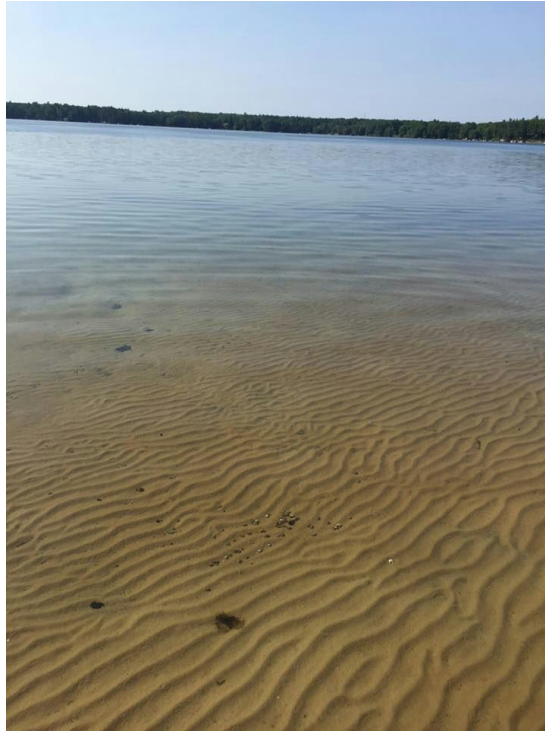


**A Limnological Survey of Bear Lake
July-August 2015**



Matthias Bonzo Cornerstone
Brian Cartularo Gordon College
Micah Hofland Covenant
Andrew Parks Oral Roberts University
Emily Paul Grace College
Sarah Swanson Oral Roberts University

Au Sable Institute of Environmental Studies
Limnology
Dr. Korstad
August 13th, 2015

INTRODUCTION:

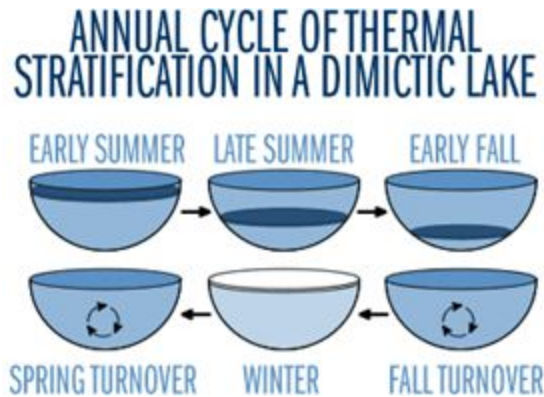
Water covers the majority of the earth and is home to millions of species. Because of this, aquatic ecosystems are found everywhere and range from floodplains that only form after huge torrents of rain, to the bottom of the oceans, where only the most resilient species can survive. The study of limnology narrows these ecosystems to just 0.016% of the water covering the earth: inland water. Within this study, there are two different categories of water systems: lentic and lotic. Lentic systems are slow moving and include lakes, ponds and marshes. Rivers and streams are categorized as lotic systems and are more fast moving. This study was done specifically with a lentic lake in the Northern Michigan region. With over 11,000 inland lakes, Michigan has become known for fishing, clear waters, and a place to retreat in order to escape the heat of the south (Inland Lake Maps by County). Because of the geography, these lakes, including Bear Lake, have specific features about them that are unique to this area.

The majority of the lakes in the north were formed thousands of years ago by glaciers that carved the landscape. The multiple ice ages created glaciers that were an average of 6,000 ft. deep and with every advancement and retreat into what is now Michigan, left lasting marks on the geography of the state (Wilson 1). Basins, kettlehole lakes, and ultimately, the foundation that explains the abundance of lakes in the Northern regions, can all be attributed to the force of the glaciers. Although there are a few man-made lakes created by dams and natural causes, the majority of Michigan lakes are ground fed from aquifers. Because of this, many of the lakes share the same characteristics including chemical and biological factors.

Variables such as the surrounding population can lead to different levels of health for specific lakes. For example, if the residents around the lake use large amounts of chemicals on their lawns, this may lead to an over-productive (eutrophic) lakes due to an overabundance of nutrients. The majority of the lakes in Michigan are oligotrophic due to the bedrock and produces little nutrients that naturally would enter the lakes. This is a sharp contrast to the eutrophic lakes found in the south that are mostly fed from run off that is full of nutrients from the abundance of agriculture. Determining whether a lake is oligotrophic, mesotrophic or eutrophic can be done with several sampling methods including the transparency, depth, plankton abundance, oxygen trends, trophic state index and nutrients levels (specifically phosphate).

Lakes often have seasonal cycles that are essential for keep nutrients, oxygen and temperature distributed throughout the lake. The frequency depends on external factors such as temperature and chemical stratification. Northern lakes are considered dimictic (mixing twice a year) in the spring and fall when no ice is present. During the summer, lakes in Michigan tend to become thermally stratified. Thermal stratification is the characteristic of a lake to be divided into vertical zones based on temperature. The top zone of the lake is referred to as the *epilimnion* and is the warmest zone due to the

exposure to sunlight and the mixing caused by wind, as well as other top water activities. The middle zone is called the *metalimnion* and this zone is characterized by a rapid change in temperature (drops more than 1 degree Celsius per meter.) The bottom zone is referred to as the *hypolimnion* and it begins where temperatures rate of



decrease is lower than in the metalimnion continues to the bottom of the lake. As the seasons begin to change in fall, the lake undergoes the *fall overturn* during which time the solar radiation reaching the water is reduced and more heat begins to escape the water. Over a short time the stratification decreases and eventually is lost and the lake becomes homothermous (isothermal) meaning its temperature is consistent from top to

bottom. When spring arrives and the ice begins to melt the lake will then undergo the *spring overturn*. During the spring overturn the solar radiation increases and the wind stirs the top waters and begins to increase temperatures throughout the lake, becoming isothermal again. In summer, thermal stratification is reestablished once again. Bear lake along with others also have different biological zones. The shallower littoral zone usually holds emergent plants and smaller nekton species. Most of the sampling in lakes is done in the limnetic zone which is the deeper and in the located in the open water of the lake.

The purpose of this survey of Bear Lake (Figure 1) is to collect samples and analyze the chemical and biological data to determine the progression of the lake compared to last year's data. This will give the those living around the lake information about the trends of their lake and may lead to changes in order to insure the lake stays healthy for years to come.

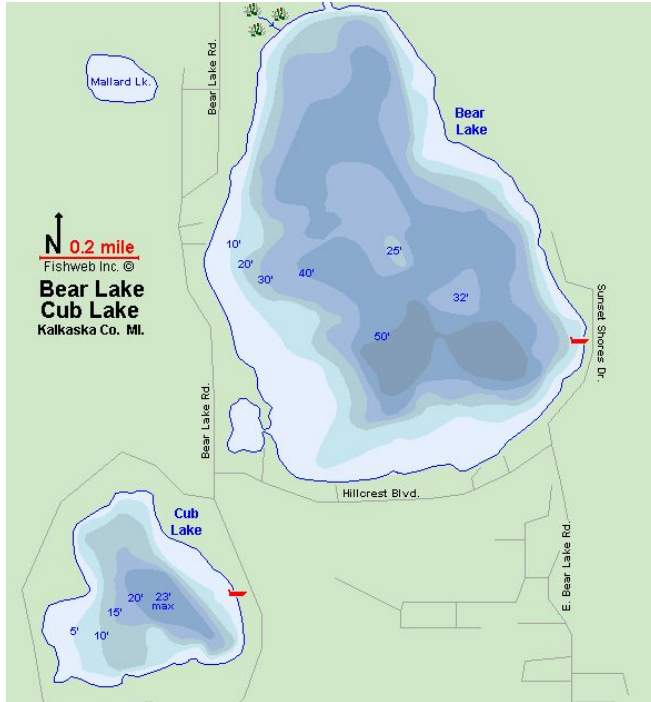


Figure 1: Morphometric map of Bear Lake.
[\(http://www.fishweb.com/maps/kalkaska/bear_lake/\)](http://www.fishweb.com/maps/kalkaska/bear_lake/)

MATERIALS AND METHODS:

Bear Lake was sampled at its maximum depth 60 feet (18.3 Meters). The location of the deepest spot is on the east side of the lake and all sampling was done from a pontoon boat. The first day of sampling occurred on July 16th, 2015 at 2:00 pm and continued for about an hour and a half. The temperature was 73.5 degrees Fahrenheit and it was partly cloudy with a the wind blowing 10-15 knots. The wind made it difficult for the boat to remain on the deepest area of the lake so some of the results for temperature, oxygen and light were skewed. The second day of sampling occurred on July 27th also at 2:00 pm and occurred over the course of an hour. The air temperature was 83 degrees Fahrenheit and there was no wind and sunny. This set of data were much more accurate and the second set of data were used the for the majority of this paper to draw conclusions from.

Temperature and Dissolved Oxygen:

A YSI DO200 Ecosense temperature and dissolved oxygen meter (Figure 2) was used to take readings for temperature, percent oxygen saturation, and dissolved oxygen at 1 meter increments. The line was marked at every meter



Figure 2: Light/Dissolved Oxygen meter.

The light penetration of the lake (light intensity) was measured in foot-candles. This was done in the same increments using a Protomatic pyrheliometer.

Light:

Light was measured using a standard light meter. The one used specifically for Bear Lake was an LI-250A Light Meter (Figure 3). On one end is the reader from which you will find the light recorded in the units (ft-candles). On the other end, you will find a water-proof light bulb. You may also find weights attached to this end. This is to help the bulb sink as well keep it level when the boat is drifting on the currents. Light measurement starts on the surface at 0 m. The bulb was lowered one meter at a time. At each depth, the reader would start showing multiple numbers. The numbers would be erratic and the range would be as much as 300 ft-candles apart (this will vary depending on the make and model of the light meter). The meter was left for a bit until it had adjusted and the light measurement was taken. When the meter would still fluctuate, the



“hold” button was used. This paused the reader at a specific number. That number was then used (sometimes this will number will be higher than the previously recorded measurement, usually due to partly cloudy conditions. Keep in mind this will change the appearance of your graphed data). The bulb continued to be lowered until either the reader reads zero or the maximum depth of the lake was reached. All light measurements were recorded on our lake sampling data sheet.

Figure 3: Light meter.

Secchi Disk Transparency

A secchi disk (Figure 4) is a tool used to measure the light transparency of a lake's water column. The actual secchi disk transparency is the depth at which the secchi disk can no longer be seen. Gauging transparency is a fairly simple process. The secchi disk was slowly lowered into the water (meter marks are on the rope) until the disk could not be seen. That depth was recorded. The disk was then slowly raised back up and the depth at which it reappears is also recorded. The average of the two depths is recorded as the secchi disk transparency depth. In oligotrophic (nutrient poor) lakes Secchi Depths can be 8-10 meters and as little as 1-2 meter in eutrophic (nutrient rich) lakes (Horne and Goldman, 1994).

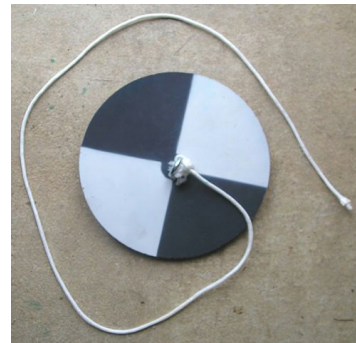


Figure 4: Secchi Disk

Hardness and Alkalinity:

A HACH Hardness titration kit (Figure 5) was used to measure the amount of calcium carbonate (CaCO_3) in the water, or more specifically, the concentration of multivalent cations. The majority of these are dissolved minerals such as calcium and magnesium are in lakes. These minerals are added when the water come in contact with deposits of limestone or chalk, usually in aquifer. A Hach Alkalinity Kit (Figure 3) was used to measure the ability of the water to buffer acid from acid rain, the equilibrium equation for this is $\text{CaCO}_3 + \text{H}_2\text{CO}_3 \leftrightarrow \text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{Ca}(\text{HCO}_3)_2 \leftrightarrow \text{Ca}_2^+ + 2\text{HCO}_3^-$. (Horne and Goldman, 1994). Both of these titrations measure the concentrations in ppm of CaCO_3 (Whitis, 2008). Both of these concentrations were measured on the surface of the water and at the bottom of the lake. The bottom sample was taken using a Van Dorn Water Bottle (Figure 6) the bottle works by leaving the ends of the bottle open, lowering the bottle to the desired depth and then sending a brass weight called the messenger down the line to close the bottle and seal your water sample. It can then be tested at the surface.



Figure 5: HACH kit.



Figure 6: Van Dorn water bottle.

pH, Conductivity, Redox and Total Dissolved Solids:

In order to measure these four aspects of the lake a specialized electronic Vernier ISE probe (Figure 7) was used for each category. pH is a measurement used to determine how acidic or basic the lake water is. More specifically, it is the measurement of Hydrogen ion (H^+) concentration and is expressed mathematically as $=-\text{LOG}(\text{Hydrogen Concentration})$. It runs on a scale of 0-14 with 0 being very acidic and 14 being very basic and is measured in pH units. Conductivity is the measurement of total ions in the water sample, measured in $\mu\text{Siemens/cm}$. This affects how much electricity the water can transport. Total dissolved solids are the measurement of how many other particles are in the water, measured in ppm. The last thing that was measured was the reduction/oxidation potential of the water or how readily ions in the water can add more electrons, measured in mV. All four of these aspects were measured at both the surface and the bottom of the lake from a small sample in a cup.



Figure 7: Vernier ISE probe.

Plankton:

The plankton was sampled in the lake using a 80- μm plankton net (Figure 8). This was done by dropping the net off the side of the boat until about 8 meters down and then quickly retrieving the net. This was done three times. The collected sample was then bottled and preserved back at the lab using Lugol's Iodine and 10% formaldehyde. Using microscopes, the preserved plankton were examined, identified, and counted for percent abundance. The value for this was obtained by tallying the number of phytoplankton and zooplankton present on a slide separately. Those values were then divided against the total number of either phytoplankton or zooplankton and multiplied by 100 to acquire a percent.



Figure 8: 80- μm plankton net.

Benthos:

Benthos are the organisms that live in the bottom sediment of a lake. They break down organic material by consuming oxygen and producing CO_2 . The benthos (bottom material/ living creatures) was sampled using an Ekman Dredge (Figure 9). This gave the class an idea of what is living on the bottom of the lake. The sample was rinsed through a screened bucket to remove sediment and then the larger creatures that were left were observed. These larger creatures included organisms such as mussels and bloodworms. The presence of certain kinds of benthos can provide evidence towards the effect temperature, oxygen concentrations, and light has on the ecosystem. Data on Bear Lake was collected on July 16th and July 27th.

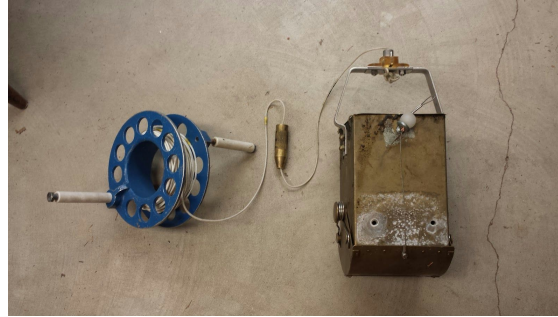


Figure 9: Ekman Dredge.

Bacteria:

A major concern with swimming water is *E. Coli*, which can cause issues for people swimming in the lake. *E. Coli* occurs when fecal matter enters the lake and includes any warm-blooded animal, such as geese or septic leaks. 3 mL samples of water from shallow, warm water areas located near the public access site and the southwest corner of the lake were obtained. These samples were then taken back to the lab and given a nutrient broth (Easygel by Colliscan) and incubated to promote bacterial growth. After 24 hours the number of bacterial colonies (red and pink) and the number of *E. Coli* colonies (blue and purple) were counted. The bacteria counts were then multiplied by 33 to give us the number of coliforms per 100 mL of water.

RESULTS:

Temperature:

The samples taken for Bear lake show typical summer stratification characteristics regarding temperature (Figure 10). The surface reading was 25° C and remained fairly constant until a rapid decrease in the thermocline around 6-9 meters until it remains steady around 12° C until the bottom of the lake. The line curves also are fairly similar compared to last years data.

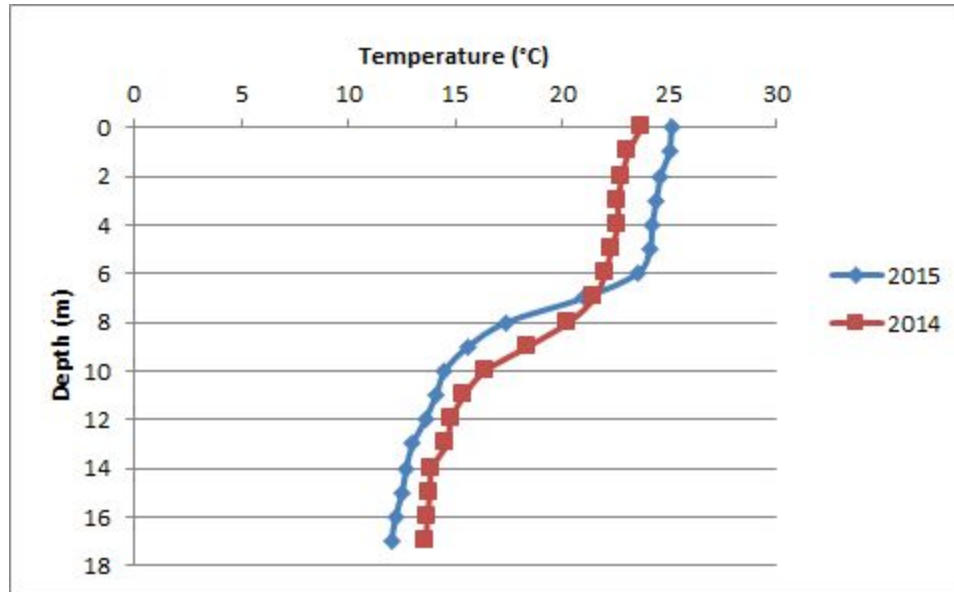


Figure 10: Temperature with decrease in depth.

Dissolved Oxygen:

Dissolved oxygen (also commonly referred to as DO) from this year follows the same pattern as last year (Figure 11). The pattern is characteristic of an oligotrophic lake showing a heterograde curve. Surface oxygen was 8 ppm, peaked at 15 ppm, and dropped back down to 8 ppm near the bottom.

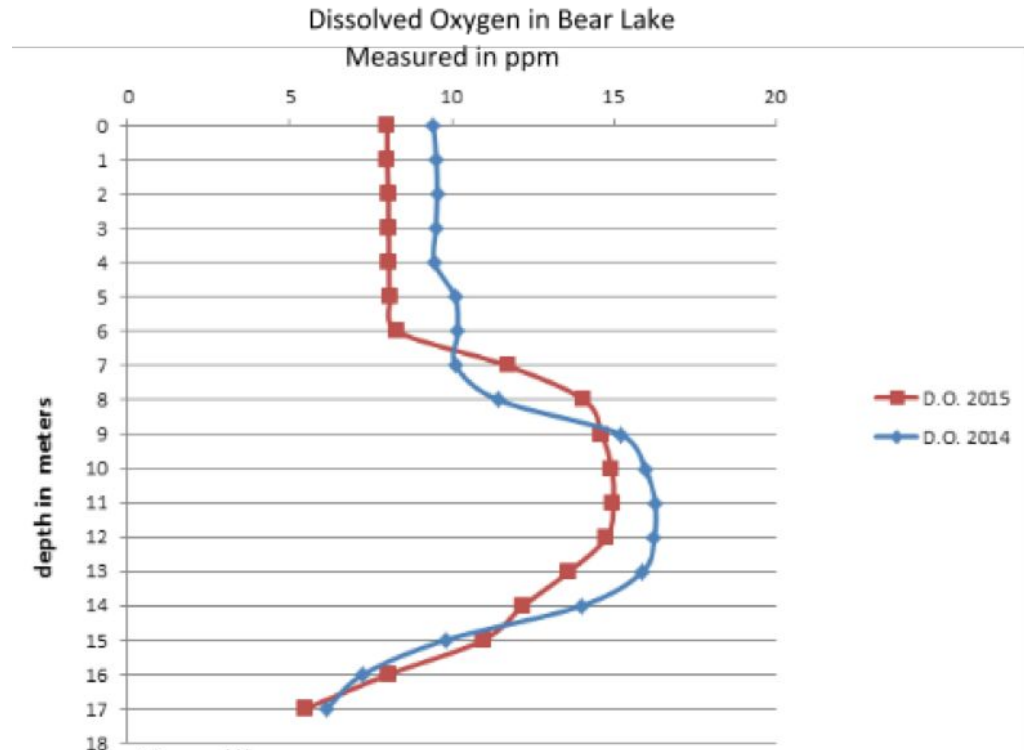


Figure 11: Dissolved Oxygen with decrease in depth.

Light Intensity:

Over the past two years, Bear Lake has shown a very slight increase in light intensity (Figure 12). Light intensity follows a logarithmic scale with the surface measuring 1400 ft-candles and decreases until 19 meters when the reading reached 0. The only difference between 2014 and 2015 light intensity is the deepest depth (17m) received light this year, but not last year.

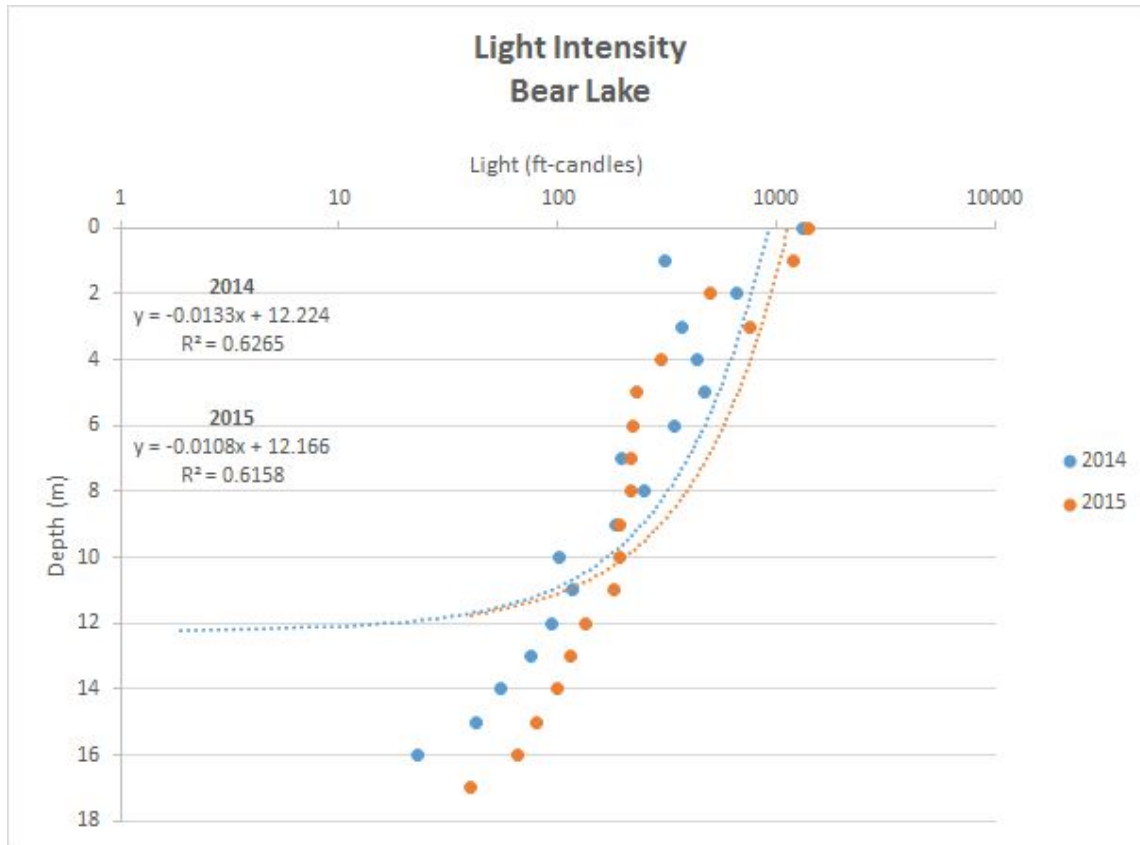


Figure. 12 Light intensity with decrease in depth.

Secchi Disk & Trophic State Index (TSI):

TSI is a calculation of lake health using either the secchi disk depth, total phosphorus, or chlorophyll a concentration to measure the nutrient concentration. The values of the past two years can be seen in the following table (Table 1).

Table 1: TSI Values for Bear Lake.

Year	2014	2015
TSI Value	33.0273	29.1616

$$\text{TSI} = 60 - [14.41 \times \ln(\text{SD})]$$

Alkalinity:

The results and comparison for the data of both 2014 and 2015 can be seen below in Figure 13. The alkalinity for Bear Lake was 62 at the surface and 70 at the bottom while last years values were 71 at the surface and 79 at the bottom.

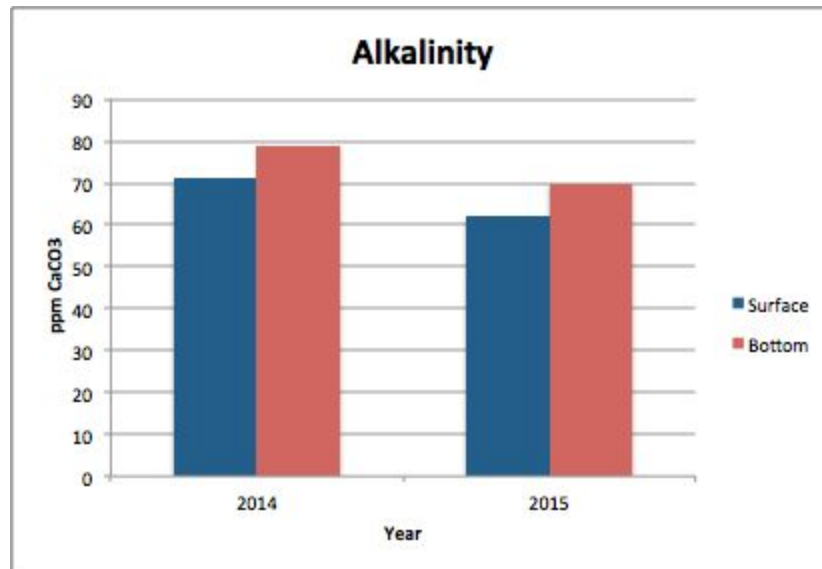


Figure 13: Alkalinity for 2014 and 2015 from surface and bottom water.

Hardness:

In Figure 14, the difference between this year and last years is compared. This year, the surface water showed a higher recording (91.5 CaCO₃ mg/L) than the bottom (75.5 CaCO₃ mg/L). Last year, however, it was the reverse: lower values for the surface (86 CaCO₃ mg/L) and higher for the bottom (103 CaCO₃ mg/L).

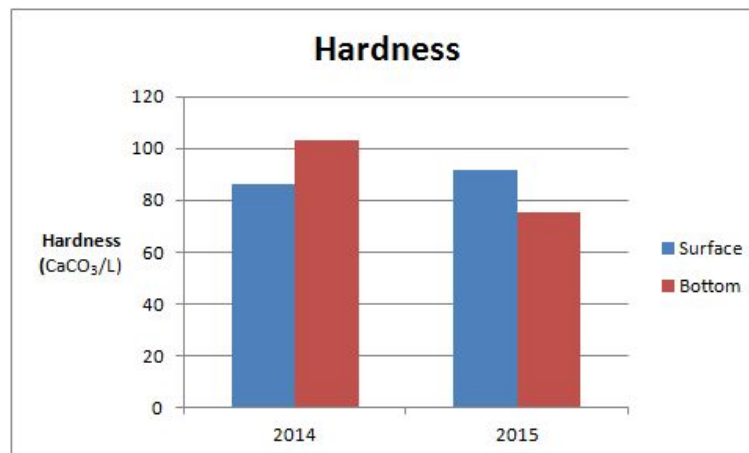


Figure 14: Hardness for 2014 and 2015 from surface and bottom water.

pH:

The surface pH was 8.5 from this year and the bottom was 9. Last years values were 8.4 at the surface and 7.4 at the bottom (Figure 15). Although there is some fluctuation between the two years, they are still fairly similar.

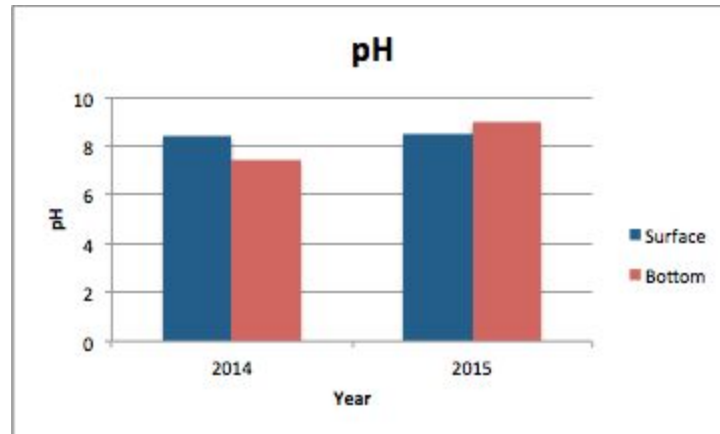


Figure 15: pH from 2014 and 2015 from surface and bottom water.

Conductivity, Redox and Total Dissolved Solids (TDS):

Although redox and TDS were not sampled last year, conductivity was and the data shows similarities (Table 2). For both years, the conductivity drops about 10 from the surface to the bottom. Redox for this year shows a much more substantial drop from 183 to 143. TDS has a much smaller drop from surface to bottom with 184 to 170 respectively.

Table 2: Conductivity, Redox, and TDS from 2014 and 2015 from surface and bottom.

		Conductivity (μ mhos)	Redox (E_h)	TDS
2014	Surface	130	-	-
	Bottom	120	-	-
2015	Surface	150	183	184
	Bottom	143	143	170

Plankton:

All of the plankton found last year were also observed this year along with some others. There was a total of ten species of phytoplankton found this year and seven of zooplankton (Table 3). Of the phytoplankton (Figure 16), *Fragilaria* was most abundant while *Diaptomus* was most abundant for the zooplankton (Figure 17).

Table 3: Species of plankton found from 2014 and 2015.

Year	Phytoplankton Found	Zooplankton Found
2014	<i>Chroococcus</i>	<i>Daphnia</i>
	<i>Diatoma</i>	<i>Cyclops</i>
	<i>Fragilaria</i>	<i>Diaptomus</i>
2015	<i>Chroococcus</i>	<i>Cyclops</i>
	<i>Fragilaria</i>	<i>Diaptomus</i>
	<i>Asterionella</i>	<i>Daphnia</i>
	<i>Navicula</i>	Nauplius larva
	<i>Ceratium</i>	Young Copepidite
	<i>Pediastrum</i>	<i>Diaphanosoma</i>
	<i>Cosmarium</i>	<i>Bosmina</i>
	<i>Dinobryon</i>	
	<i>Anabaena</i>	
	<i>Volvox</i>	

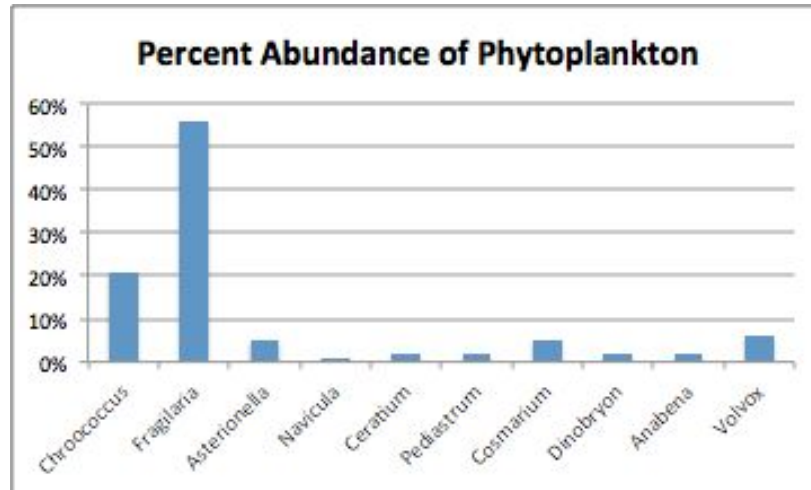


Figure 16: Percent abundance of phytoplankton from 2015.

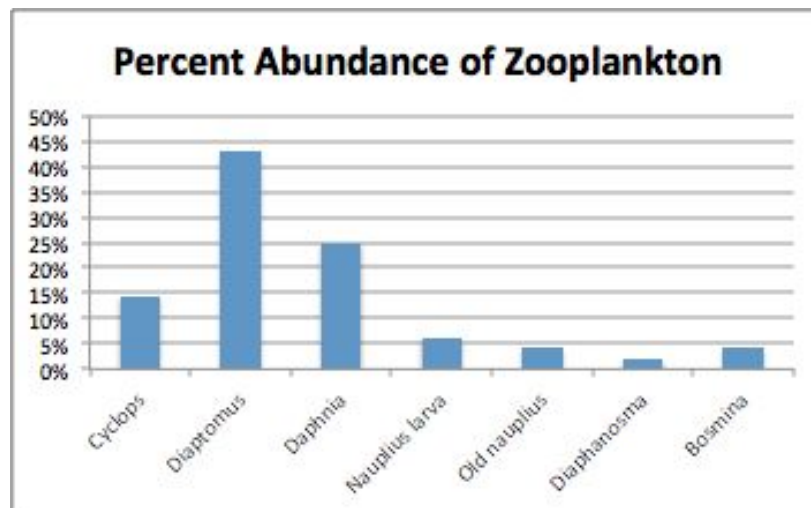


Figure 17: Percent abundance of zooplankton from 2015.

Benthic:

On the two days the lake ecology class went out and collected data, the presence of benthos was only found on the first day, July 16th. On the second day, no benthos was found. For both 2014 and 2015, Chara and Zebra Mussels were found. In 2015 native mussels, snails, and a dragonfly nymph were found (Table 4).

Table 4: Species of benthos found in 2014 and 2015.

Year	Benthos Found
2014	Chara (Muskgrass)
	Zebra Mussels
2015	Chara (Muskgrass)
	Zebra Mussels
	Native Mussels
	Snail
	Dragonfly nymph

Bacteria:

One *E. coli* (fecal coliform) was found on the petri dish after 24 hours of incubation. That number is then multiplied by 33 to get a count of *E. coli* per 100 mL. Therefore, the count of *E. coli* found along the shore of Bear Lake near the public access site is 33. The other three sites, located on the southwest corner, had zero *E. coli* coliforms.

DISCUSSION:**Temperature:**

Temperature of water is a key factor in the growth and development of the plants and organisms that are living within the lake. If too extreme, temperatures can have detrimental effects on the lake's ability to grow and distribute healthy plants and animals. Temperature samples this year show a similar pattern to those collected last year. Stratification is beginning to occur at nearly the same depths as last year, but the thermocline in this year's samples show a slightly more dramatic decrease in temperature as depth increases. The stratification that has occurred is normal for northern Michigan lakes and warrants no concern. **This is good.**

Dissolved Oxygen

Dissolved oxygen is an important measurement for assessing the relative health of the lake. Assessing the oxygen helps define whether the lake is oligotrophic, mesotrophic, or eutrophic. A more eutrophic lake will be anoxic at the bottom due to decomposition of organic material and will be high in dissolved oxygen near the surface due to photosynthesis by algae. An oligotrophic lake is going to have dissolved oxygen all the way to the bottom with a small increase in the photic zone from the algae actively producing oxygen in photosynthesis. In Bear Lake, the dissolved oxygen is fairly constant until around 7 m down. At this depth the dissolved oxygen increases dramatically. This is probably due to the "deep chlorophyll layer" where phytoplankton concentrations (and thus oxygen produced through photosynthesis) are higher at mid-depths where nutrients are slightly higher, zooplankton grazing may be lower, photoinhibition is lower, and water temperatures are lower. Dissolved oxygen is more soluble in colder water. Deep chlorophyll layers is typical of deeper lakes in the region around Bear Lake (eg, Big Twin, Pickerel, and Big Blue Lakes) and in the Great Lakes (White & Matsumoto 2012). At about 13 m down, the dissolved oxygen begins to decrease due to diminishing light and thus reduced photosynthesis. There is still some dissolved oxygen at the bottom of the lake which is necessary for organisms to live in the benthic sediment at the bottom. These organisms are vital for the lake's ecosystem because they provide important food for fish. The dissolved oxygen content of Bear Lake classifies it as being oligo-mesotrophic. Over the past two years the dissolved oxygen has been fairly consistent. Due to the fact that long term data not available, it is hard to find trends. Overall, this shows that this is a fairly well-mixed lake and that there is enough dissolved oxygen to support life in the benthic zone. **This is good and typical of a "healthy" lake. We do suggest that vertical profiles of dissolved oxygen measurements (and other important measurements such as Secchi Disk transparency and phytoplankton) be taken every summer to see if changes occur.**

Light:

Light intensity did increase this past year, but only slightly. For both years, there has been one mild increase in light intensity at one of the shallower depths. It is not significant in any way and is most likely due to the erratic range produced by the instrument that were being using. This increase in overall light intensity for 2015 compared to 2014 is more apparent at the deeper depths where 2014 data showed no light at the deepest depth (17 m) while 2015 data showed a light intensity of 40 ft-candles which means light is penetrating deeper this year than it was last year. Light intensity does tend to correlate to DO level and the DO level appears to have slightly decreased this year as well as saturation. This is normal for an oligotrophic lake and should not cause worry. Many aquatic species are adapted to low DO environments so species abundance and diversity are not threatened. The increase in light intensity also means that photosynthesis can occur at deeper depths. **This is good.**

Secchi Disk & Trophic State Index (TSI):

Oligotrophic lakes tend to have a TSI of < 30 due to low/poor nutrient levels. Mesotrophic lakes are between 31-50 and are often considered to be middle-range nutrient lakes. Nutrient rich lakes apply to eutrophic lakes, which have a TSI > 50 ; this is primarily due to excess nutrient runoff from lawn fertilizer and other sources of pollution. The higher nutrient content results in low light transparency and low DO which affects the species abundance and diversity within that lake. Since TSI is used for determining lake nutrient levels, it is important to watch for TSI values that are not within normal parameters for the lake that is being measuring. Bear Lake is an oligotrophic lake (which have a maximum TSI value ~ 30). This is only the second year TSI has been calculated for Bear Lake and with the two values being ~ 33 in 2014 and ~ 29 in 2015, Bear Lake has gone from a “low-mesotrophic” lake to a “high-oligotrophic” lake. This drop is good for the lake because the TSI is closer to a healthier state. **This is very good.**

Hardness:

The hardness was tested for both the surface and the bottom sample. In most cases, hardness varies with depth, and according to the data, it decreased with 91.5 CaCO_3 mg/L at the top and 75.5 CaCO_3 mg/L at the bottom. It is accepted that 0-60 range is considered soft, while 120-180 is hard. Hardness does not always have a correlation with pH or alkalinity because alkalinity tests for CO_3 which can also be paired with other cations. Last year, the hardness was found to be higher (86 CaCO_3 /L at surface and 103 CaCO_3 /L at the bottom). Bear lake currently can be considered to be in between hard and soft water ecosystem. Hardness is commonly referred to how difficult it is to lather soap. Although hardness has little effect on the ecological health of a lake, it can give limnologist an idea of where the water originated. Engineers and chemists use this information to avoid calcification that can lead to expensive breakdowns of equipment that uses water. **This is normal for N. Michigan lakes.**

Alkalinity:

The lake was also tested for alkalinity at the surface and at the bottom. There was a drop in this years data, but not enough past data available to make any conclusions. Most lakes in this area are going to vary slightly from year to year in the amount of cations in the water. This is due to the alkaline bedrock that Michigan is on. Years with large snowfall melt and rain will have a higher alkalinity due to the run off bringing in the cations. The average for lakes in the area are in the 80 range. Bear Lake is slightly lower (62 at the surface and 70 at the bottom) than this, but Bear Lake is also slightly larger and quite deep compared to average, so it may dilute the concentration. **This is normal for N. Michigan lakes.**

Redox Eh:

The reduction potential is positively correlated to the dissolved oxygen. In short, the more free oxygen there is, the higher the redox potential. Eh is a measurement of the tendency of a solution to donate or receive electrons, thus it is measured in millivolts (mV). A positive Eh will have an affinity for receiving electrons because oxygen is the common recipient of electrons in oxidation reactions (hence the term). It makes sense why oxygen and redox are positively correlated. Thus, a higher Eh favors oxidation reactions. This is important because the oxidized forms of metals can bond to nutrients like phosphorus and precipitate out of the solution in the bottom of the lake. This helps maintain an oligotrophic state by lowering the available nutrients that would be returned to the photic zone during mixing. An example of this is seen with Fe (iron). In solutions with a higher Eh, iron is in the form Fe³⁺. This oxidized form of iron can bind with PO₄ (phosphate) and precipitate it out of the solution and sit harmlessly at the bottom of the lake. However, if the hypolimnion becomes anoxic and the Eh becomes less positive the Fe³⁺ that is bound to the PO₄ will become Fe²⁺ and release the PO₄ back into solution. These extra nutrients encourage algae blooms and can start the lake down the slippery slope to eutrophication.

In Bear Lake, the surface Eh value of +163mV and at the bottom it was +143mV. From top to bottom there is little difference, meaning that there is a tendency for Fe to be in the form of Fe³⁺ all the way to the bottom. This can also be seen by the fact that there is DO at the bottom. **There is no concern for Redox values in Bear Lake at this time.**

Conductivity

Bear Lake conductivity increased by about 20 μ mhos in both surface and bottom waters. This indicates an increase in free ions. This increase has little impact on the quality of Bear Lake because the readings still fall near the bottom range of mesotrophic conductivity levels of 129-650. This is a healthy range for the lake because it promotes a thriving ecosystem for aquatic plant and animal productivity. **This is normal for N. Michigan lakes.**

pH:

The pH on the surface from this year was 8.5 which is slightly basic. However this pH is very common for the lakes in the area due to the limestone bedrock commonly found in Michigan. It was more basic at the bottom with a pH of 9. These values are slightly higher than last year. Last year's values were 8.4 at the top and 7.4 at the bottom. There is not enough data to conclude if this is a major change for the lake or if these are the standard ranges. **This is normal for N. Michigan lakes.**

Total Dissolved Solids:

For oligotrophic lakes, the EPA acceptable concentration for TDS ranges from 100 - 20,000 mg/L. The range for drinking water is 25-250 mg/L. With Bear Lake having a TDS of 170-184 mg/L, the water is well within acceptable and normal parameters.

This is normal for N. Michigan lakes.

Plankton:

Fragilari was the most abundant among the phytoplankton. Diatoms such as this genus are usually the most dominant algae in oligotrophic lakes. The second most abundant phytoplankton was *Chroococcus*, which is a blue-green algae. High abundance of blue-green algae in lakes is one indicator of high phosphorus leading to eutrophic conditions. Because the abundance of *Chroococcus* wasn't high in Bear Lake, this is not a reason for alarm. Algal abundance, however, should be monitored periodically (eg, every 1-3 summers).

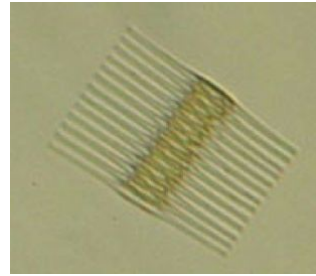
Zooplankton abundance is related to quality and quantity of food. *Diaptomus* was the most abundant among the zooplankton and is usually seen solely during the summer. *Daphnia* was the second most abundant genus. These two are both herbivores (primary consumers) and ingest phytoplankton. The abundance of both types indicates an abundance of phytoplankton as well. This is a normal condition for "healthy" lakes in N. Michigan.

Phytoplankton:



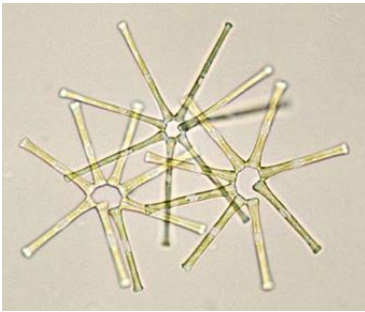
Chroococcus

<http://protist.i.hosei.ac.jp/PDB6/PCD0300/htmls/10.html>



Fragilaria

<http://microlife.parvarium.com/Ochrophyta.html>



Asterionella

<http://www.microscopy-uk.org.uk/mag/indexmag.htm>



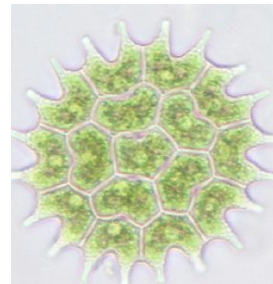
Navicula

http://protist.i.hosei.ac.jp/pdb/images/heterokontophyta/Raphidineae/Navicula/phyllepta/sp_6f.jpg



Ceratium

<http://www.palaeos.org/index.php?title=Ceratium&oldid=25417>



Pediastrum

<http://www.discoverlife.org/mp/20q?search=Pediastrum>



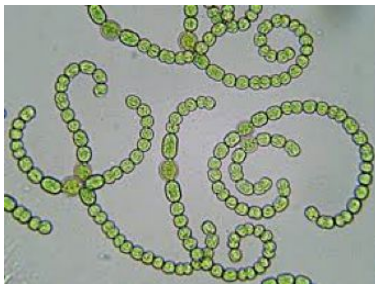
Cosmarium

https://www.algae.su/details.php?image_id=24&l=english



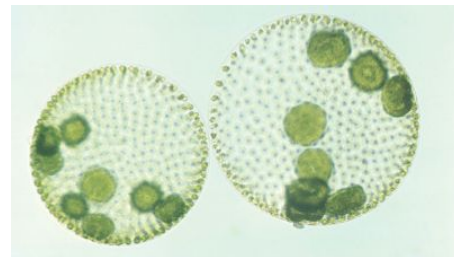
Dinobryon

http://protist.i.hosei.ac.jp/PDB/Images/heterokontophyta/dinobryon/sp_5b.html



Anabaena

<http://www.loughallenbasin.com/wlog.html>



Volvox

<http://www.carolina.com/protozoa/volvox-globator-living/131864.pr>

Zooplankton:



Cyclops

<http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2711>



Diaptomus

<http://www.photomacrography.net/forum/viewtopic.php?t=9966>



Daphnia

<http://micro.sci-toys.com/stacking>



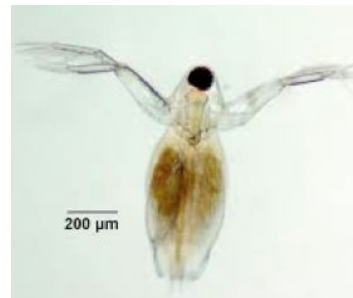
Nauplius larva

https://en.wikipedia.org/wiki/Crustacean_larvae



Old Nauplius

<http://www.icm.csic.es/bio/projects/gezm/copepods/copepods.htm>



Diaphanosoma

<http://cfb.unh.edu>



Bosmina

<https://www.studyblue.com/notes/n/larval-fish-zooplankton-benthic-inverts/deck/11413481>

Benthos:

Zebra mussels are an invasive species that are almost impossible to get rid of once they have been established in a lake. According to the Minnesota DNR, zebra mussels can clog water intakes for power plants, attach onto boat motors reducing efficiency, and attach to rocks and swim rafts causing swimmers to cut their feet. Zebra mussels were found in Bear Lake both in 2014 and 2015. This could possibly bring challenges for removal and containment in the future. Also, the lack of bloodworms

(*Chironomus plumosus*) is puzzling because we expected to find them as they are benthic residents in similar lakes in the area (eg, Big Twin, Pickerel, and Big Blue). Overall, the presence of zebra mussels is a concern. We recommend that yearly benthos samples be taken at several locations around the lake so that the presence and relative abundance of this invasive species is monitored. Presence or absence of blood worms can be assessed at the same time.

Bacteria:

E. coli is naturally found in the intestines of humans and animals but can easily be cultured in a lab with the right tools. Because of this, it is used as an indicator for the presence of sewage in lakes. According to EAI Analytical Labs, drinking water should have no *E. coli* present, whereas a level less than 88 per 100 mL is safe for swimming and recreational sites (Figure 18). Areas not designated for swimming should not have more than a level of 406. Therefore, the level found in Bear Lake (33 *E. Coli*/100 mL) is safe for both recreation and swimming, but not for drinking. Even with concerns brought up about certain homes having old septic systems very close to shore, the lack of *E. coli* present in the dishes indicates that there is minimal/no sewage leaking into the lake. Unfortunately, the bacteria samples taken during our second sampling on July 27, 2015 were misplaced and not counted. Overall, bacteria numbers for those areas of the lake where we sampled were low and not a cause for concern. In the future, these and other locations should be monitored yearly or at least every other summer .

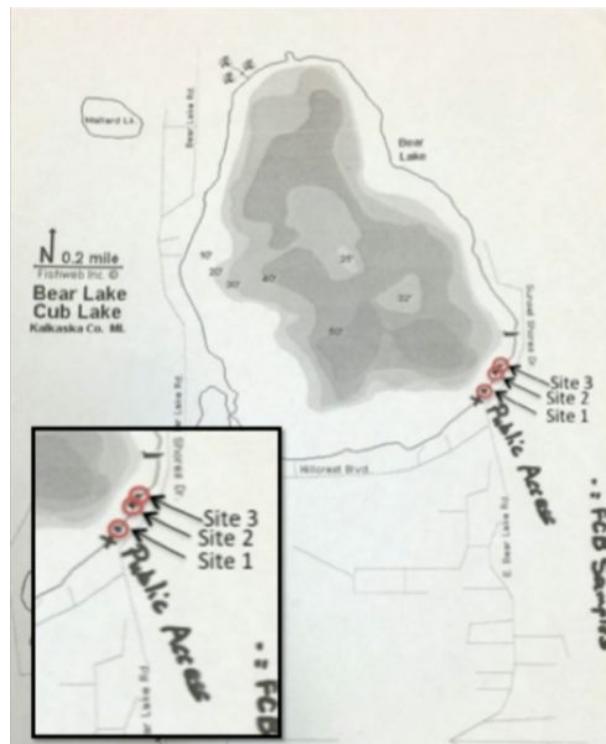


Figure 18: First three sites where bacteria samples were taken.

CONCLUSION:

Because this is only the second year the Au Sable limnology class has sampled Bear Lake, there is not enough data to conclude any definitive results. That being said, the trends that were noticed for Bear Lake through our two years of sampling, however slight they may be, do appear to be heading in the desired direction for an oligotrophic environment. This infers that the efforts of the Bear Lake residents have been effective and the continuation of such efforts are encouraged. The Au Sable Institute would like to thank the residents of Bear Lake for their kindness and generosity in allowing Au Sable students to work with them in a cooperative effort to sample and study Bear lake. The Au Sable limnology class would also like to thank the residents of Bear Lake for their valuable insight on lake life as well as congratulate the residents for their caring attitude and devotion towards the preservation of their lake.

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Disclaimer: This report is written by undergraduate students in the Lake Ecology & Management class. All results and observations are tentative and should be taken that way. While sponsoring this work, Au Sable Institute takes no responsibility for this report.