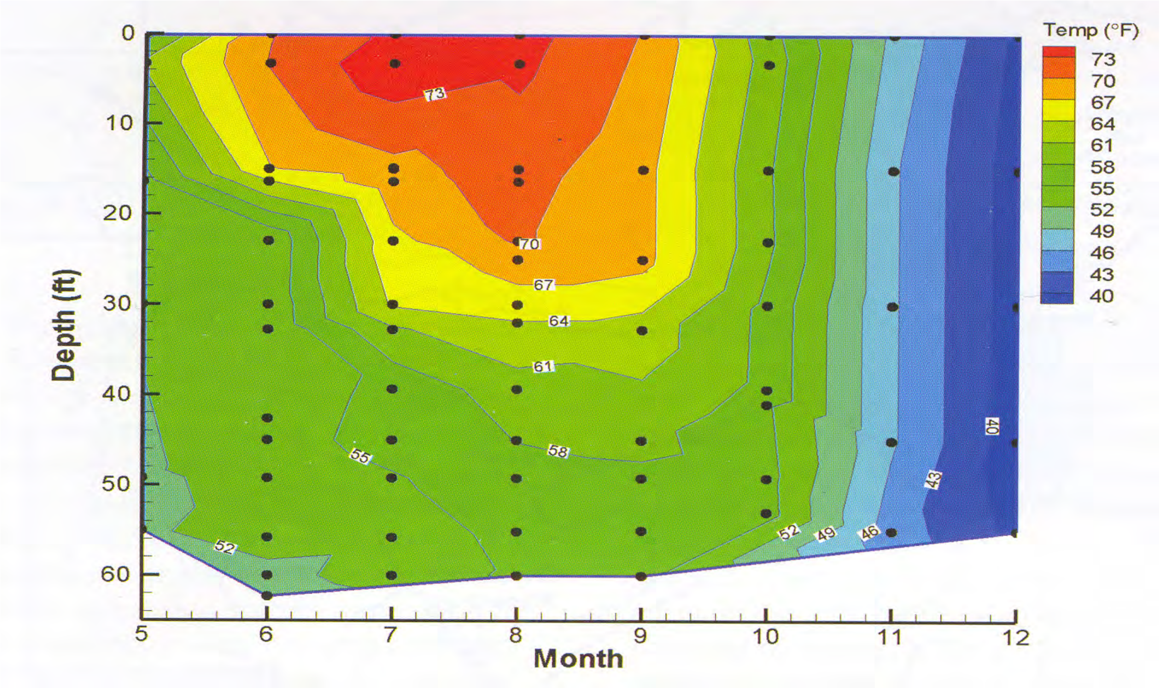

Figure 1. Depiction of the water temperature relationships in a typical 60-ft deep lake over the seasons. Note the blue from top to bottom during the fall turnover (this also occurs in the spring) and the red yellow and green (epilimnion, thermocline, and hypolimnion) that forms (stratification) during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

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

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

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

Dissolved Oxygen

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

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

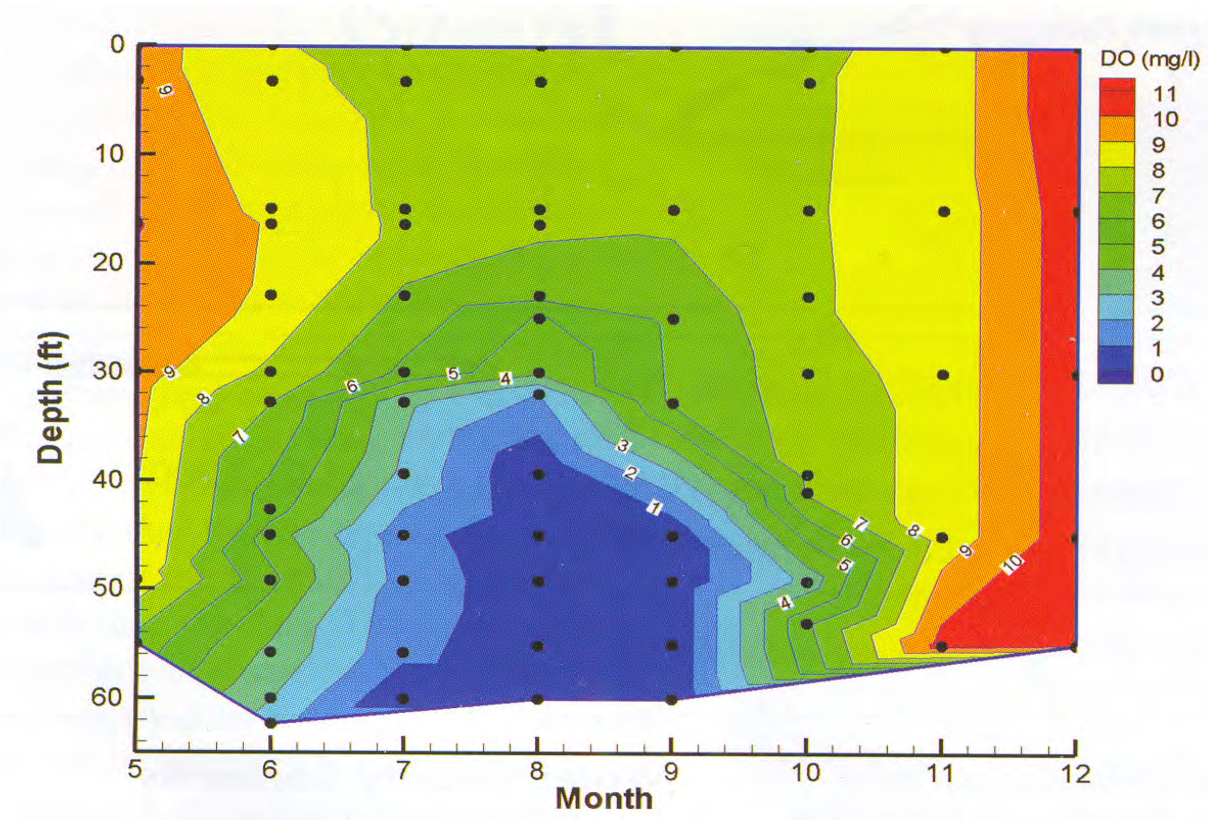

Figure 2. Dissolved oxygen stratification pattern over a season in a typical, eutrophic, 60-ft deep lake. Note the blue area on the bottom of the lake which depicts anoxia (no dissolved oxygen present) during summer and the red section in the fall turnover period (there is another in the spring) when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

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

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

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

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

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

pH

The pH of most lakes in this area ranges from about 6 to 9. The pH value (measure of the acid or alkaline nature of water) is governed by the concentration of H (hydrogen) ions which are affected by the carbonate-bicarbonate buffer system, and the dissociation of carbonic acid (H2CO3) into H + ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO2 from the carbonate-bicarbonate system. The pH will rise as a result. During evening hours, the pH will drop due to respiratory demands (production of carbon dioxide, which is acidic). This cycle is similar to the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO2 during the day in photosynthesis there is a drop in CO2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO2), thus causing a rise in CO2 concentration and a concomitant decrease in pH toward a more acidic condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution, which would cause deviations from expected values. In the field, pH is measured with color comparators or a portable pH/conductivity meter and in the laboratory with a pH meter.

Chlorides

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

Phosphorus

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

Nitrogen

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

BIOLOGICAL PARAMETERS

Macrophytes

The aquatic plants (emergent and submersed), which are common in most aquatic environments, are the other type of primary producer, besides algae, 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. They provide shelter, nursery, and spawning substrate for fishes, so care needs to be exercised in their control. Plants have a seasonal growth pattern wherein over wintering roots or seeds germinate in the spring. Most growth occurs during early summer. Again plants respond to high levels of nutrients by growing in huge beds. They can extract required nutrients both from the water and the sediment. Phosphorus is a critical nutrient for them. The aquatic plants and algae are closely related, so that any control of one must be examined in light of what the other forms will do in response to the newly released nutrients and lack of competition. For example, killing massive amounts of macrophytes may result in destruction of critical fish habitat as well as generating massive algae blooms, which are even more difficult to control.

Zooplankton

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

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

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

Benthos

The group of organisms in the bottom sediments and associated plants or those associated with the bottom is termed benthos. These organisms are invertebrates (lacking a backbone) and are composed of such animals as aquatic insect larvae and adults, amphipods (fairy shrimp), oligochaetes (aquatic worms), snails, and clams. The importance of this group for fish food and as intermediates in the food chain will be seen when diets of fishes are documented later in the report. Because of the tremendous variety of animals in each group and their respective tolerances for different environmental conditions, this group is a very important indicator of environmental quality. One of those organisms is called *Hexagenia*, the large mayfly that hatches in late July and precipitates much trout fishing in our local trout streams. This organism has a 2-yr life cycle; the larval form (naiad) lives in thick organic muds making a U-shaped burrow, so it can take in algae and detritus on which it feeds. It requires high dissolved oxygen at all times and good water quality to survive, so when present it indicates excellent water quality is present.

Fish

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

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

RESULTS

WATERSHED

Loch Erin is located in Lenawee County and is in the Raisin River watershed. The local watershed for the lake is composed of the land surrounding the lake which has water that lands on it flow into the lake. This land is composed of extensive areas of farmland (Fig. 3), which was also flooded to produce the lake originally in the 1970s. Hence the lake tends to be enriched from the existing fertile bottom sediments, including clay, the source creeks that drain the watershed, and the riparians that live around the lake. Because the lake has a low Secchi disk reading (we measured it as 0.7 m or 2.3 ft during July 2015 and Leopold (2005) measured it as 2.5 ft in 2005), the high turbidity will affect the fish community that can flourish in the lake. Many species, such as largemouth bass and bluegills are sight-feeders and rely on light to promote capture of prey. Fish species, such as channel catfish, can use their barbells and lateral line to find and consume prey under low-light or night conditions. There are many houses located on Loch Erin (Fig. 3), including lawns and large areas of grasses and shrubs and a few forested areas. Agricultural land is nearby in several localities.

The local riparian zone is very important also, especially that band right at the lake (see Appendix 1 for lawn care and other recommendations). Since some of the soil is sandy, water percolates through much faster into the groundwater than it would with loamy soils. Things that can be done to inhibit entry of undesirable and deleterious substances into the lake are: planting greenbelts (thick plants that can absorb nutrients and retard direct runoff into the lake) along the lake edge, reducing erosion where ever it occurs, reducing or eliminating use of fertilizers for lawns, cutting down on road salting operations, not feeding the geese or ducks, no leaf burning near the lake, prevention of leaves and other organic matter from entering the lake, and care in household use of such substances as fertilizers, detergents to wash cars and boats, pesticides, cleaners like ammonia, and vehicle fluids, such as oil, gas, and antifreeze (summarized in Appendix 1).

STATION LOCATION

Loch Erin is a 622-acre lake (see Figs. 3, 4) located near Onsted, MI in Lenawee county. We established two types of stations on Loch Erin for sampling various parameters in this study (Fig. 5, and Table 1). Water chemistry and zooplankton were sampled at the deepest site (station A), while station numbers and an accompanying code (S=seine, TN=trap net, GN=gill net) mark the location for sampling fish in various locations around the lake to maximize catch of fishes (Table 1, Fig. 4). Fishes were collected using seines at two stations, gill nets at two stations, and trap nets at four stations. Gill nets were only set during the day to minimize killing of large predators, while trap nets were set over night. Only those fishes required for study were saved; the rest were released.

Figure 3. Google map of Loch Erin showing the extensive development around most of the lake.

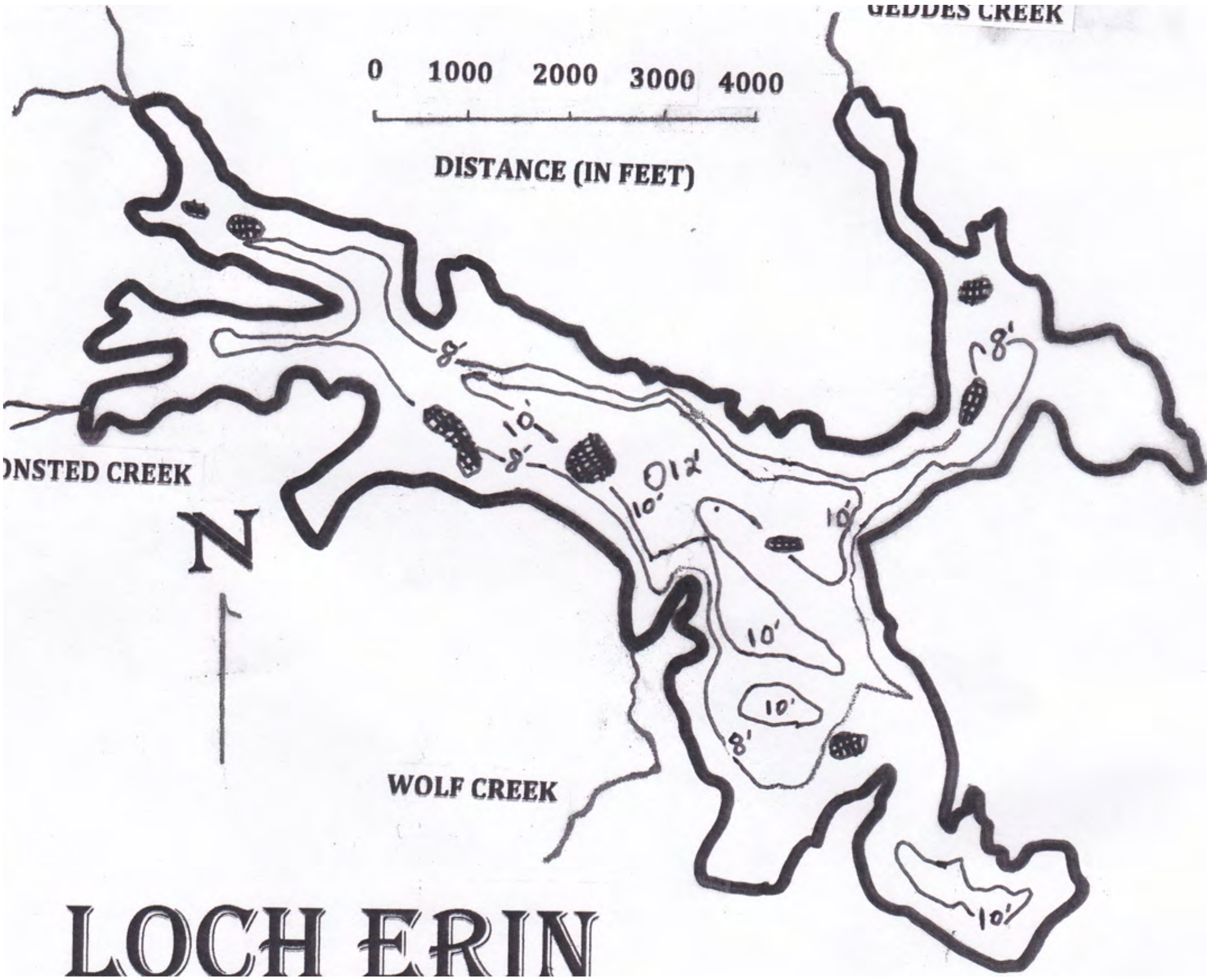

Figure 4. Hydrographic map of Loch Erin showing depth contours and other features (islands and rocky shoals) of the lake.

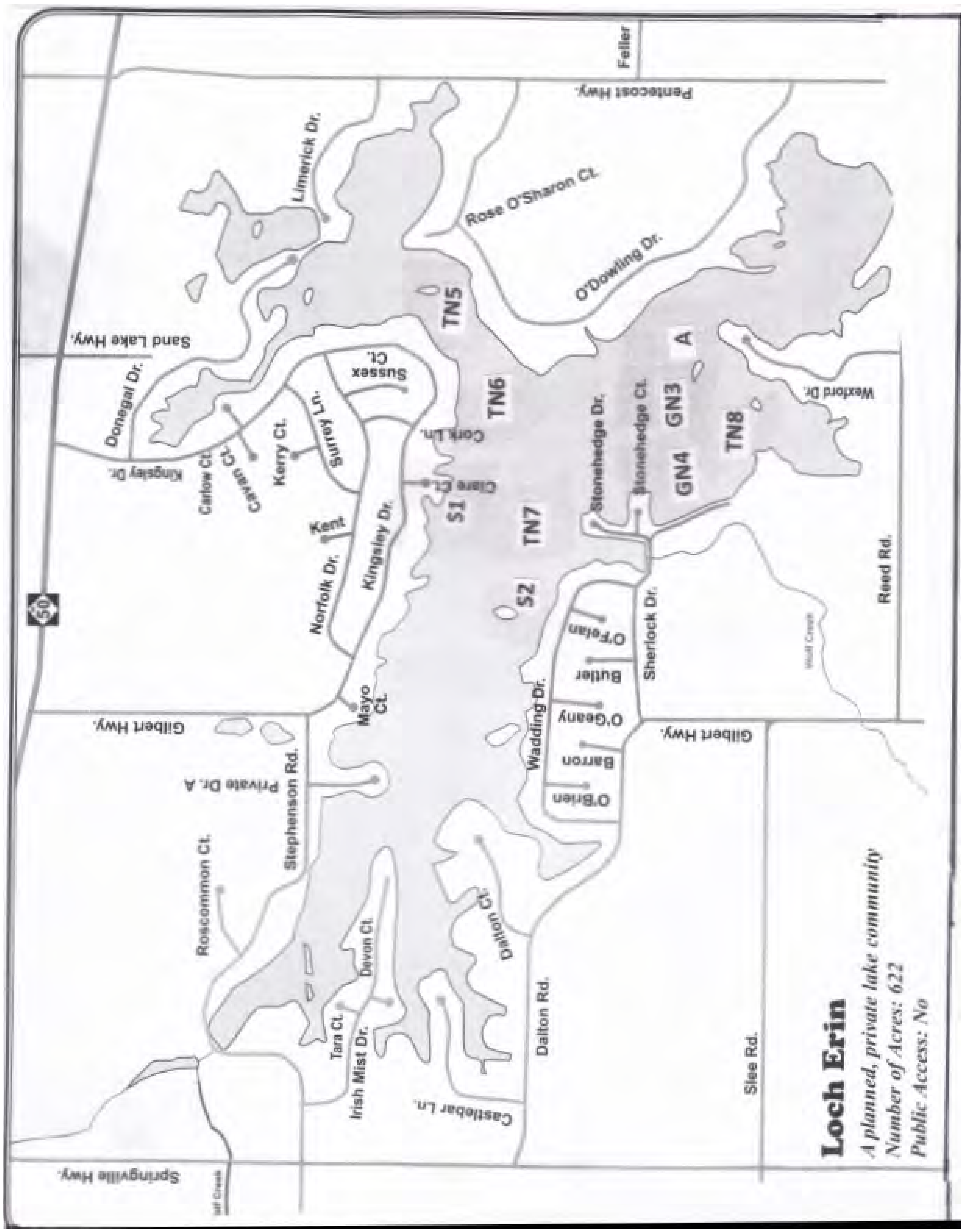

Figure 5. Map of Loch Erin showing the water quality sampling station (A- see Table 1 for description) and fish sampling sites for seining (S1, S2), gill netting (GN3, GN4), and trap netting (TN5, TN6, TN7, TN8).

Table 1. Time (*set overnight), species captured, and GPS coordinates where various gear were deployed on Loch Erin, Lenawee County, MI, 29-31 July 2015. G = gill net, T = trap net, S = seine. Under species captured: R=released, size of fish in inches is in parentheses, number of fish released precedes fish code, R1=replicate 1. Fish codes defined as: CC-channel catfish, LB-largemouth bass, SF-spotfin shiner, BM-bluntnose minnow, BC-black crappie, BG-bluegill, YP-yellow perch, GL-golden shiner, SB-smallmouth bass, PS-pumpkinseed, CP-common carp, WL-walleye.

Time Set	**Pickup**	**Gear/ Station**	**Species captured**	**GPS**
1748	1800	S1	CC,LB,SF,BM,BC,BG,YP	NA
1650	1700	S2-R1,R2	SF,GL,BC,BG,LB,SB,PS,CP,YP	N42 00.982 W-84 14.658
1238	2003	G3	9CP-R,1CC(27")-R	N42 00.376 W-84 13.686
1258	1920	G4	1CC(22")-R,4BC-R,1CP(15")-R,WL	N 42 00.2920 W-84 14.108
1405	1118*	T5	BG,BC,WL(28")-R,	N42 01.244 W-84 13.318
1458	1215*	T6	LB	N42 00.896 W-84 13.913
1519	1233*	T7	BC(8'),9CC(15-25")-R	N42 00.875 W-84 14.294
1543	1155*	T8	28BC,26BG	N42 00.193 W-84 13.757

PHYSICAL PARAMETERS

Depth

Loch Erin is a bit unusual in that at its deepest spot it was only 12 ft deep (Station A, Fig. 4, 5). The littoral zone extends throughout the entire lake and apparently in the past and other times was highly vegetated, but we observed very few and would make the plea to allow more to flourish when planning macrophyte treatments. Aquatic plants are keystone habitats in a lake for fishes; they provide aquatic insects for food, spawning habitat, and probably most importantly, nursery and shelter for smaller fishes. We clearly recognize that nuisance aquatic plants and algae can be a problem and invasive plants need to be controlled. However, in Loch Erin we believe more aquatic plants would promote a better fish community, a view also supported by the previous fish survey personnel (Leopold 2005).

Acreage

Loch Erin is 622 acres and is extensively developed around the lake with fulltime and seasonal homes. The lake has unique habitat since it is shallow, vegetated in some places, has several rocky shoals, and islands with trees and brush. During our summer survey in July the only emergent plants we observed were lily pads near the access site. Discussions with residents, Pullman (2014), and Leopold (2005) note the lake can have large beds of *Potamogeton* spp., which we did not observe. More aquatic plants would favor more fishes, since they provide shelter, nursery areas, aquatic insects for food, and the plants can help control boat wake waves which can re suspend sediments, especially clay, contributing to the high turbidity measured. Pullman (2014) also noted serious blue-green algal blooms in late summer and has taken measures to reduce their impact.

Light Penetration

The Secchi disc (measure of water transparency) reading during 29 July 2015 at station A was 2.3 ft, which is a very low reading suggesting high turbidity in the lake. A similar value was recorded during summer 2005 (Leopold 2005). We believe that the source water coming in is turbid and the bottom sediments are constantly being stirred by the boat traffic re suspending sediment and causing the high turbidity. This will limit macrophyte growth in the lake even though some large beds of plants have been noted in the past and continue to be treated. This low a reading also makes the lake a eutrophic, productive lake.

Temperature/Dissolved Oxygen

Water temperature is intimately associated with the dissolved oxygen profiles in a lake. The summer profile is the one that most characterizes a lake and the stratification impacts are very important. A lake goes through a series of changes (see introductory material-Temperature) in water temperature, from spring overturn, to summer stratification, to fall over turn, to winter conditions. During both summer and winter rapid decomposition of sediments and detritus occurs when bottom waters are fertile and can cause degraded chemical conditions on the bottom (to be discussed). Because the lake is essentially sealed off from the surface when it is stratified during summer, no dissolved oxygen can penetrate to the bottom and anoxia (no dissolved oxygen conditions- a dead zone) can result. This has implications for the aquatic organisms (fish will not go there) and chemical parameters (phosphorus is released from the sediments under anoxic conditions, which then contribute these nutrients to the lake during the fall overturn). When we measured the dissolved oxygen and water temperature profile during early summer (29 July 2015), the dissolved oxygen profile (Table 2, Fig. 6) showed that there were declining oxygen levels as one approached bottom at the 12-ft deep station we sampled. Dissolved oxygen concentrations were 6.8 mg/L at 6 ft down, 1.2 mg/L at 10 ft down (too low for most fish), and 0.6 mg/L on the bottom at 12 ft. These low dissolved oxygen levels will prevent fishes from residing there for very long during these hypoxic conditions. It also means conditions will be very stressful for walleyes, since the water temperature was 81.5 F at the surface and there was too little dissolved oxygen at 10 ft and lower in the water column. We were unable to ascertain whether the turbidity was stirred up sediments or algae, probably the former. Since the lake is so shallow, any boat traffic on the lake will stir the sediments and re suspend them into the water column (something common carp also do), exacerbating the turbidity situation and re-suspending nutrients (phosphorus and nitrates) from the muds. In addition there are probably contributions of nutrients from the lake resident’s runoff and lawn fertilization as well as input from the streams entering the lake. This will enhance aquatic plant and algae growth. We also understand that there is an ongoing aquatic plant and algae treatment program (Pullman 2014). As we noted earlier, we could find no extensive aquatic plant beds in the lake, with the exception of one lily pad group south of the access site. It seems to us that aquatic plants were over treated, since we could not find substantial stands of aquatic plants anywhere. This destruction is unfortunate since it destroys spawning, shelter, and insect habitat for fish-food organisms and fishes. It could also shift the dominance of the lake to algae from aquatic plants. In addition, beds of plants would shield the lake bottom from sediment re suspension due to extensive boat traffic we observed on the lake. A more cautious and directed treatment of plants only in areas of high use is recommended.

. Most warm water fishes require at least 3 mg/L while cool water fish, such as northern pike and walleye require 5 mg/L. Hence these cool water fishes will be subjected to the squeeze noted in Fig. 7: warm temperatures in surface water forces them downward, while no dissolved oxygen in the preferred bottom cool waters of the lake forces them into too warm surface waters. As a result, northern pike, and especially walleye which appear to be more abundant in the lake, will be stressed and probably not grow well or die during this period of the year. This finding should be kept in mind when decisions regarding whether to plant more walleyes are made. This point is important for fish management considerations.

Table 2. Dissolved oxygen (mg/L) and water temperature (F) profile for station A (12 ft.) 29 July 2015 on Loch Erin, Lenawee County (see Fig. 5 for station location).

DEPTH (M)	TEMP - C	Dissolved Oxygen (mg/L)
0	27.5	7.6
1	27.4	7.5
2	26.9	6.8
3	26.1	1.2
3.1	25.9	0.6

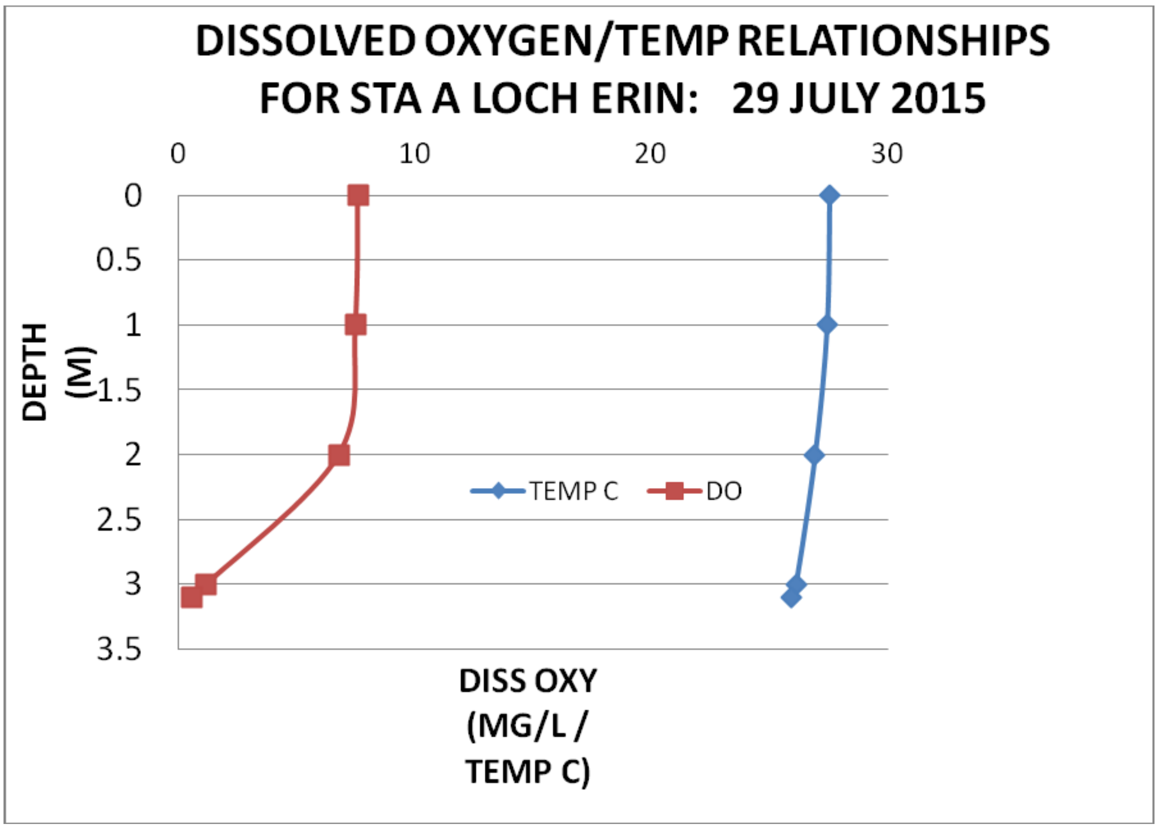

Figure 6. Dissolved oxygen (mg/L) and water temperature (F) profile for station A, Loch Erin, 29 July 2015.

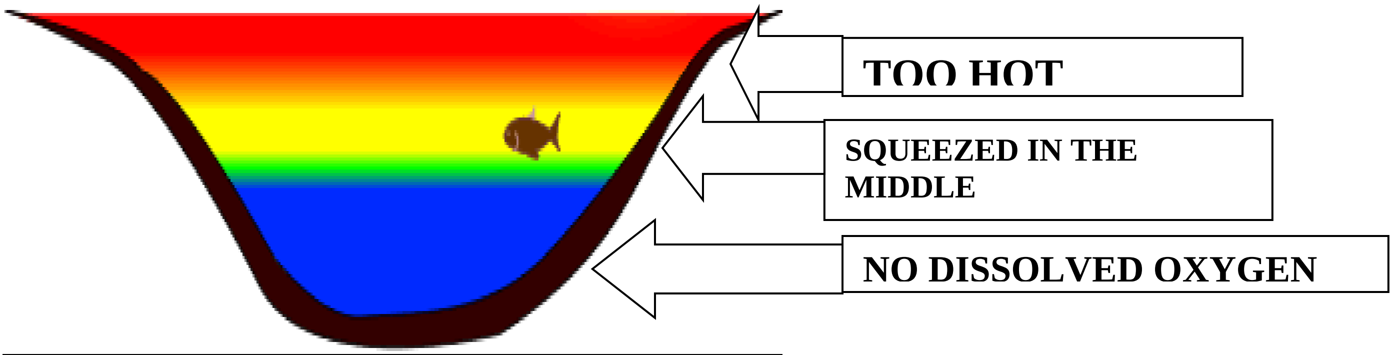

Figure 7. Depiction of the dissolved oxygen concentrations in a stratified lake, showing the surface layer (epilimnion) where warmest temperatures exist, the thermocline area where temperatures and dissolved oxygen undergo rapid changes, and the bottom layer, where the coolest water exists, but has no or very low dissolved oxygen present. Cool water fishes, such as northern pike and walleyes are "squeezed" between these two layers and undergo thermal stress during long periods of summer stratification.

CHEMICAL PARAMETERS

pH

The pH (how acid or alkaline water is) for Loch Erin during 29 July 2015 at station A (50 ft.) showed an atypical pattern with similar values from surface to bottom (8.04-8.21 – Table 3). Usually we see pH is highest at the surface where algal and aquatic plant growth remove carbon dioxide and increase pH, while it is lowest on the bottom where decomposition of bottom sediments increases the CO2 produced and reduces pH. We do see some lakes with high water clarity can have a deep chlorophyll layer lower in the water column, because the light is too intense at the surface and inhibits photosynthesis. We saw no evidence of this in the dissolved oxygen curve (Fig. 6). Interestingly enough, the other parameters, with the exception of ammonia, all followed a similar pattern.

Table 3. Conductivity (uSiemens), pH, chlorides (CL), nitrates (NO3), ammonia (NH3), total phosphorus (TP), and soluble reactive phosphorus (SRP) for Loch Erin, 29 July 2015. See Fig. 5 for location of station A. All concentrations are in mg/L.

DEPTH	PH	COND	CI	NO3	NH3	SRP	TP
Surface	8.04	499	29	<0.01	0.0214	<0.005	0.0479
10 FT	7.95	534	28	<0.01	0.1231	<0.005	

Chlorides

Chloride concentrations in Loch Erin were low ranging from 28 to 29 mg/L (Table 3). Chloride ions are conservative ions, which mean they are not altered by biological or chemical activity; they can only change with evaporation or input of water of differing concentrations of chlorides. They can derive from septic tank effluent, water softener salt discharges, road salt runoff, or can be naturally occurring. Therefore they accumulate in a lake and give a good impression of the past history of inputs of that ion, as well as co-occurring substances from runoff, such as nutrients, toxic substances, and sediment. This low a concentration indicates there are no egregious sources of chlorides in Loch Erin or its watershed now, with no suggestion of excessive septic tank or road salt runoff.

Phosphorus

We are interested in phosphorus (P) because P is generally the limiting nutrient for plant growth and the level of concentrations can indicate the trophic state or amount of enrichment in the lake. Soluble reactive phosphorus (SRP) measures only that P which is dissolved in the water, which is the form that is readily available for algal and plant growth. Total P is all the P in the water, dissolved and that tied up in algae or other detritus. During summer, SRP values throughout the water column were at trace levels (<0.005 mg/L), probably because algae and aquatic plants take up all the phosphorus (and nitrogen) for growth (Table 3). Phosphorus is probably limiting in surface waters at this time in Loch Erin. We also measured total phosphorus (TP) at the surface of Loch Erin; the concentration (0.0479 mg/L) was quite high and reflects the presence of suspended organic matter or algae.

We concluded two things from these data: first, P is probably limiting in Loch Erin in surface waters during summer and will stop growth of algae and plants until more phosphorus enters the lake (limiting nutrient). One way for that to happen is excessive water skiing and boating in the lake, which can stir up bottom sediments in shallow water, resulting in the release of phosphorus and promotion of algal and macrophyte growth. Reduced macrophyte coverage due to treatment of plants can also reduce the ability of the near shore zone to retain nutrients in the sediments. SRP could come in from runoff or from old septic systems, and by lawn fertilization. Residents need to do all they can to prevent nutrients from entering the lake so as to preserve the current water quality they do enjoy. See Appendix 1 for suggestions. Second, it confirms our suspicions that there are large quantities of organic matter in the water, either from algae or suspended sediments.

Nitrates

Nitrate is very important since it too is a critical plant nutrient as well as P; however, blue-green algae can generate their own nitrogen, favoring them when nitrate concentrations are depleted, usually in late summer (see Pullman 2014 for a discussion of this problem). Nitrates in Loch Erin during 29 July 2015 were <0.01 mg/L at the surface and bottom (Table 3). These are extremely low concentrations of nitrate and were similar throughout the water column. As noted, we usually see trace concentrations of nitrates in surface waters as we observed with SRP, so it appears that there is inadequate P and N in the lake during this period.

Ammonia

Ammonia is also a plant nutrient, but it can be toxic to fish in high concentrations. Although we found low levels of ammonia in our water column samples during 29 July (0.02 mg/L at the surface and somewhat higher on the bottom – 0.12 mg/L - Table 3). The higher concentrations on the bottom are indicative of decomposition ongoing there and despite much mixing of the water column concentrations are elevated there. Ammonia is formed by the decomposition of bottom sediments under low or no oxygen present. During fall turnover, this nutrient along with P compounds will be mixed into the lake, producing next year's crop of algae and macrophytes.

Conductivity

Conductivity is a measure of the ability of water to conduct current and is proportional to the dissolved solutes present. During our early summer survey, conductivity ranged from 499 at the surface to 534 uS (somewhat higher) on the bottom (Table 3). This suggests that the mixing of the lake during summer by boat traffic is not sufficient to drive similar concentrations of compounds from surface to bottom. These are moderately low values, compared with other lakes, partially explained by the low chlorides which often contribute substantially to the conductivity measurement.

BIOLOGICAL PARAMETERS

Algae

We did not sample algae in Loch Erin, but wanted to ensure that residents be on the lookout for an exotic species, called starry stonewort (Picture 2), which has not to our knowledge been observed in Loch Erin (see also Pullman 2014 for discussion of this alga). Note this species is an alga, and is a very destructive plant which can alter dissolved oxygen patterns and cover spawning sites for warm water centrachids. It looks a lot like *Chara*, another green alga but is somewhat different. Residents must take precaution when bringing boats and potentially contaminated gear into Loch Erin.

Picture 2. Starry stonewort

Aquatic Macrophytes

Loch Erin was populated with many species of macrophytes based on resident comments, Pullman (2014), and Leopold (2005), with former dominants being curly-leaf pondweed, Sago pondweed, and water lilies. Observations during our 2015 study suggested they were not abundant and the only ones at the surface were lily pads at the access site. More extensive data exist with other entities doing lake management activities on the lake (Pullman 2014). What we want to re-emphasize however, is the critical importance of macrophytes as habitat, shelter, nurseries, food producers, spawning substrate, and inhibitors of wave disturbance in shallow areas. We accept that access to and from residences and beach areas are important for riparians and that invasive plant species need to be controlled. However, there should be an emphasis on maintaining native species and spot treatment of exotics. Macrophytes are critical components of the ecosystem, not only for fish, but for sustaining good balance among food web components. The alternative to macrophytes is algae, so you do not want to reach a tipping point where algae dominate the lake and shade out aquatic plants.

Zooplankton

Zooplankters are small invertebrates present in most lakes and ponds (See Picture 3 for an example of a copepod and Picture 4 for an example of *Daphnia*). They are critical connectors between plants (they eat algae) and fish, since they are important as food for larval fish and other small fishes in the lake and are indicators of the amount of predation that fish exert on these organisms. Zooplankton we collected at station A (Table 4) was comprised of very few species (six), indicating that there was not a diverse group of these organisms in Loch Erin. These species included: *Daphnia* (see Picture 4), Immature *Diaptomus* spp., *Diaptomus minutes*, *Bosmina*, and *Mesocyclops.* The dominant group was a cladoceran *Bosmina* (30%) followed by copepods: *Daphnia*, the largest among these zooplankters, composed 5% by number, which has two implications. First, one of the things we look for is the presence of the large species of zooplankton: *Daphnia* especially. *Daphnia* is slow, energy-rich, large, and an easy target for fishes. Therefore, since we found very few of these large zooplankters present in the lake and none in fish stomachs that we could identify it indicates that at least during summer either there is not enough algal food present, environmental conditions (high turbidity) are adverse, or fish predation is intense, as is often seen in lakes dominated with planktivores (zooplankton eaters), such as stunted small bluegills, yellow perch, and black crappies. Our fish sampling confirmed that there were moderate numbers of small bluegills present and they along with black crappies were predators on zooplankton.

Second, *Daphnia* is more efficient than copepods (a smaller, faster group of zooplankton –*Cyclops* and *Diaptomus* are examples) at filtering algae from the water column. Since *Daphnia* were so scarce, they are not helping to control algae in the surface waters which they do during summer in lakes where they are abundant. Copepods are also not fed on as often by fish since they are faster, unless other large zooplankters are rare.

Table 4. A listing of the abundance (% composition based on counting a random sample of 150 organisms) of zooplankton species (see Picture 3-4) collected from station A in Loch Erin, 27 July 2015 (see Fig. 5 for station locations).

TAXONOMIC ENTITY	%
Diaptomus Imm.	10
Diaptomus minutus M	20
Daphnia spp.	5
Bosmina	30
Mesocyclops Immature	2
Mesocyclops edax F	30
Sida chrysallina	3

Picture 3. A copepod (zooplankter).

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

Fish

Fish Species Diversity

We collected fish using three trap nets at three stations (Fig. 5, see Picture 5) with some of the resulting fish shown in Picture 6 and 9. A 50-ft seine was deployed at two stations (Fig. 5, Picture 7), and two gill nets fished at two stations (Fig. 5, Picture 8) were also deployed in the lake. The gill nets were used during the daytime only and checked often to reduce deaths of large predators. Nets were deployed on 29-31 July 2015 (see Table 1 for times); the gill nets were picked up and reset the same day, while trap nets were left overnight. Seining with a 50-ft seine was done at two sites on the lake in different habitats. Most fish were released; we kept enough for an adequate sample for ageing and diet analyses (see Table 5). We never want to kill too many fish, especially top predators, as they are so important to fish community balance in a lake. We could have used a few more large fish (especially largemouth and smallmouth bass), but the ones we did catch provided some basic information on the lake. It should be noted that some species are difficult to catch with the gear we use (e.g., bass) and we try to do a balancing act between catching enough for good information and killing too many; we try to err on the side of too few.

The lake has a moderate diversity of eutrophic fish species, some of which were stocked (walleye, smallmouth bass, channel catfish); most were native. We collected 13 species in our sampling efforts in July (Table 5) and added to the additional six species collected by Leopold (2005) during 2000 and 2005 that we did not collect during 2015 adds to a total of 19 species of fishes in the lake. Top predators include: channel catfish, walleye, largemouth and smallmouth bass, large black crappies and yellow perch. Yellow bullheads were caught in previous studies and they can also be efficient predators on prey fish. We have already noted that cool water fish, such as northern pike (if present) and walleye, are probably stressed during summer because of the lack of dissolved oxygen in the bottom waters of the lake. Since walleyes are present during the whole year, and because the lake is so productive, the two fish we aged appeared to be growing at or above state averages during the cooler periods of the year. Several species that were caught during 2000 and 2005 (but not during 2015) included: redear sunfish (probably stocked), brook silversides, emerald shiner, white crappie, green sunfish, and yellow bullhead. It is interesting that we did not catch any emerald shiners or yellow bullheads during our sampling.

In addition to a good suite of top predators, the lake also contains a good population of bluegills and a number of 5-6 in pumpkinseeds were also documented. The strange finding about pumpkinseeds is we seined no young of the year (YOY), while Leopold (2005) did catch some in their efforts in 2005. Either they are not spawning successfully, they were distributed in places where we did not sample, or their young suffered severe mortality. There were a few YOY yellow perch indicating that some reproduction occurred. There were many YOY largemouth bass and a few smallmouth bass captured, indicating good reproduction, but we did not capture any big largemouth bass and only two smallmouth bass that were >6 inches. We captured three species of minnows: bluntnose minnow, spotfin shiner, and golden shiner, which is good diversity. Overall this is an adequate diversity of predators and prey, considering the habitat conditions of high turbidity, few macrophytes, and blue-green algal blooms in late summer. Lastly, we collected one white sucker which adds to the diversity and prey fish populations in the lake.

Picture 5. Some of the trap nets used in Loch Erin, 29 July 2015.

Picture 6. Black crappie captured in Loch Erin trap net, 29 July 2015.

Picture 7. Deployment of the 50-ft seine in the near shore zone.


Picture 8. Experimental gill net with channel catfish being brought into the boat.

Picture 9. Trap net with a large walleye being brought into the boat. The fish was measured, a scale sample taken, and released.

Table 5. Common name, scientific name, sample sizes, and length ranges of the fishes collected from Loch Erin, 29-31 July 2015. Fish collected during previous studies were done during 2000 and 2005 (Leopold 2005) and are depicted below. No. collected does not include those released (see Table 1) except for common carp.

Taxon	**Scientific Name**	**Year collected**	**No. collected**	**Range (inches)**
BLACK CRAPPIE*	*Pomoxis nigromaculatus*	2015	26	4.3-11.1
BLUEGILL*	*Lepomis macrochirus*	2015	56	1.1-7.3
BLUNTNOSE MINNOW**	*Pimephales notatus*	2015	18	0.9-3
CHANNEL CATFISH*	*Ictalurus punctatus*	2015	5	15-22.1
COMMON CARP	*Cyprinus carpio*	2015	ca. 25	21-32
GOLDEN SHINER	*Notemigonus crysoleucas*	2015	1	2.5 /
LARGEMOUTH BASS*	*Micropterus salmoides*	2015	21	1.7-2.9
PUMPKINSEED*	*Lepomis gibbosus*	2015	9	5-6.1
SMALLMOUTH BASS*	*Micropterus dolomieu*	2015	8	2-10.8
SPOTFIN SHINER	*Cyprinella spiloptera*	2015	9	2.2-3
WALLEYE*	*Sander vitreus*	2015	2	16.4-28

WHITE SUCKER	*Catostomus commersonii*	2015	1	14.2 /
YELLOW PERCH *	*Perca flavescens*	2015	6	2.4-5.3
GRAND TOTAL			162	
REDEAR SUNFISH	*Lepomis microlophus*	2005	10	NA
BROOK SILVERSIDES	*Labidesthes sicculus*	2005	3	NA
EMERALD SHINER	*Notropis atherinoides*	2005	2	NA
WHITE CRAPPIE	*Pomoxis annularis*	2000	3	NA
GREEN SUNFISH	*Lepomis cyanellus*	2000	2	NA
YELLOW BULLHEAD	*Ameiurus natalis*	2000	1	NA

*Collected during 2005.

**Collected during 2000.

Fish Diets

We collected a number of black crappies, which testifies to their moderate abundance in Loch Erin. Fish ranged from 4.3 to 11.1 inches; they were almost exclusively eating zooplankton with one eating some chironomids (Table 6). Eating zooplankton is not uncommon among black crappies, but we usually see larger individuals eating fish. Having to eat zooplankton rather than fish may be part of the reason this fish was growing poorly in Loch Erin (see below).

Table 6. Listing of the species collected, length, weight, sex, and diet information for fishes from Loch Erin, Lenawee County, MI 29-31 July 2015. NA = not available, ZOOP = zooplankton, M = male, F= female, 1= poorly developed gonads, 2=moderately developed, 3=well developed, 4=ripe running, and 5=spent. I = immature, MT = empty stomach, CHIR = Chironomidae, MT = empty stomach, xx = unknown fish. See Table 1 for a definition of fish species codes. TN=trap net, GN=gill net, S=seine. R1 and R2 are replicates. See Fig. 5 and Table 1 for station locations.

GEAR/ STATION	Species	Total length INCHES	Weight (ounces)	Sex	Diet
	BLACK CRAPPIE				
TN7	BC	4.3	0.65	II	ZOOPLANKTON
TN7	BC	5.0	1.04	II	ZOOPLANKTON
TN8	BC	5.0	1.18	II	MT
TN7	BC	5.0	1.05	II	ZOOPLANKTON
TN8	BC	5.2	1.10	II	MT
TN7	BC	5.2	1.07	II	ZOOPLANKTON
TN8	BC	5.3	1.13	II	MT

TN8	BC	5.4	1.28	F1	MT
S1	BC	5.4	1.44	F1	ZOOPLANKTON
TN7	BC	6.6	2.23	F1	MT
S1	BC	6.7	2.38	F1	ZOOPLANKTON
TN7	BC	6.7	2.28	F2	MT
S1	BC	6.9	1.38	M1	MT
TN7	BC	7.0	2.53	F2	ZOOPLANKTON
S1	BC	7.0	2.83	F1	ZOOPLANKTON
S2R1,R2	BC	7.2	3.11	CC	MT
S1	BC	7.3	3.14	M1	ZOOPLANKTON
S2R1,R2	BC	7.5	3.19	F1	ZOOPLANKTON
TN7	BC	7.5	3.51	M1	ZOOPLANKTON
TN8	BC	7.6	3.59	F1	MT
TN7	BC	7.6	3.79	M1	ZOOPLANKTON
S1	BC	7.7	3.68	M1	MT
S1	BC	7.7	3.64	M1	CHIRONOMIDS
TN7	BC	7.9	3.47	F1	MT
S1	BC	8.1	3.38	F1	MT
S1	BC	11.1	2.89	F1	ZOOPLANKTON
	BLUEGLL				
S1	BG	1.1	0.01	II	ZOOPLANKTON
S1	BG	1.2	0.02	II	ZOOPLANKTON
S1	BG	1.2	0.02	II	ZOOPLANKTON
S1	BG	1.2	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.3	0.02	II	ZOOPLANKTON
S1	BG	1.4	0.03	II	ZOOPLANKTON
TN7	BG	2.6	0.15	II	CHIRONOMID
S2R1,R2	BG	2.7	0.19	CC	CHIRONOMIDS
TN7	BG	2.8	0.20	II	ZOOPLANKTON
S2R1,R2	BG	2.8	0.21	CC	CHIRONOMIDS
TN7	BG	2.8	0.22	F1	ZOOPLANKTON
S1	BG	3.2	0.35	II	CHIRONOMIDS, AMPHIPODS HYALELLA
S2R1,R2	BG	3.2	0.36	CC	CHIRONOMIDS
S2R1,R2	BG	3.5	0.45	CC	CHIRONOMIDS
S2R1,R2	BG	3.9	0.62	F1	CHIRONOMIDS
S2R1,R2	BG	3.9	0.64	CC	CHIRONOMIDS

S2R1,R2	BG	4.0	0.66	CC	CHIRONOMIDS
S2R1,R2	BG	4.1	0.68	F1	CHIRONOMIDS
S2R1,R2	BG	4.3	0.92	CC	CHIRONOMIDS
TN5	BG	5.0	1.32	CC	MT
S2R1,R2	BG	5.0	1.29	CC	CHIRONOMIDS -MANY
S2R1,R2	BG	5.1	1.56	F1	CHIRONOMIDS
S2R1,R2	BG	5.2	1.55	F1	CHIRONOMIDS
TN5	BG	5.3	1.72	F3	ZOOPLANKTON
TN5	BG	5.4	1.54	F1	MT
TN5	BG	5.5	1.69	M3	ZOOPLANKTON BOSMINA
TN5	BG	5.7	2.20	F3	MT
TN5	BG	5.8	1.98	F4	ZOOPLANKTON
S2R1,R2	BG	5.8	2.16	F2	ZOOPLANKTON
S2R1,R2	BG	5.8	2.35	F2	CHIRONOMIDS
S2R1,R2	BG	5.9	2.21	M2	CHIRONOMIDS
GN3	BG	5.9	2.13	F3	ZOOPLANKTON
TN5	BG	5.9	2.00	M2	ZOOPLANKTON
TN5	BG	5.9	2.00	F3	MT
GN3	BG	6.0	1.77	M2	MT
S2R1,R2	BG	6.1	2.13	M2	MT
TN8	BG	6.2	2.52	M3	MT
S2R1,R2	BG	6.2	3.02	M2	CHIRONOMIDS
TN8	BG	6.3	2.52	M3	ZOOPLANKON
TN8	BG	6.3	2.75	F3	MT
S2R1,R2	BG	6.4	2.35	M2	MT
S2R1,R2	BG	6.4	2.57	F3	CHIRONOMIDS
S2R1,R2	BG	6.5	2.93	M2	ZOOPLANKTON
S2R1,R2	BG	6.5	3.29	M2	ZOOPLANKTON
S2R1,R2	BG	6.5	2.86	F2	CHIRONOMIDS
TN5	BG	6.6	3.19	F1	MT
S2R1,R2	BG	6.6	1.99	F2	CHIRONOMIDS
GN3	BG	7.0	3.33	M2	MT
GN3	BG	7.2	3.35	F3	CHIRONOMIDS
TN5	BG	7.3	2.83	CC	MT
	BLUNTNOSE MINNOW				
S1	BM	0.9	0.00		
S1	BM	1.9	0.04		
S1	BM	2.0	0.06		
S1	BM	2.0	0.05		
S1	BM	2.1	0.05		
S1	BM	2.1	0.05		
S1	BM	2.2	0.05		

S1	BM	2.2	0.05		
S1	BM	2.2	0.06		
S1	BM	2.4	0.08		
S1	BM	2.4	0.07		
S1	BM	2.5	0.10		
S1	BM	2.6	0.11		
S1	BM	2.6	0.11		
S1	BM	2.6	0.11		
S1	BM	2.7	0.11		
S1	BM	2.9	0.16		
S1	BM	3.0	0.16		
	CHANNEL CATFISH				
GN4	CC	15.3	16.16	F1	ALGAE - SPYROGRYA
GN3	CC	17.9	31.53	M1	CRAYFISH
GN4	CC	18.1	26.88	F1	CRAYFISH
S1	CC	18.7	38.03	F1	PLANTS AND CRAYFISH
GN3	CC	22.2	62.79	F5	PLANT MATERIAL
	COMMON CARP				
GN3	CP	21.0	NA		
GN3	CP	25.0	NA		
GN3	CP	32.0	NA		
	GOLDEN SHINER				
S2R1,R2	GL	2.5	0.10		
	LARGEMOUTH BASS				
S1	LB	1.7	0.04	II	MT
S1	LB	2.0	0.05	II	XX FISH
S1	LB	2.0	0.06	II	XX FISH, ZOOPLANKTON
S1	LB	2.0	0.05	II	XM FISH
S1	LB	2.0	0.06	F1	XX FISH
S1	LB	2.2	0.08	II	CHIRONOMIDS
S1	LB	2.3	0.09	II	ZOOPLANKTON:Bosmina
S1	LB	2.3	0.10	II	ZOOPLANKTON:Bosmina
S1	LB	2.3	0.12	II	WATER BOATMAN (CORIXIDAE)
S1	LB	2.3	0.10	F1	XX FISH
S1	LB	2.4	0.10	II	MT
S1	LB	2.4	0.09	II	ZOOPLANKTON:Bosmina
S1	LB	2.4	0.11	II	?INSECT
S1	LB	2.4	0.11	II	ZOOPLANKTON
S1	LB	2.4	0.14		

TN6	LB	2.5	0.10	II	MT
S1	LB	2.7	0.15	II	XX FISH
S1	LB	2.7	0.14	II	ZOOPLANKTON
S1	LB	2.7	0.13		
S1	LB	2.9	0.18	F1	XX FISH
S1	LB	2.9	0.17	F1	ZOOPLANKTON
	PUMPKINSEED				
S2R1,R2	PS	5.0	1.60	F1	CHIRONOMIDS
S2R1,R2	PS	5.1	1.56	F1	CHIRONOMIDS
S2R1,R2	PS	5.2	1.69	F1	CHIRONOMIDS
S2R1,R2	PS	5.6	2.34	M1	SNAILS, CHIRONOMIDS
S2R1,R2	PS	5.8	2.35	M1	SNAILS, CHIRONOMIDS
S2R1,R2	PS	5.9	2.63	M1	CHIRONOMIDS
S2R1,R2	PS	5.9	2.57	M1	CHIRONOMIDS
S2R1,R2	PS	6.0	2.61	F1	SNAILS, CHIRONOMIDS
S2R1,R2	PS	6.1	2.60	M1	SNAILS
	SMALLMOUTH BASS				
S2R1,R2	SB	2.0	0.08	II	CHIRONOMIDS MANY, 1 AMPHIPOD
S2R1,R2	SB	2.1	0.08	II	CHIRONOMIDS
S2R1,R2	SB	2.2	0.09	II	CHIRONOMIDS, ZOOPLANKTON - BOSMINA
S2R1,R2	SB	2.2	0.08	II	CHIRONOMIDS, AMPHIPODS
S2R1,R2	SB	2.3	0.10	II	CHIRONOMIDS
S2R1,R2	SB	2.8	0.17	F1	CHIRONOMIDS, AMPHIPODS
S2R1,R2	SB	6.3	1.87	F1	XX FISH
GN3	SB	10.8	10.26	CC	3 CRAYFISH
	SPOTFIN SHINER				
S1	SF	2.0	0.04		
S1	SF	2.2	0.05		
S1	SF	2.2	0.05		
S2R1,R2	SF	2.4	0.07		
S1	SF	2.4	0.07		
S2R1,R2	SF	2.6	0.08		
S2R1,R2	SF	2.7	0.10		
S2R1,R2	SF	2.9	0.13		
S2R1,R2	SF	3.0	0.16		
S2R1,R2	SF	3.0	0.14		
	WALLEYE				
GN4	WL	16.4	22.86	F1	?YP 102 MM
TN5	WL	28.0	NA		Released

	WHITE SUCKER				
TN7	WS	14.3	17.53	F1	MT
	YELLOW PERCH				
S2R1,R2	YP	2.4	0.08	II	CHIRONOMIDS, OSTRACODS
S2R1,R2	YP	2.6	0.08	II	ZOOPLANKTON -BOSMINA
S1	YP	2.6	0.10	II	CA 6 AMPHIPODS
S2R1,R2	YP	4.6	0.57	CC	CADDISFLIES, CHIRONOMIDS
S2R1,R2	YP	4.9	0.65	CC	CADDISFLIES, AMPHIPODS, CHIRONOMIDS
S2R1,R2	YP	5.3	0.87	F1	CADDISFLIES; SAND GRAINS

The diet of bluegills was almost exclusively zooplankton and insects (Table 6). Fish caught ranged in size from 1.1 to 7.3 inches. The smaller <2-inch group ate only zooplankton, which is typical of this group. As fish got bigger, they added chironomids (fly larvae), and amphipods to their diet, but still fed on considerable amounts of zooplankton. Interestingly, *Bosmina* was one of the zooplankters we identified in stomachs and they were common (composed 30%) in our zooplankton collection in Loch Erin. Somewhat bigger fish (>6 in) fed more on chironomids with some zooplankton in their diet. Since fish do have food in their stomachs and appear to be growing well, they seem to be adapting to the turbid conditions in Loch Erin, but we should have seen more fish > 7 inches, a finding also echoed by Leopold (2005) during his study (see Appendix 2).

We collected many bluntnose minnows in the lake that ranged from 0.9 to 3 inches (Table 6). Bluntnose minnows provide forage for top predators and eat detritus and algae that most other fishes do not. They also contribute to the biodiversity in Loch Erin.

We collected a large number of channel catfish in the lake in our seines, gill nets, and trap nets. The few we saved ranged from 15.3 to 22.2 inches and were eating crayfish, algae, and some other plant material (Table 6). They are probably the most abundant top predator in the lake based on our catches and they are probably a lot more piscivorous than our data show. They do well under turbid conditions and were a good choice for stocking into Loch Erin to help control prey fish populations. Since we did not catch any smaller individuals, it appears they are not reproducing well. We suggest some thought go into providing spawning habitat for this species in the lake. This could take the form of pvc tubes of at least 8 inches blocked on one end or small concrete tiles (at least 8 inches in diameter).

Unfortunately, there are large numbers of common carp in Loch Erin, which probably enter from small streams connected to adjacent lakes. We captured large numbers of them in our gill nets and a few in seines. The ones we saved ranged from 21 to 32 inches and this was the common size of the ones we encountered. They are a detriment to the lake, since they can increase turbidity, feed on fish food resources that other native species could eat, and they eat eggs of other species as well. They should be removed whenever caught and any efforts to increase their mortality, such as bow fishing contests, should be encouraged.

We collected one golden shiner while seining. This species was stocked previously and we highly encourage their stocking since they are an ideal forage species, they usually flourish, do well in turbid environments, and grow to large sizes, thus providing forage for the larger top predators in the lake. The fish we caught was small (2.5 in) and since we only got one, they seem to be scarce in the lake, which is unfortunate.

Largemouth bass YOY appear to be quite common in the lake, but we caught no other specimens larger than 2.9 inches (Table 6), which is very unusual. We collected fish ranging from 1.7 to 2.9 inches which were eating a wide variety of prey, including zooplankton, unknown fish, chironomids, and other insects. As we found with other fishes, the zooplankton these YOY were eating were *Bosmina*. It is interesting that even at this small size largemouth bass are already piscivorous, probably eating some of the minnows we observed in the lake. As we discussed, we always have difficulty catching larger individuals, since they do not appear in trap nets and are not collected by gill nets very well either. Never-the-less we usually collect some larger fish, so this suggest they are scarce in the lake. Obviously there are some adults present, since they produced a good year class of young fish and Leopold (2005) reported finding some large adults during their studies. We concluded that the bigger bass are uncommon probably because turbid water and the dearth of macrophytes have had an adverse effect on feeding. There seems to be good spawning substrate (gravel and sand) both for bluegills and largemouth/smallmouth bass, which build and guard nests during spring-early summer.

Pumpkinseeds are known to eat snails and mussels and those in Loch Erin also consumed members of this group. Pumpkinseeds are often stocked along with redear sunfish to control snails which are intermediate hosts for swimmers itch syndrome which can affect swimmers. We only caught large individuals which ranged in length from 5 to 6.1 inches (Table 6); no YOY were captured, which is unusual for a species that appears to be common in the lake. These fish were feeding on only two prey items: snails and chironomids. Hence snails that are usually underutilized in lake ecosystems are being eaten by pumpkinseeds and funnel energy to the upper food web, including humans. We noted the lack of YOY in our samples and have no explanation for why there was such poor survival and why there were none collected. Some were collected by Leopold (2005).

We also collected smallmouth bass, which apparently were stocked. Fish collected ranged from 2 to 10.8 inches (Table 6). We captured a few YOY indicating that there was successful reproduction, which we also found for largemouth bass as well. The YOY 2-2.8 in were eating zooplankton (*Bosmina*), chironomids, and amphipods (fairy shrimp). The 6.3-inch smallmouth was eating unknown fish, while the largest one (10.8 in) had eaten three crayfish. The fact these fish are non-native and reproducing well, suggests no stocking of this species is required.

Spotfin shiners are pretty minnows with a spot on their dorsal fins and they were moderately common in our seine hauls in the lake (Table 6). They ranged from 2 to 3 inches and are usually feeders on insects, detritus, and other organic matter. Again they are an important component of the prey fish available to small and large top predators in the lake.

Walleye is another top predator and some have been stocked into Loch Erin. We collected two walleyes that ranged in length from 16.4 to 28.0 inches (Table 6). The big one was released, while the smaller one had eaten a 4-in yellow perch, which is one of their preferred species to eat. Walleyes are known predators on bottom-dwelling fishes, especially yellow perch, and with their specialized eyes do most of their feeding at night or under low-light conditions. They appear to be uncommon in the lake. Despite strident conditions during summer, some obviously survived the summer, despite the considerable stresses experienced during summer stratification (see fish squeeze - Fig. 7: low dissolved oxygen in required cool bottom waters, while too warm temperatures in oxygenated surface waters). Walleye are also cool-water species like northern pike and probably grow poorly and suffer stress during the warmer periods of the year. However, the two we aged appeared to be growing well, probably by doing most of their growth during the cooler parts of the year (see below).

One white sucker (14.3 in) was collected in our trap net (Table 6) showing that this species is in the lake and probably spawns in the tributaries during spring. No YOY were observed so reproduction does not seem to have been too successful.

Yellow perch is one of the most sought-after fishes by fishers and we did catch some during our sampling. Fish ranged from 2.4 to 5.3 inches; there were no large individuals captured, which if they were present in any abundance, would have shown up in our gill nets (Table 6). YOY perch were eating chironomids, ostracods, zooplankton (*Bosmina*), and amphipods, which is great diversity in prey items eaten. The 4-in fish were eating caddisflies, chironomids, and amphipods, while the largest individual (5.3 in) was eating caddisflies. We concluded that yellow perch are uncommon in the lake, but that reproduction was successful.

The panfish community in Loch Erin is comprised of bluegills, pumpkinseeds, black crappies, and largemouth and smallmouth bass, all members of the sunfish (Centrarchidae family). This complex is the backbone of any warm-water lake fish community and is usually self-sustaining, since the largemouth bass have adequate spawning substrate (gravel and sandy shores) and can usually control the panfish and prevent stunting. It appears that a considerable amount of your prey resources is being efficiently converted into fishable biomass.

We also collected three species of cyprinids (minnow family) in our nets. These included the following species: spotfin shiner, golden shiner, and the bluntnose minnow. Minnow species are an excellent addition to the fish fauna, since they utilize resources that none of the other fish consume (algae and detritus and probably some insects) and they add an important forage fish for top predators, such as yellow perch, channel catfish, and largemouth/smallmouth bass. These species contribute to the species diversity we noted in the fish community, which is important for maintaining stability under the different stressors of the environment and varying population swings of the predators in the lake. The analogy to a diverse stock portfolio is apt here. Drawbacks for the fishes include a turbid lake environment, which suggests more effort be made to encourage macrophyte populations in the lake. We recognize the desire to have a clear path from ones dock for the boat, but we stress that plants should be spot treated in affected areas with plants (and algae) removed mechanically where possible to provide paths or clear beaches, so as to leave more habitat for fish, especially small ones that require them for shelter, survival, and food.

Mercury in fish

Just a note about mercury. It is a problem in most of Michigan's inland lakes. Most mercury comes to the watersheds of lakes through deposition from the air with most coming from power plants burning coal. The elemental mercury is converted to methyl mercury through bacterial action or in the guts of invertebrates and animals that ingest it. It becomes rapidly bioaccumulated in the food chain, especially in top predators. The older fishes, those that are less fatty, or those high on the food chain will carry the highest levels. Studies we have done in Michigan lakes and studies by the MDNR have shown that large bluegills, largemouth bass, black crappies, northern pike, and walleyes all contain high levels of mercury. This suggests that fishers should consult the Michigan fishing guide for recommendations on consumption, limit their consumption of large individuals, and try to eat the smaller ones. It also suggests that a trophy fishery (catch and release) be established for largemouth/smallmouth bass and walleyes (which is probably generally followed anyway – this is more incentive), and some of the larger individual bluegills, pumpkinseed, and yellow perch in the lake.

Fish Growth

Growth of the fishes we collected was determined by ageing a sample of fish of various sizes using multiple scales under a microscope and comparing the age of fish from Loch Erin with Michigan DNR standards (Latta 1958, Laaarman 1963). Bluegills are common in Loch Erin and those we aged (n=43) were growing at or slightly below state mean lengths. (Table 7, Fig. 8). The fish we aged ranged from 1 to 7.3 inches, so there is a good size range of fish present, although we should have seen a few larger individuals. This suggests a well balanced population in control by the large numbers of predators in the lake.

Table 7. Growth of selected fishes collected from the Loch Erin, Lenawee Co., 29-31 July 2015. Fishes were collected in seines, gill nets, and trap nets, scales removed, aged, and total lengths at various ages compared with Michigan state mean lengths for various fishes at those same ages (see Latta 1958; Laarman 1963). Shown is the age (years) of the fish, its total length (inches) based on MDNR state of Michigan mean lengths, and the mean length-at-age of Loch Erin fishes along with sample size in parentheses. Total no. fish aged given at top as n. See Figs. 8-14 for graphical display of these same data.

	Age (yr)	MDNR Len (in)	Loch Erin Len (in)
BLUEGILL			n=43
	0	2.1	1.6(16)
	1	2.9	3.3(4)
	2	4.3	4.2(2)
	3	5.5	5.2(5)
	4	6.5	6.1(11)
	5	7.3	6.9(5)
	6	7.8	
	7	8	
	8	8.5	
	9	8.5	
	10	9.2	
LARGEMOUTH BASS			n=20
	0	3.3	2.3(20)
	1	6.1	
	2	8.7	
	3	10	

4	12.1	
5	13.7	
6	15.1	
7	16.1	
8	17.7	
9	18.8	
10	19.8	
11	20.8	
PUMPKINSEED		n=9
0	2	
1	2.9	
2	4.1	
3	4.9	5.4(6)
4	5.7	6(3)
5	6.2	
6	6.8	
7	7.3	
8	7.8	
YELLOW PERCH		n=6
0	3.3	2.5(3)
1	4	4.8(2)
2	5.7	5.3(1)
3	6.8	
4	7.8	
5	8.7	
6	9.7	
7	10.5	
8	11.3	
9	11.7	
BLACK CRAPPIE		n=27
0	3.6	
1	5.1	4.3(1)
2	5.9	5.2(8)
3	8	6.4(4)
4	9	7.4(13)
5	9.9	
6	10.7	
7	11.3	11.1(1)
8	11.6	

WALLEYE

0	6.6	
1	9.1	
2	12	
3	15.9	
4	17.8	16.4(1)
5	18.9	
6	18.8	
7	18.8	
8	21.4	
9	19.7	
10	22.6	28(1)

SMALLMOUTH BASS

		n=8
0	3.3	2.3(6)
1	5.9	6.3(1)
2	9	
3	11.2	10.8(1)
4	13.3	
5	15	
6	15.3	
7	16.4	
8	16.8	

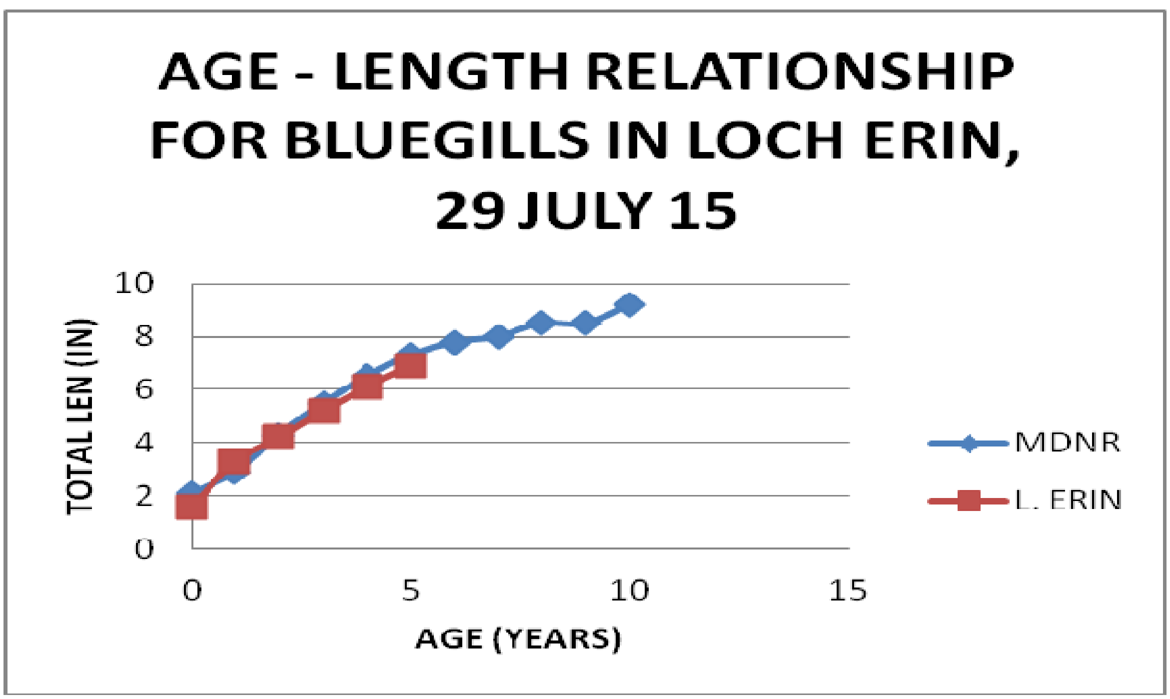

Figure 8. Growth of bluegill in Loch Erin (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 29 July 2015. See Table 7 for raw data. N=43.

We only caught YOY largemouth bass in Loch Erin. Fish collected ranged from 1.7 to 2.9 inches and the age-length relationship for Loch Erin bass (Fig. 9) based on ageing 20 fish was mostly similar to the growth rates of Michigan DNR's YOY fish. This species is one of the important predators in your lake and responsible for keeping the bluegills in check, so the big fish should be left in the lake to the degree possible (catch and release unless hooking leads to death). The other reason, as noted elsewhere, is that large individuals are probably contaminated with mercury and should not be eaten anyway. We concluded the following: first, the YOY are generally growing at state averages, and second, based on our findings of large numbers of young-of-the-year fish caught (personal observations in seine hauls; Table 6), we think that largemouth bass are reproducing adequately in the lake. We explored the near shore zone in the lake, and there definitely was considerable gravel/sand bottom along shore that is good spawning substrate for sunfish family members, including largemouth bass. This finding also has implications for fish management recommendations. There must be larger fish in the lake, since they spawned during 2015 and some large individuals were collected in 2005 (Leopold 2005). It appears they are scarce however, which could be due to the poor visibility they have in this turbid lake.

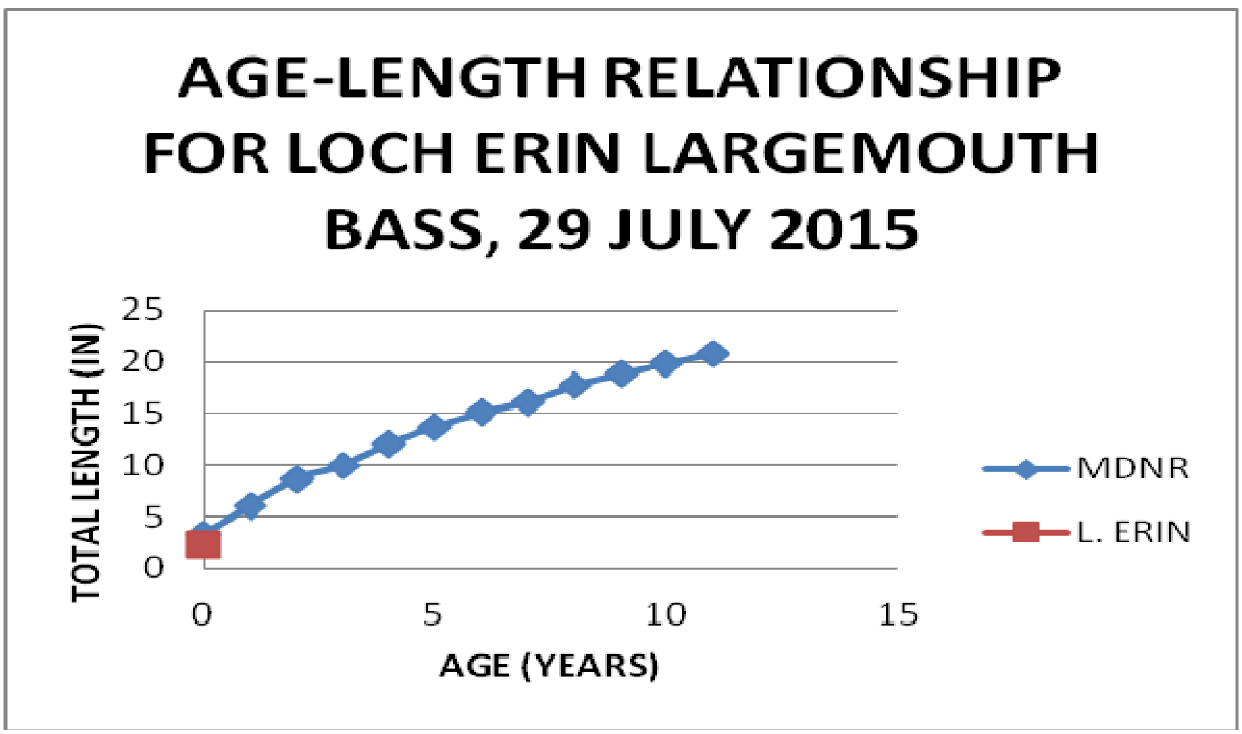

Figure 9. Growth of largemouth bass in Loch Erin (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 29 July 2015. See Table 7 for raw data. N=20.

Yellow perch populations seem to also be scarce and limited in size in the lake, since we only collected six specimens from 2.4 to 5.3 inches long (Table 6) and they were 1 to 3 yr old fish (Fig. 10). They were growing at state means. Yellow perch are important prey fish that are usually not too susceptible to bass predation, however they are preferred prey of walleyes (one walleye we caught ate a 4-in perch) and would be sitting prey at night for channel catfish. Hence, we believe predation is severe on yellow perch and would like to have seen more of them in the lake. It appears this condition also existed during the 2005 study, since only fish 4-7 in were collected. Leopold (2005) recommended a minimum size limit of 8 in for yellow perch which is a good idea to allow more individuals to grow big enough to reproduce to enhance the current reproductive output by this species.

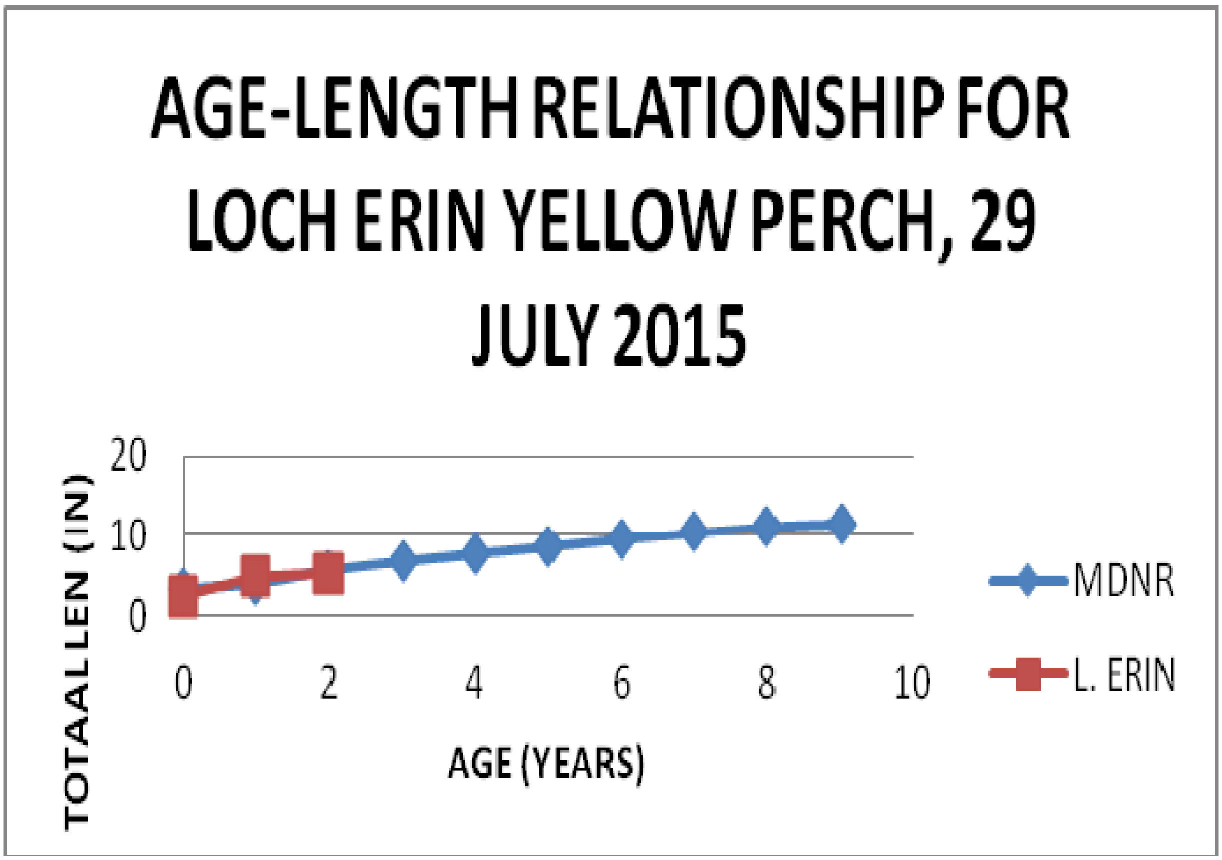

Figure 10. Growth of yellow perch in Loch Erin (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 29 July 2015. See Table 7 for raw data. N=6.

Black crappies we collected (4.3-11.1 in) were growing below state averages for ages 1 to 4 but at averages for the 7-yr old fish (Fig. 11). Black crappies appear to be common in the lake, but are growing slowly. This can be partially explained by diet, which was mostly zooplankton; large crappies need to switch over to fish, which was apparently not the case during our July sampling bout. We also did not see any YOY, which is odd, since the other species that spawn in nests, bluegills, produced a considerable number of offspring. The same problem existed with pumpkinseeds, which also showed a lack of YOY fish in our collections. Leopold (2005) caught a few YOY pumpkinseeds and attributed the declining population of black crappies to channel catfish predation, which were stocked during the 1990s.

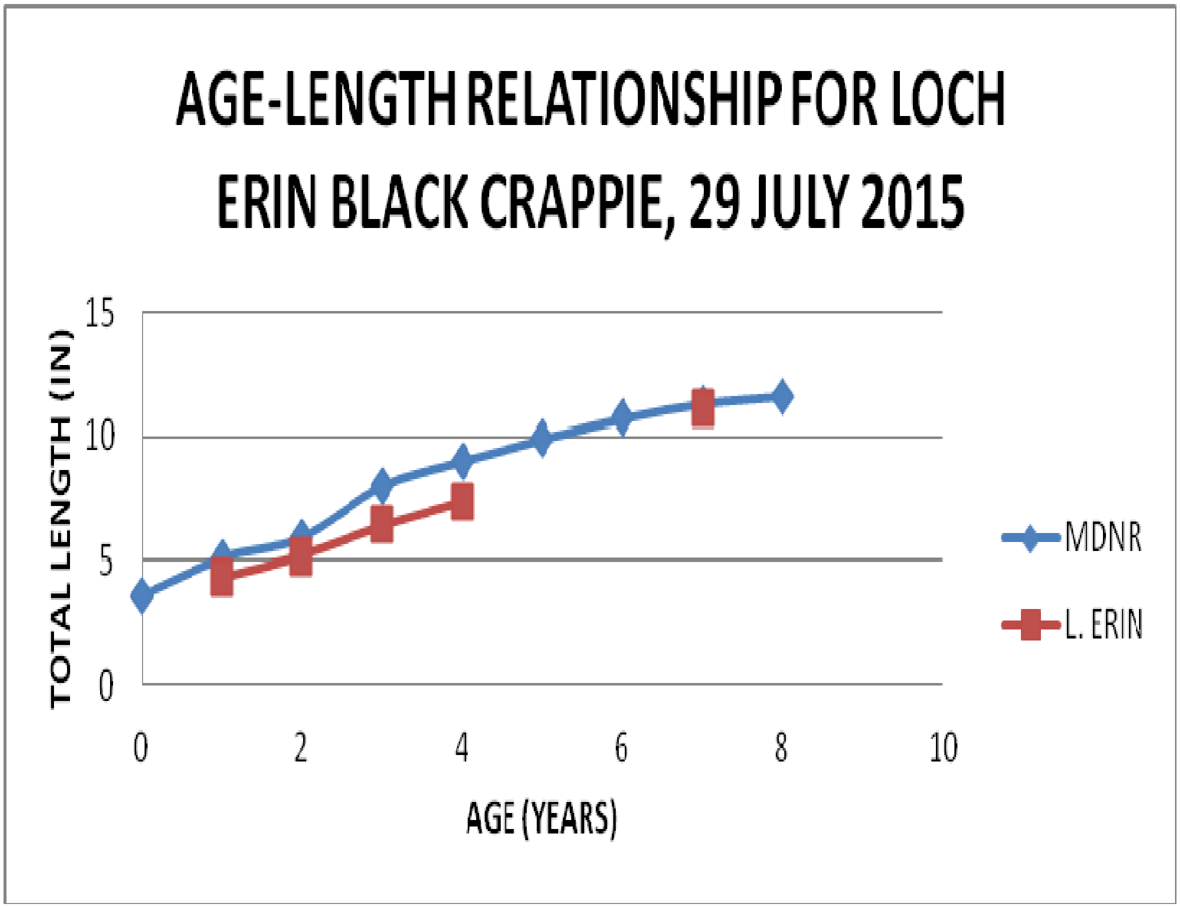

Figure 11. Growth of black crappies in Loch Erin (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 29 July 2015. See Table 7 for raw data.   n=27.

Pumpkinseeds presented an interesting case, since we only were able to collect large specimens (range: 5-6.1 in, n=9). Growth of this species for the 3- to 4-yr old age group was comparable to state averages. As noted this species is a known molluskivore and therefore feeds on a food supply that is not usually consumed by other sunfish species. The lack of smaller fish collected is an intriguing unanswered question, especially since they were collected during 2005.

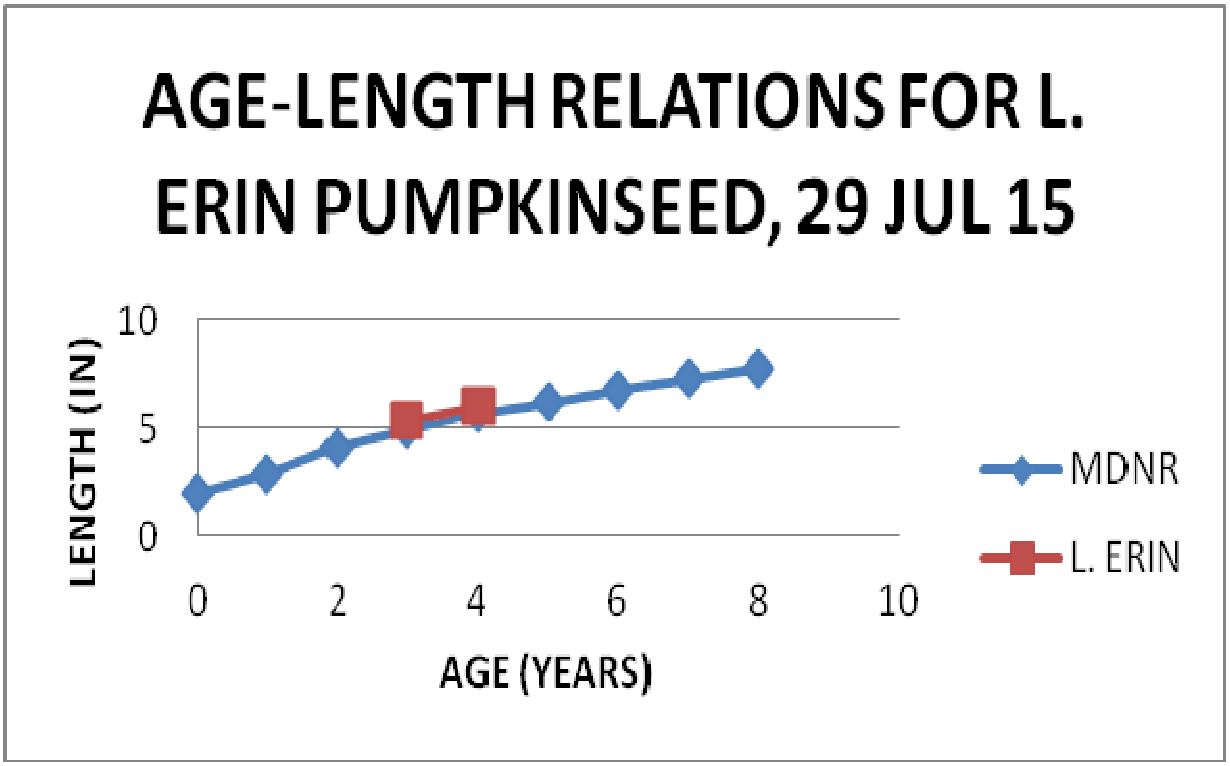

Figure 12. Growth of pumpkinseeds in Loch Erin (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958), 29 July 2015. See Table 7 for raw data. N=9.

Some walleyes have been stocked into Loch Erin in the past since we collected two specimens, one which was 10-yr old. Leopold (2005) also collected two that were 12.9-23.1 in. Stocking walleyes into an established fish community that has evolved as a warm water fish ecosystem is controversial we believe. They do provide another top predator and are a popular fish with fishers, even though they are notoriously difficult to catch. We believe stocking walleyes is an activity that runs contrary to fish management principles for three reasons: first, walleyes are not native to this lake and are not expected to reproduce, and will consume prey that other native species would eat (including perch). Second, stocking is only acceptable under a number of conditions that must be clearly documented. This includes a situation where the species is native and some catastrophe reduces numbers to very low levels and stocking can assist recovery of the species. In some cases we have seen stunted bluegill populations reduce the number of largemouth bass surviving by eating eggs and larvae from nests, justifying stocking more predators. Winterkill can also eliminate susceptible species and re stocking may be the only alternative to restore populations. Third, Loch Erin is a classic example of a lake which puts the squeeze (see Fig. 7) on cool water species, such as walleye and also northern pike if present. These species require cool water with high dissolved oxygen. These conditions are met in Loch Erin during fall, winter, and early spring. However, during summer stratification, water warms in surface waters to unacceptable levels, while the cool water required for survival is devoid of or has low dissolved oxygen concentrations. During this time, cool water species are stressed, some probably die, and growth is restricted until other times of the year. Interestingly, growth of the walleyes we aged (range: 16.4-28 in) was below and above state averages (Table 7, Fig. 13). Hence, the argument that they are stressed is weak. Never-the-less, we recommend against stocking walleyes, but recognize that they do survive and provide a small fishery for Loch Erin fishers. Therefore we could accept some low numbers of stocked fish provided decision makers realize 1.) these fish are not well adapted to conditions in eutrophic lakes and 2.) there is a strong desire on the part of sport fishers to have some in the lake.

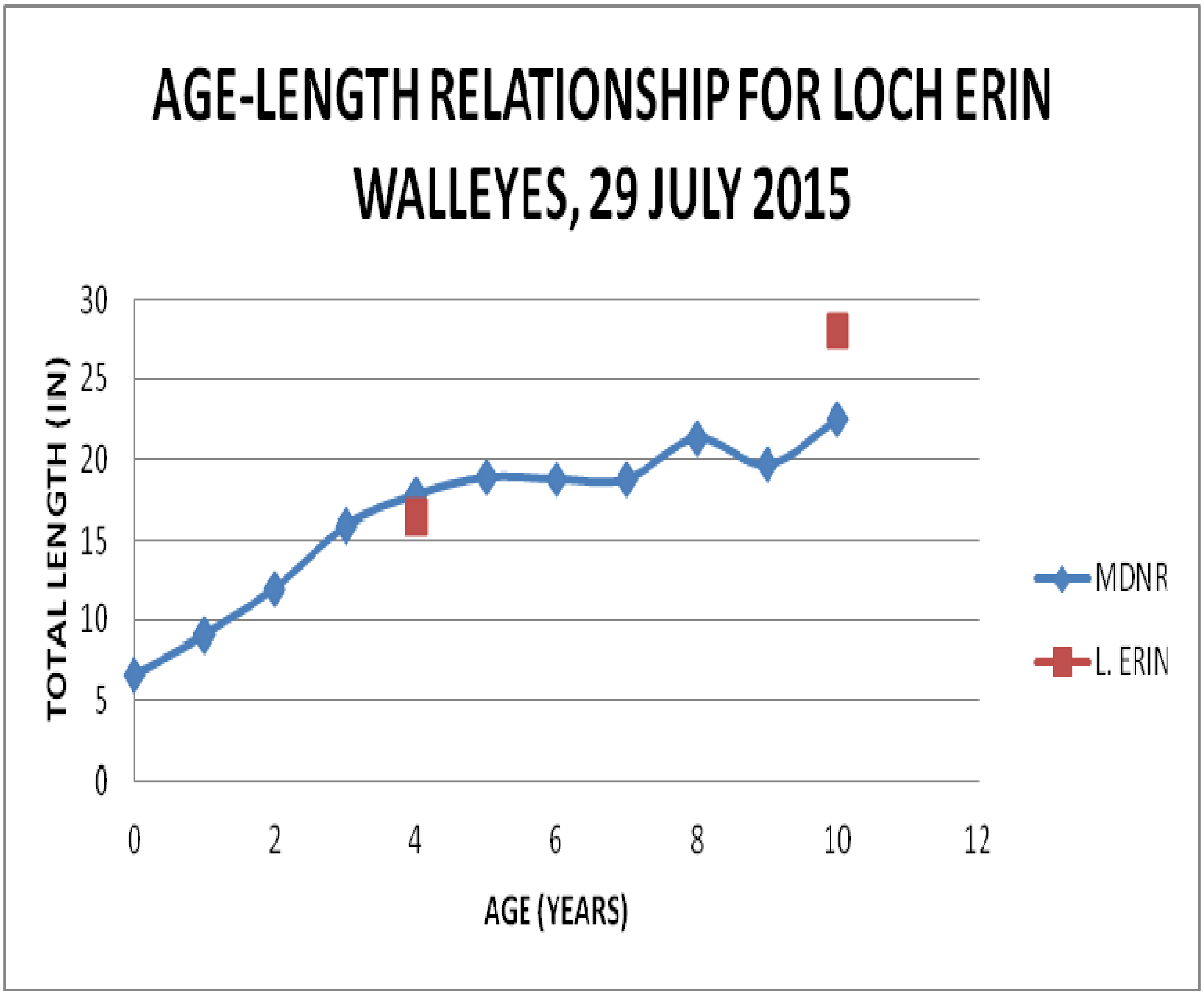

Figure 13. Growth of walleyes in Loch Erin (red squares) compared with Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 29 July 2015. See Table 7 for raw data. N=2.

Smallmouth bass were also probably stocked into Loch Erin, but they have survived and reproduced to a small degree. They appear to be rare in Loch Erin. We collected eight specimens that ranged from 2 to 10.8 inches (Table 7, Fig. 14). Fish were growing at state averages up to 3 yr old and there were many YOY indicating good reproduction. As noted, both species of bass are difficult to catch with the gear we deployed, so there may be more, especially large adults, in the lake than indicated by our data. Certainly Leopold (2005) was able to collect two large adults.

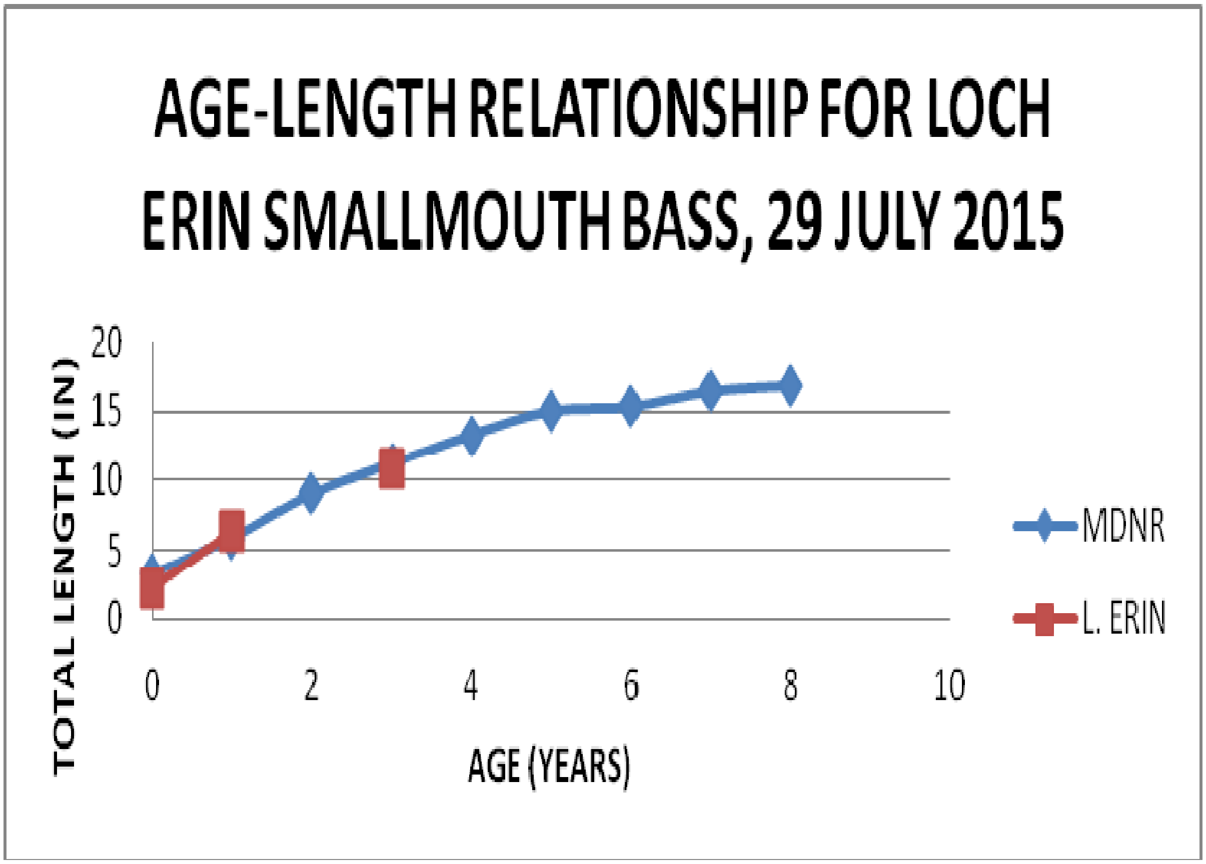

Figure 14. Growth of smallmouth bass in Loch Erin (red squares) compared with the Michigan state averages (blue diamonds) (see Latta 1958, Laarman 1963), 29 July 2015. See Table 7 for raw data. N=8.

Fish management Recommendations

There are two overarching concerns we have for Loch Erin that bear directly on fish management recommendations. All water bodies have an innate carrying capacity and increasing that carrying capacity involves activities such as fertilization, increasing valuable macrophyte fish habitat (and hence fish-food organisms), or perhaps stocking a native species that could utilize more fully an underutilized food resource such as mollusks (pumpkinseed currently fulfill this niche in Loch Erin). Our other possibilities usually involve shifting of resources and fish species within this food web complex, for example by stocking walleyes, which will consume prey items that native species, like largemouth bass would eat. There are other techniques, such as creation of artificial structure (brush piles) that do nothing to increase productivity, but are just fish attractors that concentrate fish so they are easier to catch. This was encouraged by Leopold (2005) for Loch Erin. There may be some algal growth on these structures that would foster aquatic insect production and hence lead to some increases in fish production.

Considering this background, our first concern is the overall productivity of Loch Erin. Based on our 2015 water clarity which was very low, the dissolved oxygen profile (detrimental to cool water fish in summer), and nutrient data, Loch Erin is a eutrophic lake which develops hypoxia (low dissolved oxygen) on the bottom during summer stratification. Loch Erin may be limited in productivity by the high turbidity in the lake which can degrade basic productivity for the lake leading to lower fish communities compared to lakes with higher water clarity. Encouraging more macrophyte growth in isolated bays and decreased boat traffic would help increase water clarity. Second, we wish to foster as many native macrophytes as possible to supplement fish habitat, which would benefit the entire Loch Erin ecosystem, especially the fish. This not to ignore the needs of boaters and those with beaches nor the primary goal of controlling invasive plants like Eurasian milfoil and blue-green algal blooms. We are also concerned about copper treatments of algae and hope there are more healthy alternatives to copper which can also kill lots of snails and other mollusks, important fish food for fish such as pumpkinseeds. Simply put, try to balance the needs of the recreationalists with those of the fish resource.

Fish management strategies emanating from these data include the following. First, regarding largemouth bass and smallmouth bass, we believe they are reproducing, probably not as well as we would like, but adequate and that there are probably many larger ones in the lake that we were unable to collect. Our recommendation is to not stock any at this time and promote more macrophytes which favor this species. Leopold (2005) found many and larger bass of both species during their 2005 study which may be related to their sampling among macrophytes and different gear. Interestingly, he found almost a complete lack of young bass, 2-7 in, which is the opposite of what we found; an abundance of YOY and no adult largemouth.

Second, we recommend catch and release of the bigger largemouth bass, smallmouth bass, and walleyes, say those > 15 inches, so they can control prey fish populations, especially bluegills. Leopold (2005) noted that the sunfish/panfish population was stunted and the maximum size of bluegills he found was similar to our data. A catch-and-release policy is also supported by the fact that larger individuals of many sport fishes in many Michigan inland lakes are contaminated with mercury, limiting their consumption to small fish or long intervals between meals (see M*ercury in Fish* for a discussion).

Third, as we pointed out, stocked walleyes are stressed in Loch Erin during summer stratification by too warm water at the surface and no dissolved oxygen on the bottom where cooler waters reside (see the Fish Squeeze – Fig. 7). This usually results in poor growth during summer and probably some fish die as a result. In addition, as pointed out, stocking walleyes into Loch Erin violates at least four principles of fishery science: 1. The fish is not native and most likely will not spawn, 2. The existing fish community is a co – evolved, warm-water fish community and should not be de-stabilized by introduction of another keystone predator, 3. Water quality conditions, warm surface water and no dissolved oxygen in cool bottom waters, are not conducive nor optimal for a cool water fish, 4. You are playing ecological roulette with stocking, since you could introduce diseases (VHS see below), parasites, or non-indigenous species through stocking of fish, especially if done by non-professionals. We therefore recommend against stocking any more walleyes into Loch Erin and suggest if fishers want walleyes (they are difficult to catch anyway) they go to Saginaw Bay or Lake Erie where a world-class fishery exists. Despite these concerns, it is obvious that some stocked walleyes did survive and actually grew above Michigan state averages in Loch Erin. Not knowing how many survived, we have no indication of what the morality rate was. If a majority of fishers still want to stock walleyes, despite all these warnings, they should be obtained from a reputable source, few and large individuals should be stocked, and obviously they should be stocked during the cooler periods of the year, spring or fall.

Fourth, there was good spawning by sunfish family members (especially largemouth bass, but apparently not pumpkinseeds) and yellow perch. Hence, because of the favorable substrate (sand and gravel) for sunfish/bass spawning, there is no need for stocking any of these species.

Fifth, channel catfish are probably the most abundant predator in the lake and a welcome addition. However, we caught no YOY as was found by Leopold (2005). Hence we recommend that some spawning structures be considered for the lake. These could take the form of culverts, PVC pipes, wooden boxes with one large hole in the side, etc. The opening needs to be large enough (i.e., 10-12 inch) to allow two large catfish inside and blocked on one end to prevent other fish from eating eggs/larvae.

Sixth, we support the recommendation by the previous survey personnel to stock golden shiners in the lake because they provide good forage for many of the top predators and smaller predators as well.

Seventh, common carp should be reduced by any means necessary, including killing them when caught and promoting bow fishing for these destructive fish. Leopold (2005) noted this species had increased from levels measured in 2000 and we saw and caught many in our gear.

Eighth, live bait use (minnows, crayfish) should be discouraged or banned because of the threat of introduction of exotic species (e.g., goldfish) and VHS (viral hemorrhagic septicemia) which killed many muskies and other species in many lakes, including Lake St. Clair. As noted above, any stocking should be done with a guarantee from the stocker that the fish are VHS-free. Any stocking by individuals should be banned for this very reason: introduction of fish from other water bodies or launching of contaminated boats may bring in parasites and diseases or non – indigenous species (e.g., quagga mussels), including VHS, that could have a devastating effect on the fish community of Loch Erin.

DISCUSSION AND RECOMMENDATIONS

To summarize, Loch Erin is eutrophic lake with a maximum depth of around 12 ft, making the entire lake littoral zone. Such a lake has positive features and drawbacks. Because it is so shallow, it will be very productive and should produce an abundance of fish. Unfortunately, that same shallowness and the fertile soil on which the reservoir was placed, have resulted in low water clarity, a dearth of macrophytes, and blue-green algal blooms in late summer. Nutrient concentrations on the bottom during July were modest but there was some buildup, suggesting considerable N and P may be regenerated from the bottom muds during quiescent periods in summer. The deep areas during summer stratification generate an area of low dissolved oxygen near bottom which is a stressful environment for the cool water fish, the walleye. Interestingly, chlorides, an indicator of septic tank leakage and road salt runoff was fairly low, a good sign. Riparians also contribute to the lakes enrichment through lawn fertilization runoff of nutrient-rich water from their property. To reduce the footprint of residents, no lawn fertilization should be done, but if necessary only nitrogen-based fertilizer should be used. See Appendix 1 for other suggestions to reduce nutrient input. The littoral zone has been reported to have extensive beds of macrophytes (curly-leaf and Sago pondweed and water lilies), but we only saw water lilies with very little other plant growth. We have argued that more macrophyte growth should be fostered to improve fish community habitats. The bottom has extensive areas of sand and gravel near shore which we think has lead to moderate reproduction by members of the sunfish family. Our zooplankton (small invertebrates in the water column) sample showed that a large species, *Daphnia,* composed only 5% of the zooplankton present in the sample. This indicates that there is probably considerable predation on the zooplankton (many fish especially black crappies were eating zooplankton), since lakes with an abundance of planktivores, such as small bluegills and in this case black crappies, usually consume most of the *Daphnia* present, leaving only smaller species. The high turbidity and prevalence of blue-green algae may also reduce the abundance of zooplankton. The other cladoceran *Bosmina*, was much more abundant (30% of total) and consumed by many fish species as well.

We collected 13 species of fishes and another six were caught during 2000 and 2005 (but not during 2015) including: redear sunfish (probably stocked), brook silversides, emerald shiner, white crappie, green sunfish, and yellow bullhead. It is interesting that we did not catch any emerald shiners or yellow bullheads during our sampling, since they were suspected of being abundant in the lake. In all that would be 19 different fish species recorded in the lake. This is good biodiversity. Members of the sunfish family (Centrachidae) dominated the species collected. Top predators included largemouth and smallmouth bass along with contributions from channel catfish and walleyes, which were stocked into the lake. Channel catfish appeared from our sampling to be the dominant predator in the lake. Other species that act as predators include: large yellow perch and black crappies (however none we caught were eating fish). Loch Erin also had white suckers, bluntnose minnows, and spotfin shiners. Unfortunately, common carp are also present in large numbers and should be reduced by any means possible. Diets of fishes reflected the species, life stage, and feeding strategy of the fish. Small fishes were feeding on zooplankton and benthos, while the large specimens of predaceous fishes were feeding on fishes and sometimes crayfishes. Black crappies were mostly eating zooplankton, which apparently has led to poor growth. Predators ate yellow perch and a number of others we could not identify (probably minnows). Growth of the fishes we examined generally was at MDNR state averages for a given age, with the exception of black crappies, which were growing slower than state averages.

From the data we collected we made the following fish management recommendations.

1. Do not stock any largemouth or smallmouth bass; promote more macrophytes.
2. Catch and release of the bigger largemouth bass, smallmouth bass, and walleyes
3. Do not stock any walleyes unless fishers demand them and they are aware of the consequences of doing so
4. There is favorable spawning substrate for members of the sunfish family; do not stock
5. Promote reproduction of channel catfish by placing spawning structures in the lake
6. Golden shiners are excellent forage; stock some to promote increased abundance
7. Common carp should be reduced by any legal means necessary
8. Consider banning bait from outside the lake; alert residents to clean boats coming in from outside the lake of clinging vegetation and ballast water (chlorinate) that might contain veligers of zebra or quagga mussels

SUMMARY OF RECOMMENDATIONS

Recommendations are summarized more concisely below:

1. Largemouth and Smallmouth Bass

We recommend catch and release for all bass and walleyes > 15 inches (and other large top predators), unless fish are foul hooked and would die. They help control stunting in sunfish populations. Some thinning of the abundant channel catfish population may increase survival of larger individuals.

2. Centrachridae

The panfish populations (bass, pumpkinseeds, bluegill, and black crappie) appear to be spawning moderately well, so none need be stocked. Promote more macrophytes to increase habitat for these species.

3. Largemouth Bass and Smallmouth Bass

Both bass species are reproducing; hence no stocking of these species is recommended.

4. Walleye

Walleye have been stocked into Loch Erin. Some have survived, providing a small fishery. We oppose further stocking, because they are not native, they are difficult to catch, they will not spawn, stocking may introduce diseases, and most importantly, they will be severely stressed during summer stratification. However, they appear to be growing well and certainly some have survived. We would not oppose stocking some walleyes provided managers are aware of drawbacks and there is demand for these fishes.

5. Prevent Exotic Species from Entering Loch Erin

Prevent exotic species, besides Eurasian milfoil, which has already been introduced, from entering the lake. Consider banning bait from outside the lake to avoid the introduction of more exotic species, such as quagga mussels and VHS. Fishers and skiers need to dry out boats and gear that come from other lakes that might be contaminated with exotic species, such as quagga mussels, which have recently been found in the first inland lake in Michigan.

6. Promote spawning by channel catfish

We suggest you introduce artificial spawning structures into the lake to increase survival of young catfish. These can take the form of small culverts, 5-gal pails, wooden boxes, or PVC pipes with a diameter of at least 10-12 inches.

7. Golden Shiners

Golden shiners were stocked in the past and are excellent forage fish. We recommend some be stocked to encourage population increases in Loch Erin.

8. Common Carp

Common carp are detrimental to the lake; they need to be removed by any means possible.

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

Condition Documented	Qualitative assessment	Problem Potential	Action to Take
Physical			
Water Clarity	-	Low water clarity	Reduce nutrients
Water Depth	-	Sediment buildup	Reduce nutrients, no wakes
Water Temp.	-	Warms up in summer	No walleye stockin
Sediments	-	Sandy, organic	No wakes, drawdown?
Chemical			
pH	0	None	None
Dissolved oxygen	-	Reduced DO on bottom	Monitor, reduce nutrients
Chlorides	+	Low	None
Nitrates	0	Monitor	See Guidelines; reduce N&P
Ammonia	0	Monitor	See Guidelines; reduce P
SRPhosphorus/TP	0	Monitor	See Guidelines; reduce P
Hydrogen sulfide	+	Not present in July	Monitor

Biological

Macrophytes	-	Eurasian milfoil	save more plants
Zooplankton	-	*Daphnia* present; low	Reduce planktivores
Benthos	+	*NA*	NA
Fish			
Largemouth bass	-	Plenty YOY; few big adults	C @ R
Smallmouth bass		Not very abundant; YOY present	C@R
Bluegill	0	Adequate	Maintain predator balance
Yellow perch	0	YOY seen;growing well	Monitor top predators
Minnows	+	Common; good diversity	Monitor
Northern pike	0	Rare to none	C @ R
Walleye	-/0	Stocked	Stock if desired; not recommended
Pumpkinseed	+/-	Adults growing well; no YOY	Monitor
Black crappies	+/-	Abundant; growing poorly	Improve water clarity

ACKNOWLEDGEMENTS

I want to thank Terry Michaels who was our on-lake guardian and who tried to provide us with a pontoon boat for sampling; we appreciate his help. We also want to thank the neighbor next door to the access site; she fed us and provided us with information on the lake. I appreciate the support and information provided by Christian Malcom. I thank my assistant James Hart for his enthusiastic help with the study. Jason Jude provided help with some of the figures.

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Leopold, W. 2005. Fisheries survey of Loch Erin. Jones Fish Hatcheries, 3433 Church St., Newtown, Ohio. 7 pp. (see Appendix 2).

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APPENDIX 1

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

1. DROP THE USE OF "HIGH PHOSPHATE' DETERGENTS. Use low phosphate detergents or switch back to soft water & soap. Nutrients, including phosphates, are the chief cause of accelerated aging of lakes and result in algae and aquatic plant growth.

2. USE LESS DISWASHER DETERGENT THAN RECOMMENDED (TRY HALF). Experiment with using less laundry detergent.

3. STOP FERTILIZING, especially near the lake. Do not use fertilizers with any phosphate in them; use only a nitrogen-based fertilizer. In other areas use as little liquid fertilizer as possible; instead use the granular or pellet inorganic type. Do not burn leaves near the lake.

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

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

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

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

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

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

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

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

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

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

APPENDIX 2.

Appendix 2. Leopold (2005). Jones Fish Hatchers, INC. Loch Erin fish survey, 2005.

USA 1-800-662-3474
Ohio 1-800-733-0180

JONES FISH HATCHERIES, INC.

Local (513) 561-2615
Fax (513) 561-6251

3433 Church Street
Newtown Ohio 45244

Thursday, July 28, 2005

Loch Erin Property Owners Association
Terry Michaels
8863 Kingsley Dr.
Onsted, MI 49265

Mr. Michaels and fellow members:

Thank you for contacting Jones Fish and Lake Management for your lakes needs. The Lock Erin Lake near Onstead, MI was sampled through a fish population survey on 6/15/05 and 6/28/05. It is estimated at 600 surface acres, approximately 50 years old, a maximum depth of 12', and an average depth 6-8'. The following is a review of what was collected (please see following appendix of more detailed collections at each sample site):

Review:

Species	Number	Size Range	Average	% Relative Weight
Bluegill	231	2.7" – 7.1"	5.6"	14.7
Largemouth Bass	46	2.9" – 18.3"	13.4" 1 lb. 5 oz.	38.2
Common Carp	20	15" – 20"	n/a	26.9
Pumpkinseed Sunfish	15	2.8" – 5.7"	4.7"	0.8
Yellow Perch	13	4.3" – 6.7"	5.5"	0.8
Channel Catfish	11	14.6" – 19.8"	17.6" 1 lb. 11 oz.	11.5
Redear Sunfish	10	2.6" – 5.2"	4.1"	0.4
Smallmouth Bass	4	5.7" – 18.0"	12.2" 1 lb. 9 oz.	4.0
Black Crappie	4	6.3" – 8.0"	7.0" 2 oz.	0.3
*Silverside	3	2.2" – 3.5"	n/a	-
Walleye	2	12.9" – 23.1"	n/a	2.4
Emerald Shiner	2	3.1" – 3.5"	n/a	-

*indicates new species collected this year, not collected previously

The following species were collected during the 2000 survey, but not this year:

White Crappie	3
Green Sunfish	2
Bluntnose Minnow	1
Yellow Bullhead Catfish	1

General Observations:

Fish observed, not collected:

- very many bluegill and/or pumpkinseed <3", high numbers 4 – 6"
- extremely high numbers of common carp, 15 – 20"
- many emerald shiners in several collection sites
- good numbers of largemouth bass 12 – 18+"
- several yellow perch 4-7"
- several walleye 15 – 20"

Water initially clear, lightly colored, Secci Disk = 30 inches

Significant amounts of aquatic vegetation in several shallow coves, mostly western sides of lake

Time Series Comparison Data:

With this being the second population survey conducted, we are able to compare some aspects of data collection between the two surveys (5 years apart). To do so, actual numbers collected are converted to percentage of total number of fish collected during each survey. This is presented in the enclosed graph titled "Time Comparison: Percentage Catch (number collected)".

Site Locations:

We attempted to follow the previous site locations from 2000 as closely as possible. Some slight adjustments were made due to shoreline development over the intervening period, in an effort to continue with the sampling of a variety of habitat locations. During the latter half of the survey, recreational activities upon the lake reduced or prevented sampling activities at several locations. Our utmost concern is the safety of residents and those using the lake. With these concerns in mind, we could not adequately survey the final two sites on the lake this year. Please refer to the enclosed map for depiction of these sampling locations.

General Assessment:

The overall results indicate the fish population in Lock Erin is progressing towards greater domination by sunfish, principally intermediate sized bluegill, compounded by the concurrent pumpkinseed population. Much of this condition is being exacerbated by the common carp population and their detrimental impacts upon the reproductive success of nesting species such as bluegill and largemouth bass. As noted in the previous survey, Loch Erin still suffers from a stunted sunfish/panfish population, as seen in the more detailed analyses below.

The Time Comparison graph indicates a significant increase in the relative numbers of bluegill and common carp, with a significant decrease in the relative numbers of largemouth bass and yellow perch. Nearly all other species are either not significantly different, or the existing data is too limited to make an appropriate determination. Many of the variations in these other species may be explained by the difference in weather conditions or submerged weed cover between the two survey events (2000 versus 2005).

Species Specific Analyses:

Largemouth bass were collected at lower relative numbers this year over the previous survey, though this species does dominate in percentage relative weight of all species collected. As noticed previously, largemouth bass at lengths of 13" and less are slightly below average in weight, while those above this size range are at or above average weight (see enclosed graph "Largemouth Bass: Growth Data"). Compared to the previous survey, the smaller largemouth bass are slightly lighter in weight, consistent with the continued dominance of the forage base of intermediate sized sunfish which are too large for these smaller bass to consume. Those largemouth bass that exceed 13" length are able to prey readily upon the available forage base and grow to above average lengths for most lakes.

The majority of the largemouth bass population is comprised of 11-14" or 16-18" individuals. There is a significant lack of sub-adult largemouth bass (7-10" length) and nearly complete lack of juvenile largemouth bass (2-7" length), as seen in the enclosed graph "Length Frequency Histogram: Primary Species". A significant amount of this lack of smaller sized bass is due to two causes; 1) high predation on the eggs from common carp activity (largemouth bass nesting and common carp invasion of shallow waters occurs approximately the same water temperature range), and 2) high predation on fry from the dominating numbers of intermediate sized bluegill/sunfish populations. During the first half of this years survey (6/15/05) there was a high level of submerged vegetation growth present, and all collected largemouth bass less than 12" length occurred on this date. The second half of the survey occurred after the annual weed treatment (6/28/05), and no largemouth bass less than 12" were collected. The annual treatment of submerged weed growth throughout the entire lake may also contribute to lower survival rates of juvenile and sub-adult largemouth bass from year to year.

Bluegill were collected at significantly higher relative numbers during this survey, having a smaller maximum size (7.1" versus 7.5" of 2000) and very slightly lower average length. Bluegill comprised the third most dominant species in terms of relative weight collected, due to their high numbers. This species appears to be establishing a greater dominance of all prey and forage species in the lake. The primary predatory species on bluegill and other sunfish species are largemouth bass and channel catfish. The other predatory species present in Loch Erin (smallmouth bass, walleye and northern pike) all prefer elongated, soft-rayed prey such as minnows, shiners and yellow perch.

The bluegill collected were dominated by the 5-6" size class, individuals too large to be consumed by largemouth bass less than 14" length. High numbers of 1-2" bluegill were observed within the standing weed beds, although they cannot be adequately collected with our equipment. With their extremely high and repetitive reproductive output, bluegill are less impacted by the common carp activity than are largemouth bass. Very few bluegill greater than 7" length were collected, indicating this population stunting process has been present for a number of years.

Common carp were the third most dominant species collected in numbers and second in weight. This does not do justice to the existing carp population, as after the first collection site, we discontinued collecting carp due to the extremely high numbers encountered. It appears that this species was more prevalent this year than the previous survey, although again we did not observe or collect any individuals less than 15" length. Unfortunately this species does have an average life span of 12 to 20 years, indicating the common carp population will still be a major nuisance well into the future. The detrimental impacts of this species upon gamefish populations cannot be understated.

Pumpkinseed sunfish were the fourth most common fish collected, though contributing a small amount to the relative weight. When combined with redear sunfish (seventh most common) and black crappie (ninth most common species collected), they comprise the bulk of the minor species forage base. All three of these species exhibit similar stunting effects as the bluegill population (see graph "Length Frequency Histogram: Minor Species"), with pumpkinseed sunfish being dominated by 4-6" size class, redear sunfish by 4-5" size class and black crappie by 6-8" size class. This effect is caused by the exceedingly high number of prey species (all combined) competing for a limited forage base, primarily minnow species and aquatic insect larvae. The regular weed treatments further limit their food supply, compounding this condition. The black crappie population may possibly be diminishing in numbers throughout the lake, possible a result of the catfish stocking/control program established in the '90's.

Yellow perch was the fifth most common species collected, though it does exhibit a significant decrease in percentage relative number collected from 2000 to this year. All yellow perch collected were within a "stunted" size range of 4-7" length, for the same reasons as mentioned above. I believe the decrease in number collected (actual and relative) can be attributed to higher predation activities over the past several years. You had mentioned the regular stocking of smallmouth bass and walleye, both of which prey selectively upon yellow perch over sunfish species. This impact upon the yellow perch population may indicate the decreasing abundance of this species in future years.

Channel catfish are the sixth most common species collected, contributing to the fourth highest level of relative weight. All catfish collected appeared in extremely good health and fitness, indicating their ability to feed upon the large forage base of stunted sunfish present. We did not observe any fingerling catfish, though that does not eliminate the possibility that this species is capable of successful reproduction in Loch Erin. The predatory impact of this species would be considered beneficial at this time, though not adequate for the stunted sunfish population present.

Smallmouth bass were collected in numbers (4 individuals) and a size range indicating the successful establishment of this population in the lake. The adult smallmouth bass collected (17-18" length and in excess of 3 pounds each) exhibited very good growth and fitness. Reproduction was again evident with the collection of 5-7" individuals. I believe the future development of this species population should be encouraged and will be beneficial to the total population of the lake.

Emerald shiners were again primarily observed in high densities within the heavy submerged weed beds of the western and southern sections of the lake. We also collected a very similar species not observed in the first survey, that being silversides. Both species exhibit similar life habits and characteristics, comprising the majority of the small forage base population. I believe both species suffer from the annual weed control applications throughout the lake. If these two species can be encouraged to greater population levels, it will make up for considerably limited food resources for the stunted sunfish and lower growth rates of smaller largemouth bass observed.

Four species collected during 2000 were not collected during this survey, namely white crappie, green sunfish, bluntnose minnow and yellow bullhead catfish. Northern pike were not observed or collected during the survey this year. As mentioned previously, all of these species were considered to be non-significant in the total fish population dynamics of Loch Erin. With this understanding, it is not surprising that these species were not necessarily collected during this years survey. While these species may still be present within the lake, their presence is of little to no ecological consequence.

Complete Review:

Loch Erin is certainly a complex habitat comprised of a multitude of fish population dynamics. It appears the primary detrimental conditions are the continued overpopulation of panfish (bluegill, pumpkinseed, redear and black crappie combined) and lower than average fitness and growth of predatory species at smaller sizes. These conditions are compounded by the limited primary forage base comprised of emerald shiners and silversides. The gamefish population is currently dominated by a big bass fishery (largemouth and smallmouth bass included), with the supplemental aspects of channel catfish and an occasional walleye, though low reproductive success, survival and growth rates of fingerlings is a significant concern.

Recommendations:

Future fish population management should continue to focus on increasing predation upon sunfish, enhancing the limited forage base, providing greater amounts of protective structure within the lake, and decreasing the common carp population.

1. FORAGE BASE DEVELOPMENT. I still firmly recommend the establishment of an additional forage fish species for the betterment of the largemouth bass population, specifically the golden shiner. Currently, the vast open areas of Loch Erin are not being utilized by many fish due to the lack of food resources present. Golden shiners are principally an open water species, growing to lengths of 7 to 8". With these characteristics, golden shiners will inhabit areas of the lake currently devoid of other fish species, with minimal competition and impact on those species established within the lake. This will provide a much needed food resource for the predatory fish populations not able to adequately utilize the predominant sunfish populations.

A. Stocking:

Species	Number	Price	Cost
Golden Shiner	600 lbs.	$8.50/lb.*	$5,100.00

*price per pound good on orders over 200 pounds for 2005. Price is not guaranteed in future years.

This recommendation is for an initial stocking, preferably this fall or next spring. I would then recommend at least an annual stocking each subsequent spring of a minimum of 300 pounds golden shiners. Our company is now able to provide for delivery of fish directly into Michigan, meeting all of the Michigan Department of Natural Resources requirements for fish stocking. Delivery is available at no additional cost.

B: Weed Control:
In addition to stocking, enhancement of the existing forage base throughout the year can be a critical element in improving the total fish population structure. I recommend you limit the amount of lake shoreline that is treated for weed growth each year, allowing specific areas to be left untreated. There are

numerous coves of Loch Erin that do not appear to be utilized or developed, and could conceivably be left alone to develop submerged weed growth all summer. I recommend setting aside at least 10% of the shoreline areas currently not required for access, eliminating weed treatment applications in these sections. These areas can then act as a nursery for the reproduction and survival of forage fish and fingerling gamefish.

C. Artificial Structure:
One of the most productive sections of the lake for big largemouth bass included artificial structure piles purposefully placed into shallow water areas. I recommend you encourage this activity among residents, possibly with specifically identified and/or marked locations for such placement. This must of course take into consideration recreational water craft activities and traffic flow. This process should be approached as a long term investment program in the enhancement of gamefish development throughout the lake.

2. FISH POPULATION MANAGEMENT. Recommendations for future fish population management will be geared towards limited harvest of larger sized gamefish and unrestricted harvest of panfish populations.

A. Predatory Species:
Largemouth and smallmouth bass populations currently are structured to enable support of harvesting larger sized fish. I recommend a minimum length limit of 15" for harvest on both species, though catch-and-release should still be encouraged as most beneficial to total population growth.

Walleye and channel catfish populations have been enhanced through past stocking programs. Neither species appears present in numbers too high to be of a concern. I suggest you maintain your past stocking strategies with these two species, to support the current and future harvest activities allowed or conducted. If any length limits are under consideration, I would recommend 18" minimum on walleye and 21" minimum on channel catfish.

B. Prey Species:
Bluegill, pumpkinseed, redear sunfish and black crappie populations should be treated with impunity. I recommend harvesting of all panfish caught, with no size or limit restrictions. Reduction of the heavy competition between these species will be the key to increasing average lengths in future years, creating a more desirable recreational panfish population. This program should be continued until the average length of bluegill exceeds 6", and the average length of redear sunfish and black crappie exceeds 8". I expect through harvesting and increased predation activity that this will take at least 3 to 5 years to become apparent.

Yellow perch should be managed differently than these other prey species. The yellow perch population is most likely the one most heavily impacted by the stocking program of smallmouth bass, walleye and channel catfish. Yellow perch are predominantly a deeper water, bottom oriented species, which makes this species one of the more common prey items that the bottom oriented predatory fish will intercept most frequently. With this in mind, I recommend a minimum length limit on yellow perch of 8". This will help to protect at least one year of reproduction prior to harvest.

C. Stocking:
I agree with the past stocking program of smallmouth bass and walleye, and believe this should be continued at your past levels. The population structure of largemouth bass is currently devoid of second and third year age classes, creating an additional concern for the continued health of this population. I would also recommend considering stocking up to 2000 largemouth bass 5-7" each year for several years. Combined with the enhancement of the smallmouth bass (via stocking and natural reproduction) and walleye populations, this will encourage greater predation activity upon the stunted panfish populations.

Species	Number	Price	Cost
Largemouth Bass	2000 6-8"	$250.00/100	$5,000.00

All fish will be certified for delivery into the state of Michigan as required. I recommend these fish be stocked this fall, as the price listed is not guaranteed for delivery in future years.

D. Common Carp:
As noted in 2000, this species is detrimental to the reproductive success of largemouth bass directly, with other detrimental impacts upon the survival of smaller fish throughout the lake. I recommend you continue to encourage the removal of common carp through any and all methods possible.

E. Northern Pike:
This species was again not represented in our survey or observed in the lake. I cannot predict whether this species is decreasing in abundance due to natural processes or harvest activities. I have not had any input as to the performance of this species in recent years, so cannot provide any recommendations for the management of the current population. I do not believe that additional stocking of northern pike would be beneficial to the existing fish population, as this species is in general not a heavy predator upon sunfish/panfish over 3" in length. Consider this species to be of minimal importance in the total management program of the lake.

Again, thank you for choosing Jones Fish and Lake Management for your lakes needs. If you have any questions concerning this report, please call to discuss them.

Sincerely,

Bill Leopold
Fishery Biologist

cc: File

Survey Locations
2000 - Black
2005 - Highlighted Green

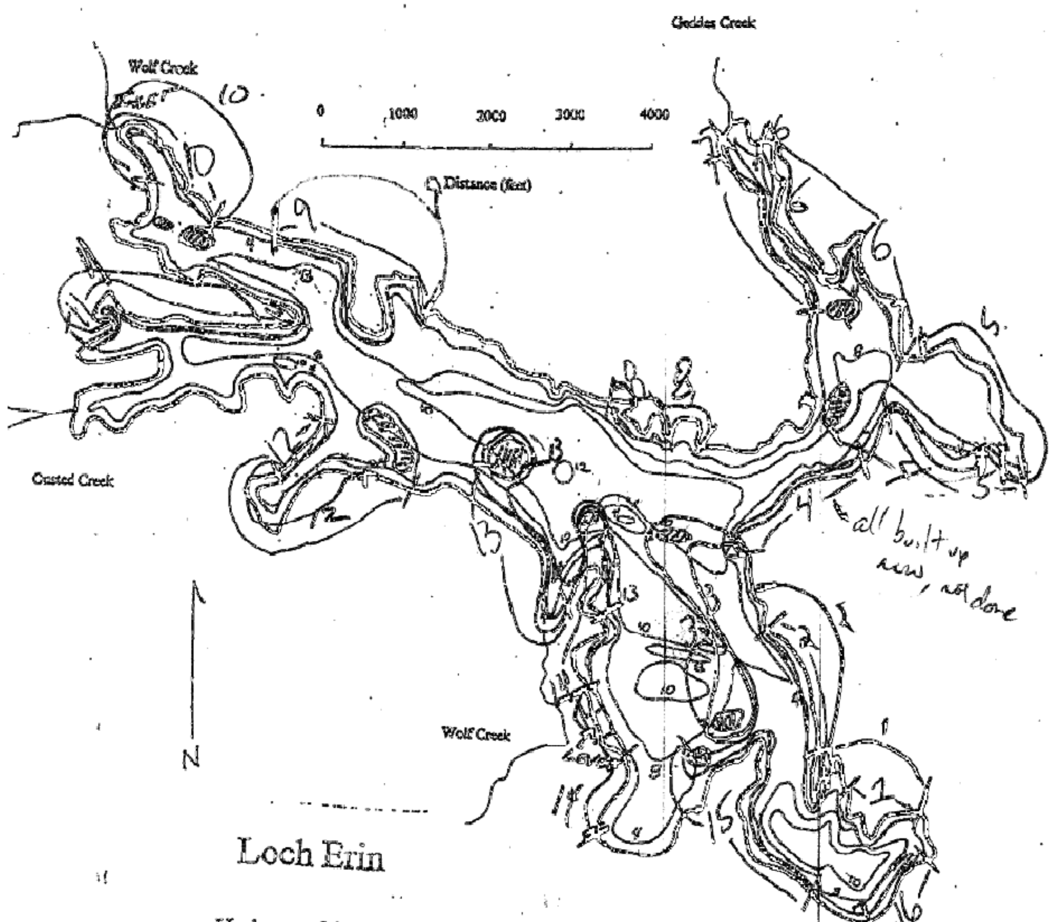

Figure 5