Summer Session II Limnology Report:
Bear Lake

Bear Lake Township, Kalkaska County, MI.

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<u>Introduction</u>

Bear lake is a 316-acre glacially formed lake in Kalkaska County, Michigan that lies within the Manistee River watershed. Bear lake is a well developed lake with residences covering the circumference of the entire lake. This lake is managed as a two-story lake, meaning that the epilimnion and metalimnion zone provides suitable habitat and nutrients for gamefish such as bass and panfish, while the hypolimnion zone provides habitat and nutrient requirements for fish such as trout.

Bear Lake is specifically a kettle lake. When a glacier is retreating in the glacial outwash plain, large blocks of ice are left behind that form a depression, and if below the water table, a kettle lake is formed such as Bear Lake.The topography surrounding Bear Lake is hilly, mostly forested, with predominantly sandy soils. The southeast corner of Bear Lake provides public access with a paved launch ramp, and parking for a few vehicles with trailers.

Bear Lake is fairly round and of uniform shape with no inlets or outlets. However, it does have a small, shallow connected “pond” named Elanor Bay on the southwest corner, as seen in Figure 1, several acres in size that at its deepest point is only 1 to 1.2 meters deep. With only 16 per cent of the waters shallower than 2 meters, Bear Lake has a small littoral zone that borders the edge of the lake, and an extensive limnetic zone with 45% of the lake being deeper than 6 meters as seen in Figure 2. In these zones, the light does not penetrate to the bottom for plant growth.

We were asked by the Bear Lake Association to perform a shoreline assessment and advise accordingly. The assessment, sampling and data collecting were performed

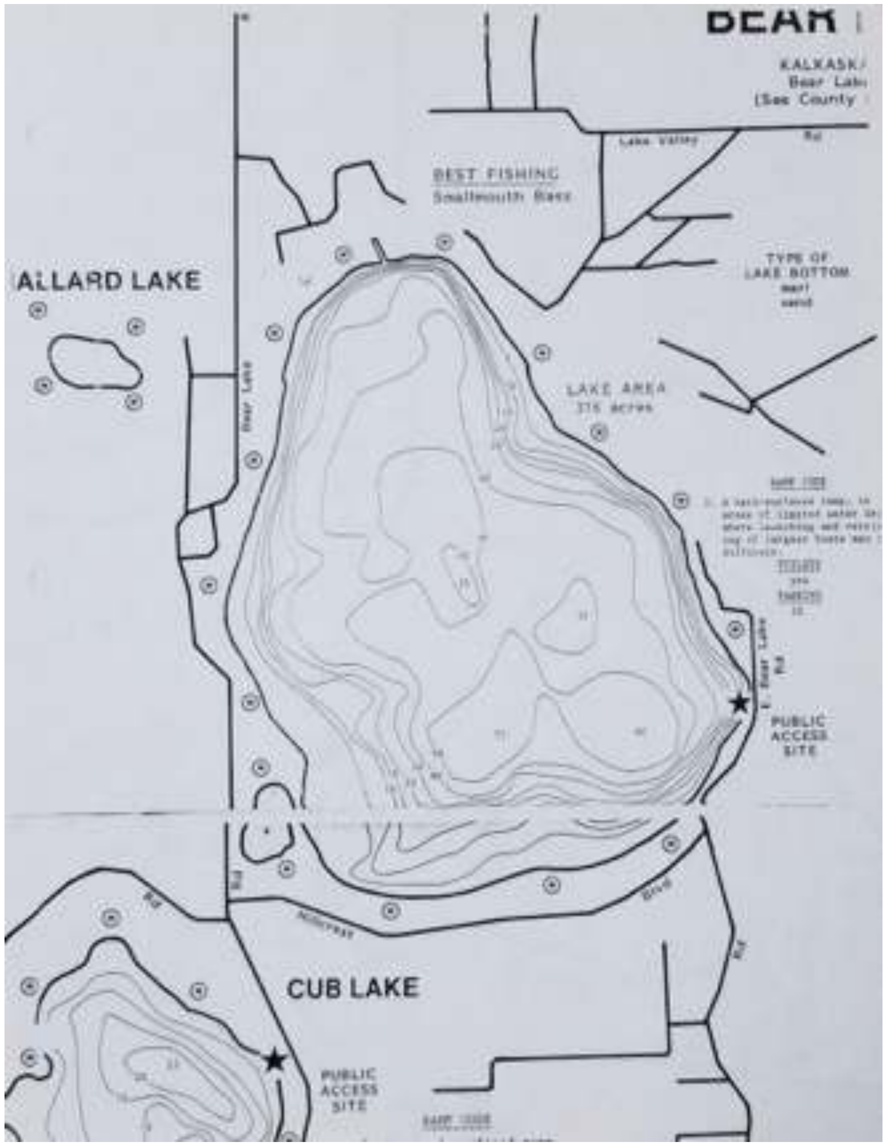


Figure 1: Bathymetric map of Bear Lake (Source: Lake maps of Kalkaska County)

on Tuesday July 23rd and Thursday July 25th. Due to the wind and the instability of the boat, confidence in the accuracy of the data collected on July 23 is limited, and therefore will not be included. On July 25th, the wind speed was only 4 mph and with the air temperature of 27°C, the weather allowed for better data collection. It was approximately 25% cloudy at 14:00, the time of sampling Bear lake. This report is on the current condition of Bear Lake by the 2019 limnology class taught by Dr. John Korstad.

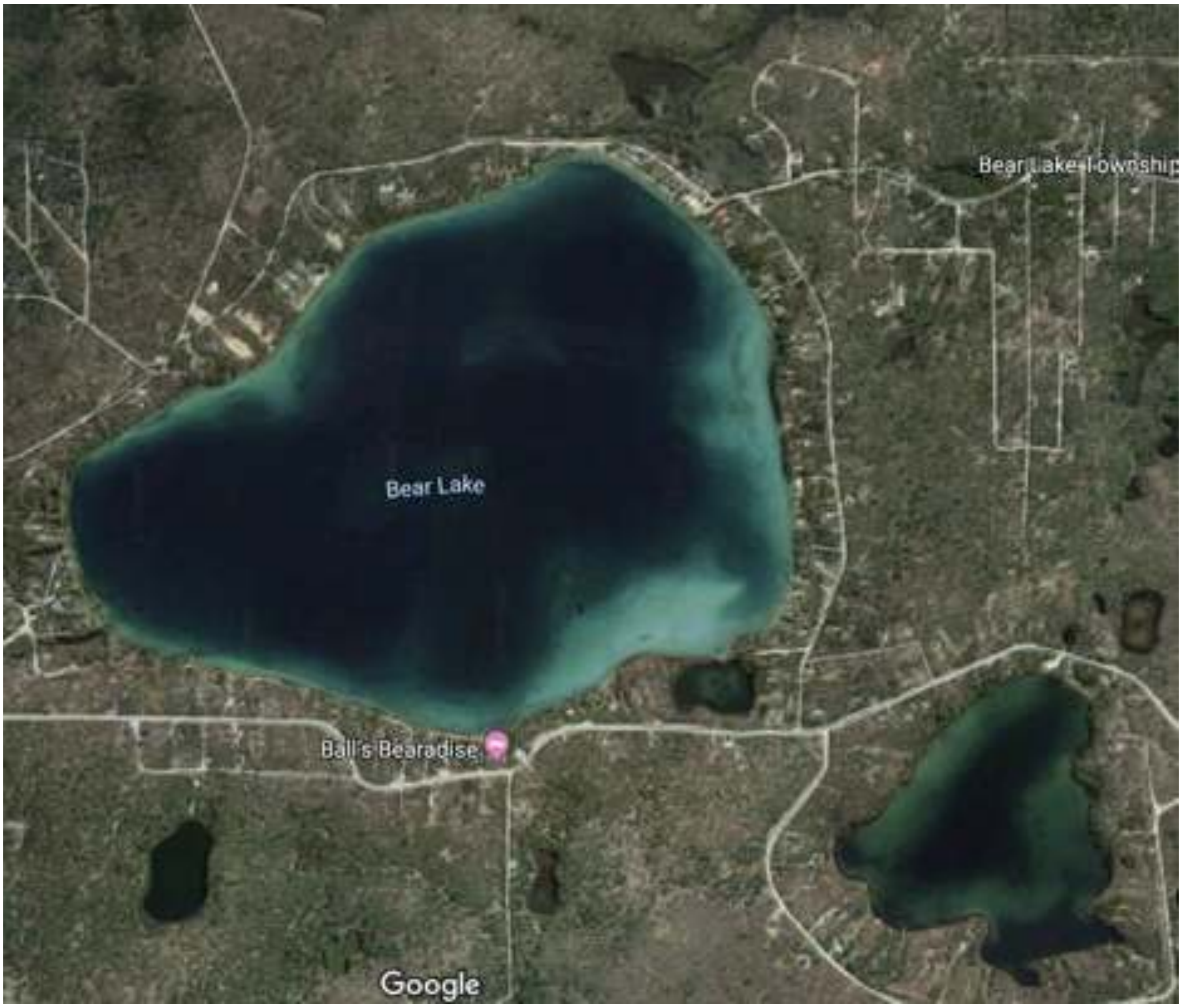


Figure 2: Satellite map of Bear Lake (Source: google maps)

<u>Materials and Methods</u>

Our class sampled Bear Lake using resident Sam Rahaim's pontoon boat. We also completed a shoreline assessment, assessing the vegetation and seawall per cent cover, and shore angle around the entire lake.

Temperature of Water: Thermal Stratification and Lake Turnover

Thermal stratification is a phenomenon that causes the waters to form distinct layers as a result of sunlight that penetrates the surface waters. The density of water is dependent on its temperature. The colder the water, the higher density it is. Conversely, the warmer the water, the less dense it becomes. Water density affects the mixing of the waters because the greater the difference in density, the more unlikely the water layers will mix. As a result, the lake "stratifies," typically forming three different layers and is known as thermal stratification.

The layer closest to the surface, called the epilimnion, readily receives the sunlight, is the warmest and has the least dense waters. The deepest layer at the bottom of the lake, known as the hypolimnion, is the coldest and has the most dense waters. The middle layer, or metalimnion, is the transition zone between the warm waters of the epilimnion and the cool waters of the hypolimnion. Within the metalimnion, at the point of the greatest temperature and density differences, is the thermocline. In this zone the temperature decreases an average of 1° Celsius per meter.

In areas that experience seasonal temperature differences, such as northern Michigan, lakes often undergo a turnover. As the surface waters begin to cool they become denser, causing the epilimnion to extends down towards the hypolimnion, weakening the thermocline so that mixing between the layers becomes easier. The mixing occurs until the entire lake is the same temperature, known as isothermal, and allows lake turnover to occur. In lakes like Bear Lake, in climates such as northern Michigan, Lake turnover occurs twice a year; in the fall and the spring.

Transparency of Water (Secchi Depth) and Trophic State Index

The Secchi disk is used to measure relative transparency of the water. It is lowered into the water until it is no longer visible from the surface and the depth at which this point occurs is recorded. This test gives an idea of the particulate matter, mainly phytoplankton in the water. If the Secchi depth is between 8-40m it is considered to be an oligotrophic lake due to low levels of nutrients leading to low phytoplankton present in the lake. Likewise, if visibility is between 0.1-2 it is considered a eutrophic lake due to much higher levels of nutrients. Resulting in higher algal growth and therefore higher turbidity of water.

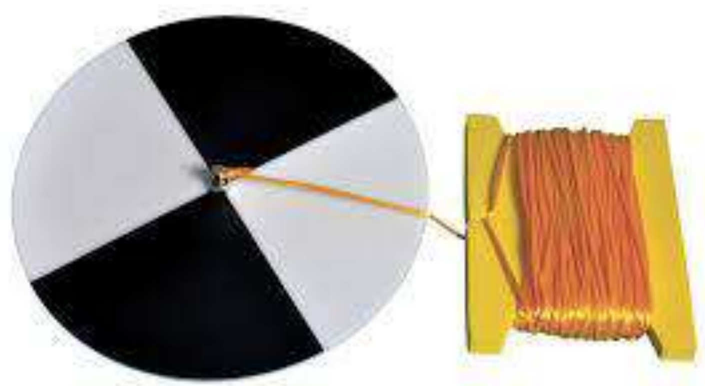


Figure 3: Secchi Disk (Source: schoolspecialty.com)

The Trophic State Index (TSI) is a classification system that rates a waterbody based on the biological productivity that occurs in the water. The TSI quantifies water quality using the Secchi depth, chlorophyll-a concentrations (algal biomass), and total

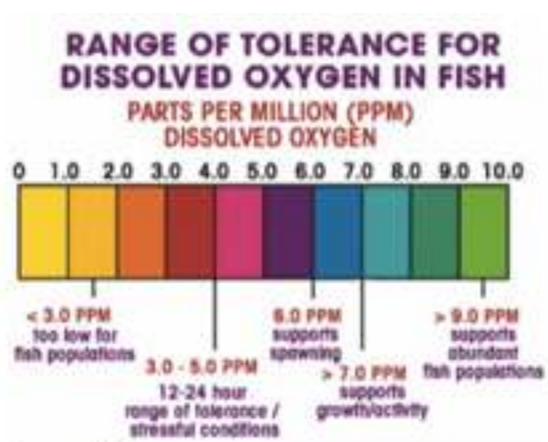
TSI (Carlson 1977)	TROPHIC STATUS INDEX & WATER QUALITY (for additional information, go to: MPCAs Citizens Monitoring Handbook)
< 30	Oligotrophic; clear water; high DO throughout the year in the entire hypolimnion
30-40	Oligotrophic; clear water; possible periods of limited hypolimnetic anoxia (DO =0)
40-50	Moderately clear water; increasing chance of hypolimnetic anoxia in summer; fully supportive of all swimmable/aesthetic uses
50-60	Mildly eutrophic; decreased transparency; anoxic hypolimnion; macrophyte problems; warm-water fisheries only; supportive of all swimmable/aesthetic uses but "threatened"
60-70	Blue-green algae dominance; scums possible; extensive macrophyte problems
70-80	Heavy algal blooms possible throughout summer; dense macrophyte beds; hypereutrophic
> 80	Algal scums; summer fish kills; few macrophytes due to algal shading; rough fish dominance
	TSI - P = 14.42 * Ln [TP] + 4.15 (in ug/L) TSI - C = 30.6 + 9.81 Ln [Chlor-a] (in ug/L) TSI - S = 60 - 14.41 * Ln [Secchi] (in meters) **Average TSI = [TSI-P + TSI-C + TSI-S]/3**

Table 1: Trophic State Index
Source: *Lake Access*, www.lakeaccess.org/lakedata/

phosphorus level on a scale between 0 and 100, shown in Table 1. For this report however only Secchi depth was used to calculate TSI.

Dissolved Oxygen and Temperature YSI Electronic Probe

Dissolved oxygen (DO) is naturally 10,000 times more concentrated in air than water. Oxygen dissolves into water in one of two ways: physically at the surface air mixes with water, and biologically when aquatic plants undergo photosynthesis. The level of DO required by aquatic animals varies, but a value of at least 5.0 ppm is desirable for most aquatic organisms.



DO decreases with rising temperature, so values are expected to be higher in winter and lower in the summer. DO also usually decreases with depth so surface DO values are higher than at the bottom of the lake. The DO in lakes and ponds with high nutrient concentration can change dramatically throughout the day because of photosynthesis. YSI electronic probe was used to measure the dissolved oxygen content and temperature in degrees Celsius was recorded at every meter from the surface to the bottom. Dissolved oxygen is measured in units of parts per million (ppm).

Figure 4: Dissolved Oxygen Tolerance
Source: PBS.com

Figure 5: YSI Electronic Probe
Source: nclabs.com

Light

Light penetration was measured every meter of depth from the surface to the bottom. A protomatic light photometer was used (Figure 6). This is another way to assess whether the lake is oligotrophic or eutrophic based on the amount of phytoplankton in the water.

Figure 6: Protomatic light photometer
Source: ebay.com

Alkalinity & Hardness

Alkalinity is the measurement of the water's ability to resist changes in pH. If a lake has low alkalinity it is more susceptible to rapid changes in pH when acids or bases enter the water. Using a Van Dorn Bottle Sampler (Figure 7), we collected water from the bottom of the lake. A Hach titration kit (Figure 8) was used to test water samples from both the surface and bottom of the lake.

Figure 7: Van Dorn Bottle Sampler
Source: ecoenvironmental.com

Figure 8: Hach Titration kit
Source: hach.com

Hardness

Hardness is a measure of the amount of Calcium and Magnesium ions in water which results mainly through the weathering of rocks. Limestone is a natural source of hardness; which interestingly enough the bedrock in this area of North America was previously coral reefs. Its chemical name is calcium carbonate ($CaCO_3$), or magnesium carbonate ($MgCO_3$).

Table 2: Water Hardness as CaCO3	
0 - 20 mg/L	soft
21 - 60 mg/L	Moderately soft
61 - 120 mg/L	Moderately hard
121 - 180 mg/L	Hard
More than 181 mg/L	Very Hard

Dissolved limestone is an important feature of healthy lakes, but too much calcium or magnesium ions not only makes the water "hard", leading to scaly deposits, but it can also lower fish reproduction. Most fish and aquatic organisms live in water hardness between 15 and 200 mg/L Table 2. Hardness was performed with the Hach titration kit (Figure 8) with surface and bottom water being tested.

Source: *Water Chemistry Monitoring*. 6th ed., Alabama Water Watch Association, 2018.

pH, Conductivity, & Redox Potential

The pH of a lake can change throughout the season and sometimes even daily. The pH is affected by atmospheric carbon dioxide (CO_2) because CO_2 in water forms a weak acid known as carbonic acid. The optimal pH range for healthy aquatic life is between 6.0 and 8.5. A pH that is higher than 11 or lower than 4 is lethal to fish and most aquatic life.

Figure 10: Wireless Probe
Source: vernier.com

Monitoring pH levels of a lake after a heavy rain can inform homeowners about potential runoff issues. Vernier GoDirect Wireless Probes

(Figure 10) was used to calculate pH, Conductivity, and Redox Potential of surface and bottom water in the lake.

Source: coastadapt.com

Table 3: Effects of pH on Fish and Other Aquatic Life	
pH	Effects
Higher than 11	Alkaline death point
9.0 - 11.0	Slow growth and limited production
6.0 - 8.5	Optimum range
4.0 - 5.5	Slow growth, no reproduction in many species
Under 4.0	Acid death point

Plankton Samples

The diversity and abundance, or lack of zooplankton and phytoplankton can inform us about the health of a lake. An 80μm mesh plankton net (Figure 12) was used to collect samples of zooplankton and phytoplankton from the lake. The net was lowered three times from the surface to the bottom to obtain a dense sample that was later preserved and identified using a microscope in the lab.

Figure 12: Plankton net
Source: sciencefirst.com

Coliform Bacteria

We used Coliform Easygel and a pipet at each of the 10 sites. The test was done twice at each site for a total of 20 tests. Sites were selected by the Bear Lake Association representatives for three reasons: to ensure older septic tanks were intact and not releasing coliform bacteria; as advised by limnologist, excessive/new aquatic plant growth. Following the Coliscan Easygel kit directions, we sampled 3 ml of water from each site and took the sample back to the lab to put them in Petri dishes and placed them in an incubator at 37 degrees Celsius for 30 hours.

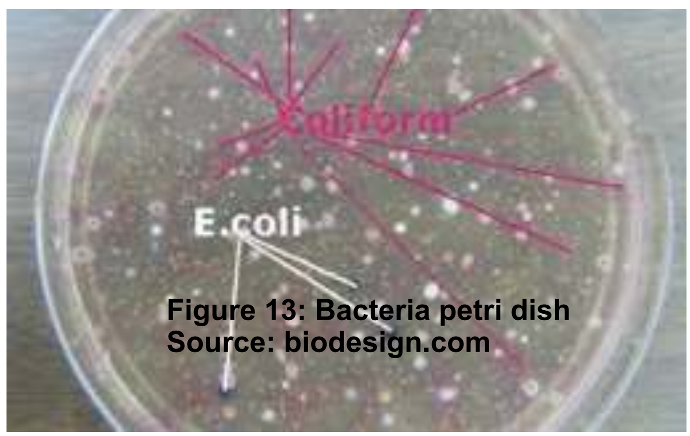


Figure 13: Bacteria petri dish
Source: biodesign.com

Benthic Sample

Benthos were collected using an Ekman Dredge (Figure 14) lowered to the bottom of the lake. The sample was placed in a sieve bucket in order to examine organisms collected from the benthic zone. The amount of organisms present in this sample gives us a good idea of the amount of dissolved oxygen present at the bottom of the lake.

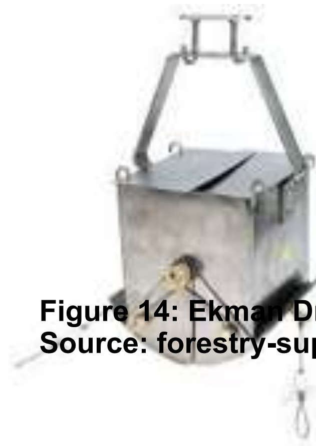


Figure 14: Ekman Dredge
Source: forestry-suppliers.com

Shoreline Analysis

The rate at which erosion of your shoreline occurs depends on a number of factors, including:

- Height and composition - such as silt, sand, gravel, and boulders.
- Amount and type of vegetation
- Groundwater movement and drainage patterns

As seen in this diagram from the Environmental Protection Agency (EPA).

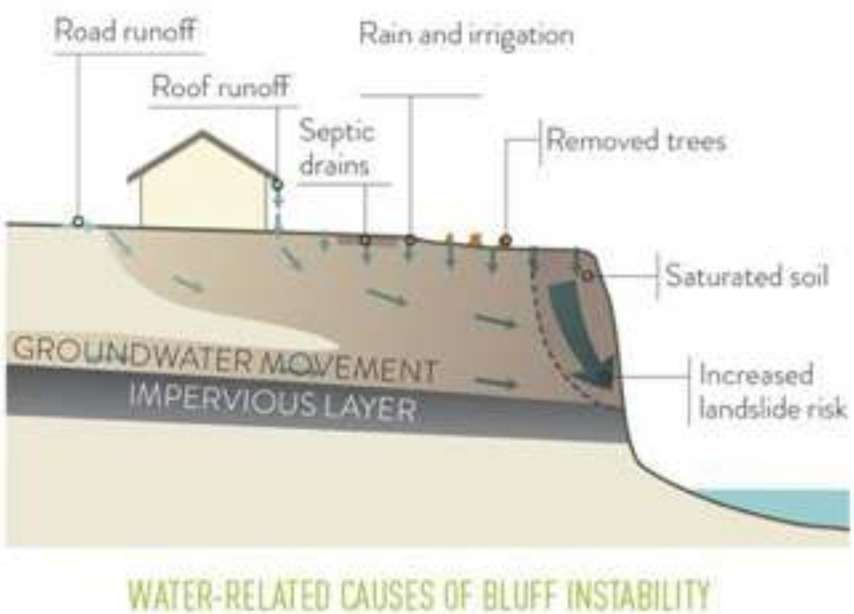


Figure 19: “EROSION ON BLUFFS.”
Source: EPA

As waves erode the bottom of lakeshore bluffs they loosen the soil, washing it away. Additionally, increased groundwater movement from road and roof runoff, septic drains, rain and irrigation increase the saturation of the soil.

Vegetation along the shoreline mitigates erosion because root systems hold soil in place. Vegetation, such as native plants, and drift logs help dissipate wave energy, mimicking nature and protecting property.

Not only are steep slopes, or bluffs, at a larger risk of erosion, but they also are at risk of sudden landslide or collapse. This is because as the wave hits the shoreline, it “licks” out the soil beneath the surface of the water, leading to an unstabilized bank that eventually collapses into the water.

Ground Water Movement and Drainage

Land development, can increase the intensity and effects of runoff. Surfaces such as roads, roofs, driveways and grass all increase the amount of water runoff that would otherwise penetrate the ground. Nutrients, pollutants and sediments that were on the surface are picked up in the runoff and carried into the lake, each adding to the particulates and overall concentration of the various “contaminants.” In this way, runoff is the number one process of cultural eutrophication, and something that should be managed closely.

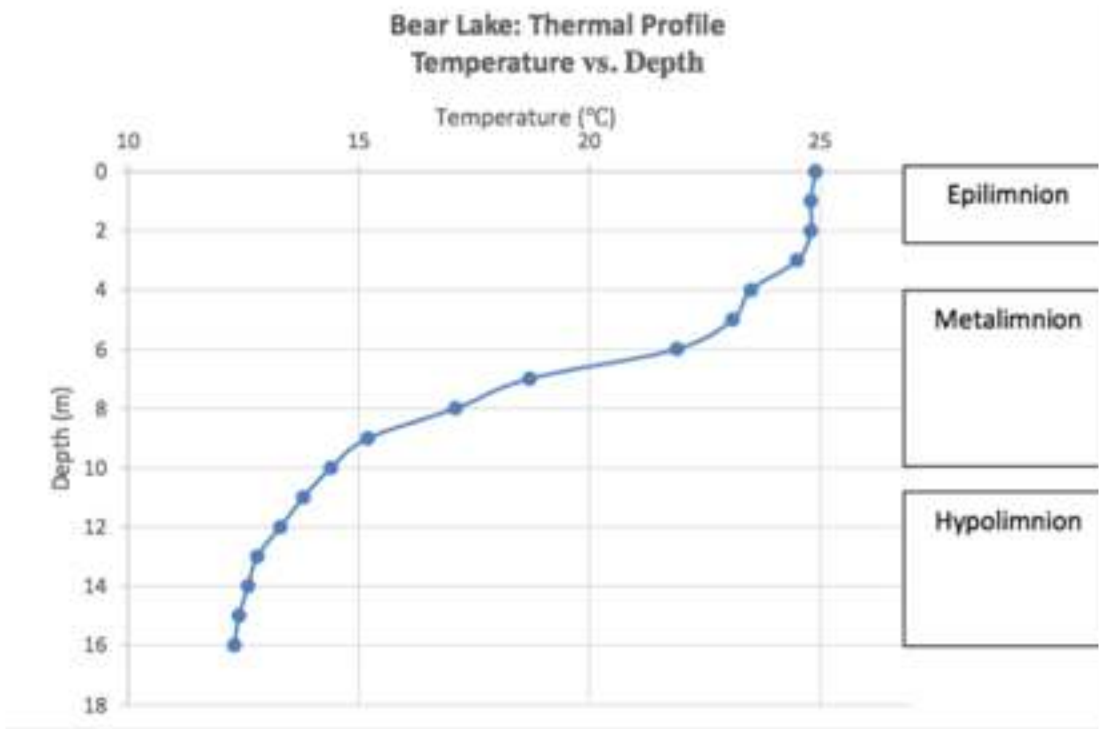
<u>Results</u>

Temperature with Depth

Figure 15 shows the characteristic summer lake temperature of a thermally stratified lake. The temperature gradually decreases in the upper waters of the epilimnion. At about 3 meters deep, the water temperature decreases much more rapidly until about 10 meters deep, this zone of transition zone in the metalimnion layer is known as the thermocline. This is an expected response of a healthy lake and is a function of the temperature and densities of the water. Because the lake is not undergoing a mixing in the summer this gives evidence that this lake is undergoing thermal stratification.

Dissolved *Oxygen with Depth*

The dissolved oxygen vs depth graph (Figure 16) shows the average content of DO at given measured depths of the lake. In the epilimnion, from the surface to about 2 meters DO levels are just below 10 ppm. The DO content then suddenly rises at 4 meters until 11 meters of depth. At 12 meters of depth the DO levels begin to drop until they level out at 11 ppm. The DO levels are above the minimum levels in each zone and well within the healthy range of supporting an abundant amount of life. Due to its very



low nutrient level, Bear Lake is able to maintain

Figure 15: Temperature vs Depth Graph

dissolved

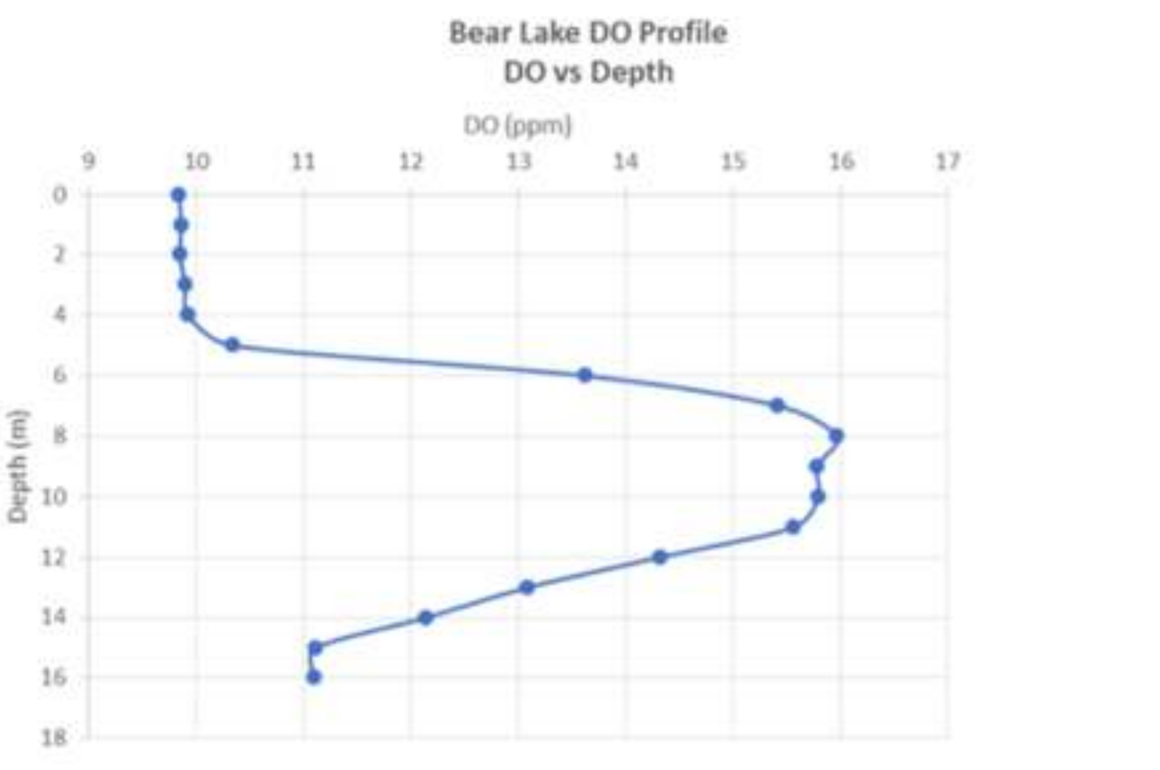


Figure 16: DO vs Depth Graph

oxygen throughout most of the water column for the entire summer. Only in the very deep waters does the dissolved oxygen become low.

Light Penetration with Depth

As we lowered the protomatic light photometer every meter starting at the surface light penetration decreased as evident in our graph (Figure 17), which is not surprising because most lakes are this way due to nutrients and other elements limiting light penetration.

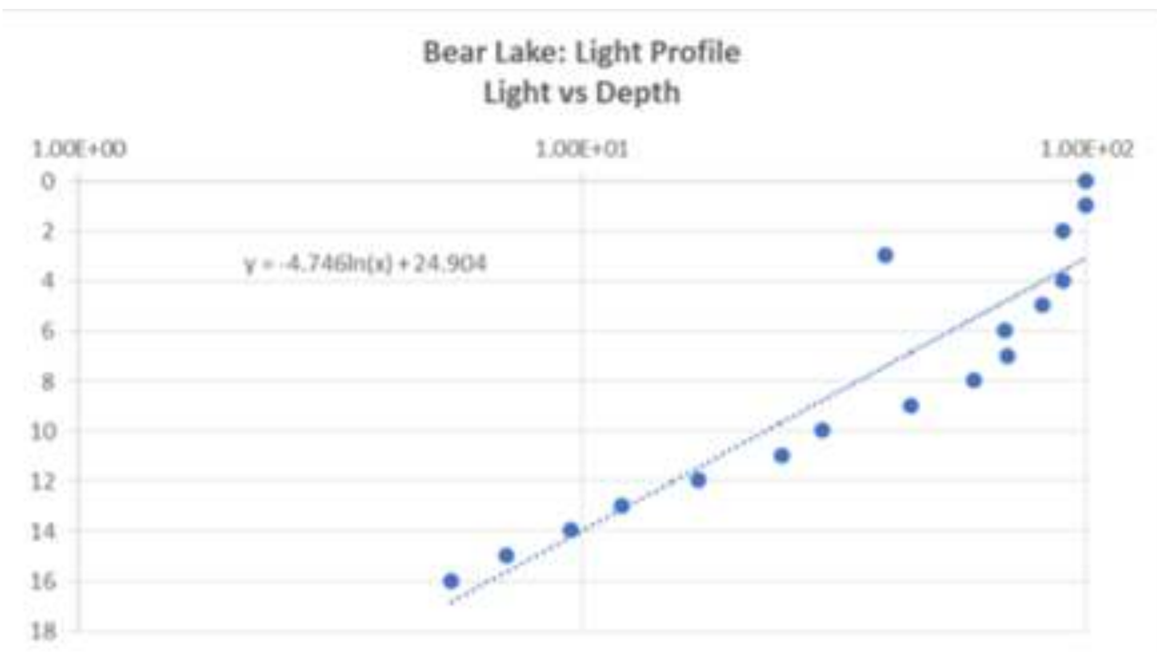


Figure 17: Light vs Depth Graph

Chemical Data

Table 4: Chemical Data

	Secchi Depth (m)	pH	Conductivity (µmhos)	Redox Potential (mv)	Alkalinity(mg/L)	Hardness (mg/L)
Surface	5.0	7.3	211.3	112.4	98	79.6
Bottom		7.54	232.7	119.8	86	83.2

Data collected on July 25, 2019, from Lake Ecology 330

According to Table 4 below, Bear Lake has an average alkalinity and hardness for an oligotrophic lake. Hardness is higher at the bottom compared to the top because it is groundwater fed like most lake in this area of Northern Michigan. Alkalinity

decreases at the bottom compared to the surface because calcium precipitates toward the bottom. Conductivity is higher at the bottom because of dissolved calcium ions that originate from weathering of rocks which are found at the lakebed. Redox potential is lower at the bottom of the lake because there is less dissolved oxygen in the benthic zone.

Shoreline Analysis

The shoreline angle, seawall and percent vegetation can be seen in Table 5, below. In the analysis of the shoreline survey, it can be evident that there is a wide variation of bank slopes, vegetation, and run off, with a large percentage of the shoreline area having a slope over 75°. Natural vegetation is important in limiting

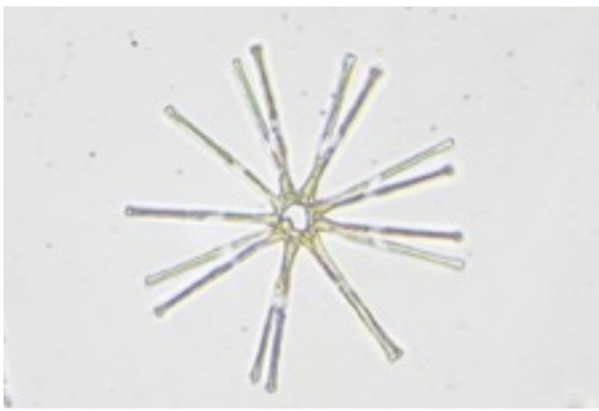
Table 5: Shoreline Data

Section Number	Location name	Coordinates	Shore Angle	Percent Vegetation	Percent seawall	Photo time	Notes
1	Public access	44.7245665-84.9371625	15°	1%	80%	2:20pm	Human interaction
2	Turtle Rentals	44.7256528-84.9359693	25°	75%	0%	2:24pm	Little vegetation
3	First Cottage	44.7269743-84.9357121	80°	10%	90%	2:27pm	Seawall into water Eroded Sand exposed
4	Chiarrellia	44.7278888-84.9364752	70°	90%	0%	2:32pm	Sand + exposed Erosion 6 decks
5	Murray	44.7308391-84.9386005	45°	10%	40%	2:36pm	Sand beaches, lowered hill
6	Donaldson	44.7311408-84.9394179	75°	95%	75%	2:44pm	Erosion on steep slope Water lilies smartweed
7	Barrett	44.7355890-84.9433651	15°	80%	10%	2:56pm	Smaller lot
8	Inlet (Waynes)	44.7351365-84.9476104	70°	90%	50%	3:07pm	Cattails
9	Winstead	44.7299499-849500100	35°	60%	20%	3:17pm	Lakeside construction 2 properties with erosion
10	Zeno	44.7280801-84.9501920	45°	80%	30%	3:28pm	3 coniferous dying
11	Root	44.7269131-84.949190	10°	95%	5%	3:33pm	Road end-overgrown
12	Purtill	44.7230603-84.9478930	60°	75%	40%	3:36pm	Undercut

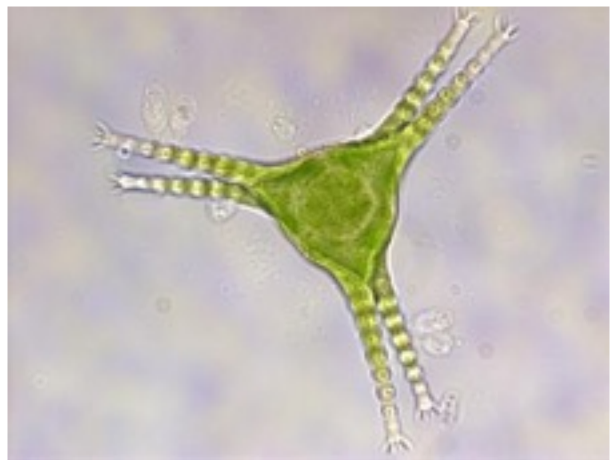
erosion of the shoreline. Examples of this can be seen along the shoreline in areas with vegetation compared to areas without vegetation.

Plankton

Plankton that was collected from Bear Lake included genus *Ceratium*, *Staurastrum*, *Diaptomus*, *Gleocapso*, *Aphanocapsa*, *Ceeosphaerium*, *Oedogonium* and *Polyarthra*. Although a benthic sample was collected, we did not identify any benthos.



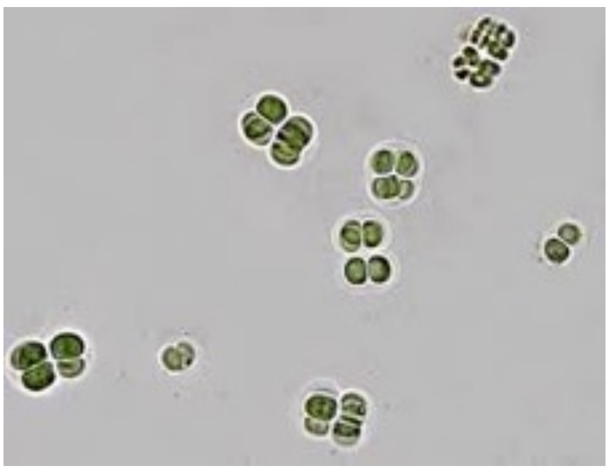
Asterionella
Source: shetlandlochs.com



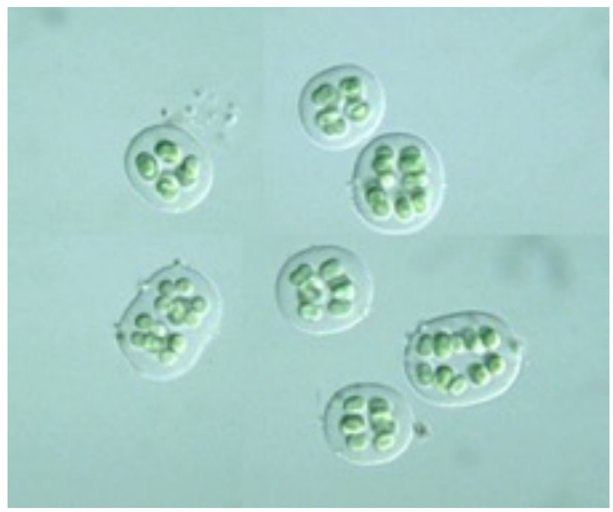
Staurastrum
Source: http://oceandatacenter.ucsc.edu

Ceratium
Source: Algal Web

Diaptomus
Source: Coinme



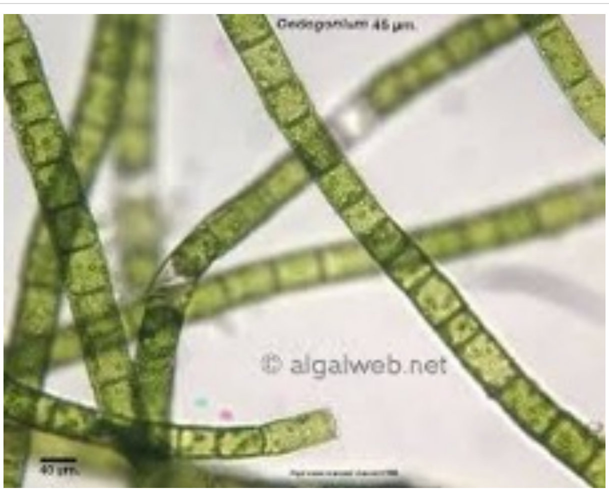
Gleocapso
Source: PhycoKey



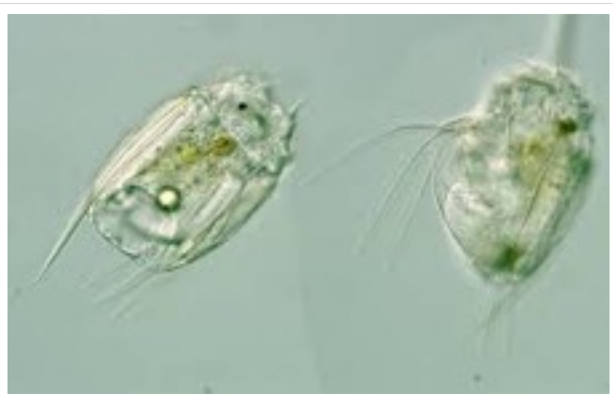
Aphanocapsa
Source: Protist information server

Table 6: Coliform Bacteria

Location of Sample	#Blue+Purple Colonies (Fecal Coliforms)	Average CFU/100ml per site	#Pink + Red Colonies (Non-Fecal Coliforms)	Average CFU/100ml per site
Public access	0		10	
Public access	0	0	4	233.1
Turtle Rentals	0		0	
Turtle Rentals	0	0	0	0
First Cottage	0		0	
First Cottage	0	0	0	0
Donaldson	0		1	
Donaldson	0	0	1	33.3
Inlet (Waynes)	0		0	
Inlet (Waynes)	0	0	0	0
Zeno	0		0	
Zeno	0	0	1	16.65
Purtill	0		0	
Purtill	0	0	0	0
McKee	0		0	
McKee	0	0	0	0
McClain	0		0	
McClain	0	0	0	0
Loonhardi	0		0	
Loonhardi	0	0	0	0



Oedogonium
Source: AlgalWeb



Polyarthra
Source: Protist information server

Coliform Bacteria

A summary of the bacteria data are included in Table 6 below. There were no fecal coliforms found in any of the 20 samples of taken from Bear Lake. Very few non-fecal coliforms were found in the samples, no more than 1 coliform, except for the public access site.

Trophic State Index (TSI)

The Trophic State Index using the Secchi disk depth was calculated to be 37; using the formula: 60 - [14.41 * ln(5.0)]= 36.81. This TSI indicates that Bear Lake is an oligotrophic lake, meaning it is good water quality with low biological productivity because of low nutrient content.

Recommendations and Conclusion

Bear Lake has shown to be a healthy oligotrophic lake after our sampling and data interpretation. With no identification of fecal coliforms the Bear Lake residents seem to be practicing good septic tank management strategies, and should continue to monitor and update them as needed in the future. The highest level of Non-fecal coliforms was 233 CFU/100mL, and was found at the public beach access. At 233 CFU/100mL, Bear Lake is performing exceptionally well.

There was a relatively high level of plankton diversity. This could suggest that the aquatic ecosystem is in a healthy equilibrium. However, it should be noted that there were increased numbers of bluegreen algae. Because an abundant amount of bluegreen algae is an indicator eutrophication, this should be closely monitored. Bear Lake is well within a healthy range of bluegreen algae; however, moving forward it will be important to continue to monitor. If increasing trends of bluegreen algae is noted it is important to take action. Having an action plan ready ahead of time is a good idea. Often, the most common reason for bluegreen algae growth is increased nutrients (usually phosphorus) so a good place to start an effective action is to communicate to the homeowners to be aware of their nutrient inputs. Encourage everyone who lives around the lake to not fertilize their lawns, or at least use non-P fertilizers; do not use garbage disposals; have septic tanks/fields inspected and upgraded as often as possible; mulch 'green' waste and use that to place around yard plants; use lake water to irrigate lawns and flowers; keep the littoral zone (nearshore aquatic plants like cattail) 'healthy' by protecting existing plants, adding more plants, etc. All of these actions add up and contribute to the over all health of your lake.

In conversation with home owners and lake association members from the area, the water level is higher than it has been in approximately 50 years, and levels are still rising. If this trend continues, bank erosion and sedimentation will continue. As a result, water quality could be negatively affected. Therefore, it is important to implement shoreline management plans to reduce the probability and rate of occurrence. The recommendations given here are by no means exhaustive; a much more thorough shoreline examination would be needed.

One of the best ways to protect your lake is to protect your shoreline. And one of the best ways to protect your shoreline, whenever possible, is to leave it in its natural state. If that is not possible, naturalization with native plantings, log berms/fallen dead trees and other natural wake protections as seen in this picture below.

Residents living on Bear Lake need to be encouraged to not remove natural vegetation from their property, particularly at the shoreline, as this removal of a buffer zone will increase the rate of erosion and eventually harm the ecosystem of the lake. Planting native aquatic plants at the shoreline can help filter the runoff and acts to clean the water.

As a waterfront property owner, you are the steward of your own special piece of Bear Lake. By naturalizing your shoreline where possible, you can help maintain the survival of native fish and wildlife. Protecting your property from erosion and cultural eutrophication is feasible, affordable and a smart investment for Bear Lake's future. In

conclusion, Bear Lake is in good condition and the continuation of management strategies will ensure a stable and healthy lake for the residence to enjoy!

Figure 18. Source: Shore Friendly

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