Bear Lake Report

23 June 2023

Au Sable Institute of Environmental Science

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Introduction

Bear Lake is one of many kettle lakes found in Northern Michigan. Located in Kalkaska County, it was formed after the Wisconsin glacier retreated from Michigan approximately 4,000 years ago (Kelley, 1960). Kettle lakes form as a result of glacial ice remaining in the ground and melting to form a lake. As a result, Bear Lake and all other kettle lakes normally do not have an inlet or outlet for their water. Bear Lake is a generally oval lake with a small lagoon attached to the southwestern corner of it called Eleanor Bay. This can be seen in the satellite image (**Fig. 1**). The depth of Bear Lake varies across the bottom of its basin, as seen in the morphometric map of the lake (**Fig. 2**). This kind of map displays the variation in depth which occurs across the bottom of bodies of water. As the map shows, the deepest part of the lake is approximately 18 meters (60 feet) deep (Michigan Lake Maps). Water level fluctuations are also normal, influencing factors coming from yearly precipitation, the quantity of vegetation in the watershed, and the water levels of lakes in the surrounding area. Five years ago, Bear Lake was at its highest level, but now it has gone down by approximately 0.6 meters (2 ft). Bear Lake currently has just over 150 houses along its shoreline. While shoreline erosion has been a problem historically, many improvements have been made to help reduce this. Other items to note include the monitoring of invasive species. Bear Lake has had some issues with the invasive reed *Phragmites,* but it appears these reeds have successfully been eliminated. Eurasian Watermilfoil (*Myriophyllum spicatum*) is another invasive species present in Bear Lake. This aquatic plant is currently receiving chemical treatment and it appears these population numbers have been going down.

Figure 1: Satellite imagery of Bear Lake, MI. Sites where bacteria samples were taken are labeled (Google Earth).

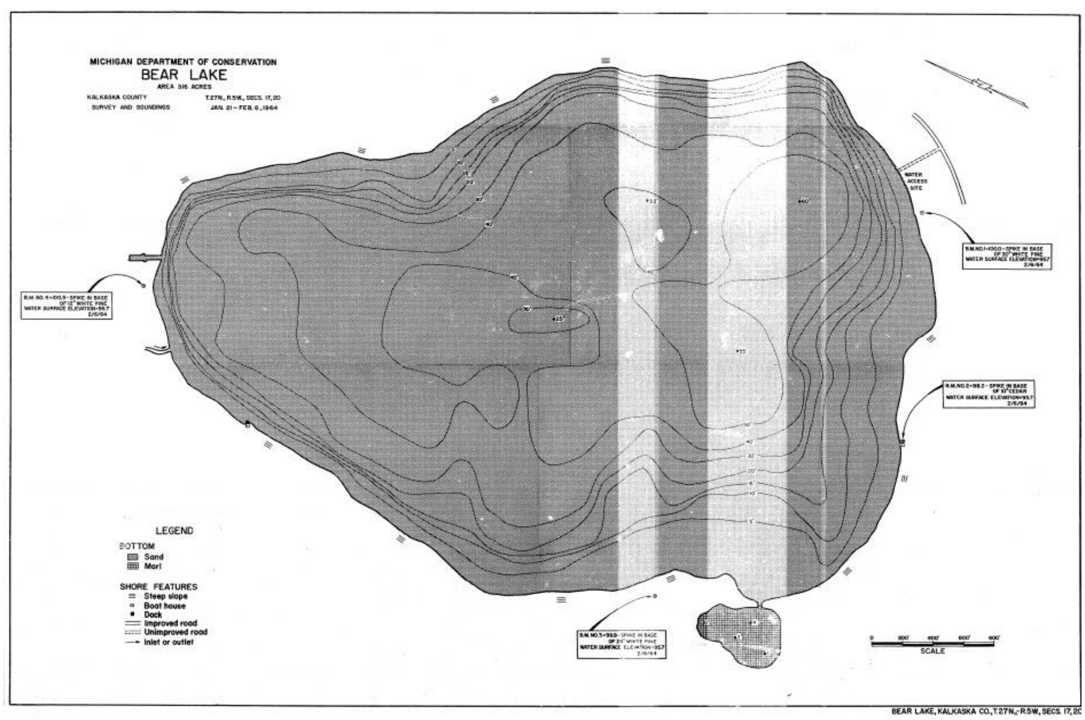


Figure 2: Morphometric map of Bear Lake indicating the variation in depth along the bottom of the lake (Michigan Lakes Maps).

There are a variety of fish species in Bear Lake including largemouth, smallmouth, and rock bass, bluegill, yellow perch, and rainbow, brown, and brook trout. All of these species are native to the area except for brown trout and rainbow trout. Brown trout were introduced from Europe in 1883, while rainbow trout were introduced from California in 1876 (Fish, 2023). In Bear Lake, each of the trout species are stocked yearly.

There are many ways in which lakes can be tested. For the most part, the reason this is done is to determine the health of lakes. Lake health is classified in the most basic sense by how productive the organisms living in it are. If there is little to no productivity in a lake, it is said to be oligotrophic. If a lake is high to very high in productivity, it is said to be eutrophic. Lakes with levels of productivity in between these two extremes are called mesotrophic. When it comes to lake health, there can be issues with those at both ends of the spectrum. Lakes that are too oligotrophic cannot host much life, having too few nutrients and thus low productivity. Lakes that are too eutrophic are not healthy because they have too many nutrients built up, resulting in excessive algae growth. When there is too much life and productivity in a lake and that life dies, all of that organic matter falls to the bottom and is decomposed. Decomposers need oxygen, so dissolved oxygen levels in a eutrophic lake can drop so low that other organisms like fish are unable to survive. These are extreme cases, though, so a lake can still be classified as oligotrophic or eutrophic and be considered relatively healthy. In fact, most lakes fall well in between the most extreme cases of oligotrophic and eutrophic states.

Materials and Methods

Our class sampled Bear Lake on June 23, 2023 with local resident Sam Rahaim using his pontoon boat. On the day we sampled the air temperature was 28°C (82°F) with 3.5 knot (4 mph) wind out of the northeast and approximately 95% cloud cover.

Temperature Probe:

Water temperature is measured in lakes at different depths using a YSI probe (**Fig. 3**; https://www.ysi.com/prodigital). These measurements are used to indicate variation in temperature from the top to the bottom of the lake, as well as used as a baseline for comparing how much of certain nutrients would be expected at different depths based on if the lake is thermally stratified (no mixing) or isothermal (mixing).

Figure 3: YSI probe used to measure temperature and dissolved oxygen.

Dissolved Oxygen Probe:

The quantity of dissolved oxygen in a lake is also measured at different depths using a YSI probe (**Fig 3**). It is recorded in parts per million (ppm) and percent saturation. These measurements are some of the biggest indicators of water quality in lakes. In general, dissolved oxygen is highly related to temperature, so temperature vs depth graphs can be used to predict how much dissolved oxygen should be present at a certain temperature and depth in the lake. Differentiation from this becomes important to look at, especially towards the bottom temperature of lakes. When dissolved oxygen is much lower than expected at the bottom temperature of lakes, this is generally an indicator of eutrophication and poorer lake health because of high levels of decomposition in the bottom using up the dissolved oxygen. When dissolved oxygen is much higher than expected, this is generally an indicator of the opposite—low levels of decomposition can indicate low levels of productivity of a more oligotrophic lake. The majority of dissolved oxygen in lakes is produced by the photosynthesis of phytoplankton in the upper photic (lighted) zone.

Secchi Disk Depth:

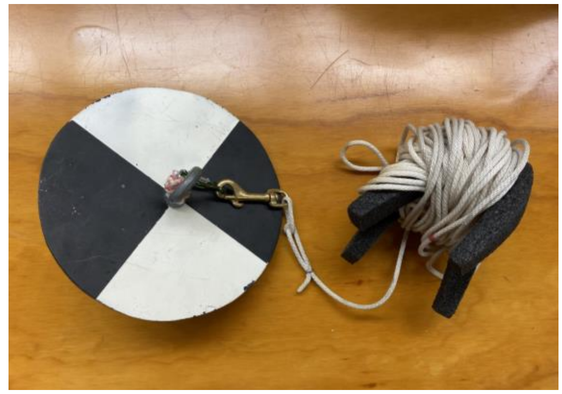


Figure 4: Secchi disk used by class.

Secchi disks are 20 cm diameter and painted in quadrants of contrasting white and black (**Fig. 4**). They are used to measure relative transparency (light penetration) of water in lakes by being lowered to the depth at which they can no longer be seen. Water transparency is determined by a number of things, but the most significant part is the presence or absence of phytoplankton. When phytoplankton are abundant, the lake is said to be less transparent or more turbid. This results in a shallower Secchi depth. When phytoplankton are few, the lake is said to be more transparent or less turbid, resulting in a deeper Secchi depth. One of the biggest factors which can influence water transparency is the presence of suspended particles in the water. More suspended particles from living or non-living sources can also result in a higher turbidity and a lower Secchi depth measurement. Because Secchi depth gives a relative measurement of how much phytoplankton is in the water, it can also be used in a calculation to estimate Trophic State Index (Carlson, 1997).

Light Probe:

Figure 5: LI-COR probe used to collect light measurements.

Light is also more directly measured by a LI-COR probe (**Fig. 5**; https://www.licor.com/env/products/light/light_meter) which is lowered down to different depths throughout the lake. Instead of just a relative measurement like Secchi depth, this probe gives a quantitative measurement of light penetration in the water. This helps indicate more specifically the depth at which photosynthesizing phytoplankton stop receiving adequate light for photosynthesis to occur. When more particles are in the water, higher quantities of light get refracted faster than when there are fewer particles in the water. This has similar implications as are explained with the Secchi depth.

Alkalinity, Hardness, and pH:

Figure 6: HACH alkalinity test kit (https://www.hach.com)

Water alkalinity and hardness were both measured for surface water using a HACH kit (**Fig. 6**; https://www.hach.com/p-digital-titrator-test-kits/2063700). Alkalinity indicates how much a lake is able to buffer changes in pH. Hardness shows the quantity of minerals like calcium, magnesium, and other cations dissolved in the water. pH was also measured on the surface of the water using a different probe. This measurement is highly related to alkalinity.

Plankton:

Plankton were collected using an 80 µm meshed net (**Fig. 7**) that was lowered to the bottom of the lake and pulled back to the surface twice vertically through the water column. This allows a representative sample of plankton populations in a lake to be collected and observed under a microscope. Plankton are microscopic organisms which live in water bodies. Phytoplankton are microalgae autotrophs at the bottom of the food chain because they photosynthesize to produce their own energy. Zooplankton are primary consumers (herbivores) in the food chain and feed on mostly phytoplankton for their energy. The presence of different types of plankton can be used to indicate the water quality of lakes. Higher numbers of diatoms, a type of phytoplankton, and lower numbers of other plankton usually indicate that a lake is oligotrophic. Lower numbers of diatoms and higher numbers of blue-green algae (another type of phytoplankton) usually indicate that a lake is eutrophic. Large blooms of algae are concerning for lake health because they indicate that high quantities of nutrients (especially phosphorus and nitrogen) are entering the lake. Algal blooms cause problems because when the phytoplankton die and sink to the bottom of the lake, this results in high levels of decomposition, resulting in lower dissolved oxygen levels. Large blooms of blue-green algae are of particular concern for lake health because some blue-green algae produce toxins which can be harmful to other organisms, including humans.

Figure 7: 80 µm net used to collect plankton

Fecal Coliform Bacteria:

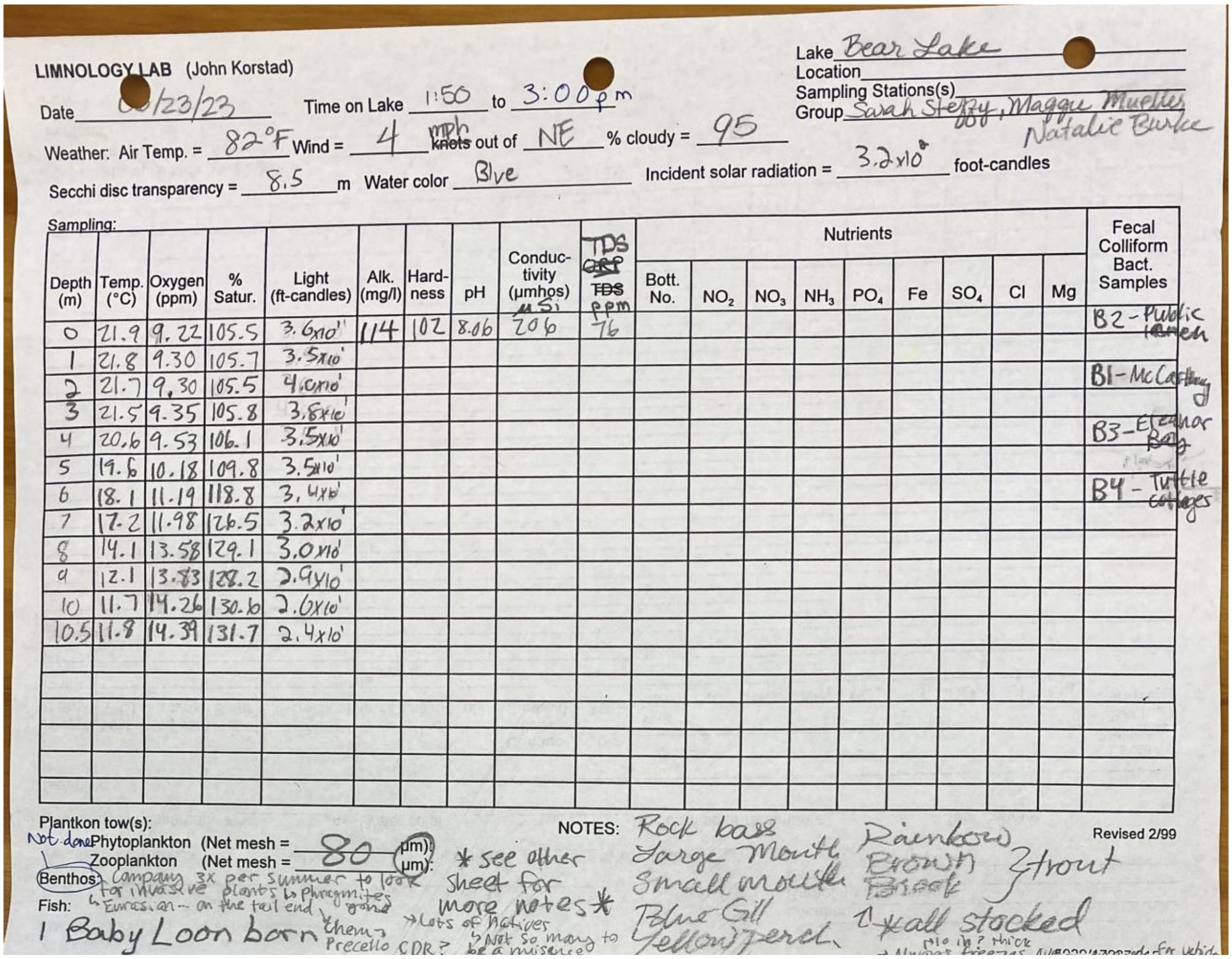
Fecal Coliform bacteria are a group of bacteria types which come from the intestines of warm-blooded animals. These bacteria are tested for by collecting water samples and mixing them with a medium which gets incubated to see what (if any) bacteria grow (https://www.micrologylabs.com/product/coliscan-easygel/). Fecal coliform bacteria can be present in lakes from a variety of sources, most commonly birds and other warm-blooded animals, including humans. At lakes where septic drainage fields are nearby, this can be a particular risk, and so testing for fecal coliform bacteria is a helpful indicator of possible leaking fields. The location where fecal coliform bacteria are found can be telling what their sources are. The presence of high quantities of fecal coliform bacteria is concerning, even if it is just from birds or other animals. These bacteria can be dangerous when exposed to, particularly if they happen to be ingested while swimming or wading in the water (Swimming, 2021).

Trophic State Index (TSI):

The Trophic State Index of a lake is a calculation that can be done using three different test sources: Secchi depth, total phosphorus, and chlorophyll a. With each of these, the calculation is used to determine how productive a lake is. We used Secchi depth for our calculation.

Results/Discussion

Table 1: Data sheet including all tests done on Bear Lake on June 23, 2023.



LIMNOLOGY LAB (John Korstad)

Lake: Bear Lake
Location:
Sampling Stations(s):
Group: Sarah Steffy, Maggie Mueller, Natalie Burke

Date: 06/23/23 Time on Lake 1:50 to 3:00 pm

Weather: Air Temp. = 82°F Wind = 4 mph ~~knots~~ out of NE % cloudy = 95

Secchi disc transparency = 8.5 m Water color Blue Incident solar radiation = 3.2×10^{3} foot-candles

Sampling:

Depth (m)	Temp. (°C)	Oxygen (ppm)	% Satur.	Light (ft-candles)	Alk. (mg/l)	Hard-ness	pH	Conduc-tivity (µmhos) µS	TDS ~~ORP~~ ~~TDS~~ ppm	Nutrients: Bott. No.	NO_2	NO_3	NH_3	PO_4	Fe	SO_4	Cl	Mg	Fecal Colliform Bact. Samples
0	21.9	9.22	105.5	3.6×10^{1}	114	102	8.06	206	76										B2 - Public Beach
1	21.8	9.30	105.7	3.5×10^{1}															
2	21.7	9.30	105.5	4.0×10^{1}															B1 - McCartney
3	21.5	9.35	105.8	3.8×10^{1}															
4	20.6	9.53	106.1	3.5×10^{1}															B3 - Eleanor Bay
5	19.6	10.18	109.8	3.5×10^{1}															
6	18.1	11.19	118.8	3.4×10^{1}															B4 - Turtle cottages
7	17.2	11.98	126.5	3.2×10^{1}															
8	14.1	13.58	129.1	3.0×10^{1}															
9	12.1	13.83	128.2	2.9×10^{1}															
10	11.7	14.26	130.6	2.6×10^{1}															
10.5	11.8	14.39	131.7	2.4×10^{1}															

Plankton tow(s):
Not done Phytoplankton (Net mesh = 80 µm)
Zooplankton (Net mesh = µm)
Benthos: Company 3x per summer to look for invasive plants → Phragmites, Eurasian – on the tail end, gone → them → Precello CDR?
→ Lots of natives → Not so many to be a nuisance
Fish: 1 Baby Loon born

NOTES: * see other sheet for more notes *
Rock bass, Large Mouth, Small mouth, Blue Gill, Yellow perch
Rainbow, Brown, Brook } trout ↑ *all stocked

Revised 2/99

Temperature:

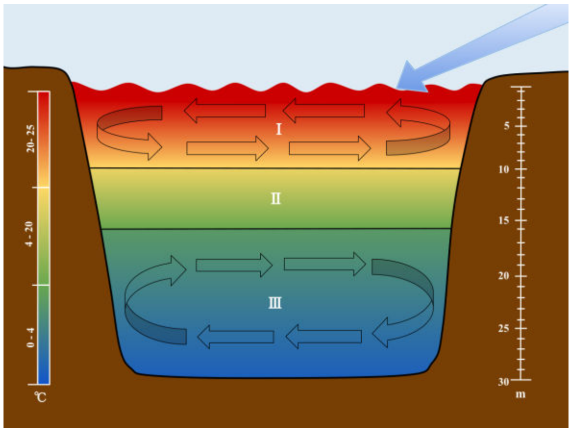


Figure 8: Diagram of a thermally stratified lake (Wikipedia).

Figure 9 shows the relationship between depth and temperature in Bear Lake (2023). The shape of the curve indicates that the lake is thermally stratified. A thermally stratified lake (**Fig. 8**) divides into three distinct layers: top, middle, and bottom. The layers are created by a difference in density. As surface waters heat disproportionately during summer months, cool water sinks to the bottom. This is because cold water is denser than warm water (for temperatures greater than 4°C). The top layer, called the epilimnion, and the bottom layer, called the hypolimnion, are separated by the middle layer, called the metalimnion. Since warm water resides at the top and cold water at the bottom, the metalimnion becomes defined as a layer of rapid change in temperature (1°C per 1 meter of depth). This rapidly changing layer is called the thermocline. Since the water in the epilimnion is all close to the same density, it can mix together. Likewise, water can mix throughout the bottom layer. The middle layer acts as a barrier between the top and bottom layers. This means that nutrients cannot be exchanged between layers, and so when organisms die and are decomposed, no nutrient recycling can occur until summer ends and stratification breaks down. While we did not sample as deep as previous years (**Fig. 10**), especially 2018 and 2022, we can still see that the lake is thermally stratified this year. This is normal for lakes in North Temperate regions like Northern Michigan.

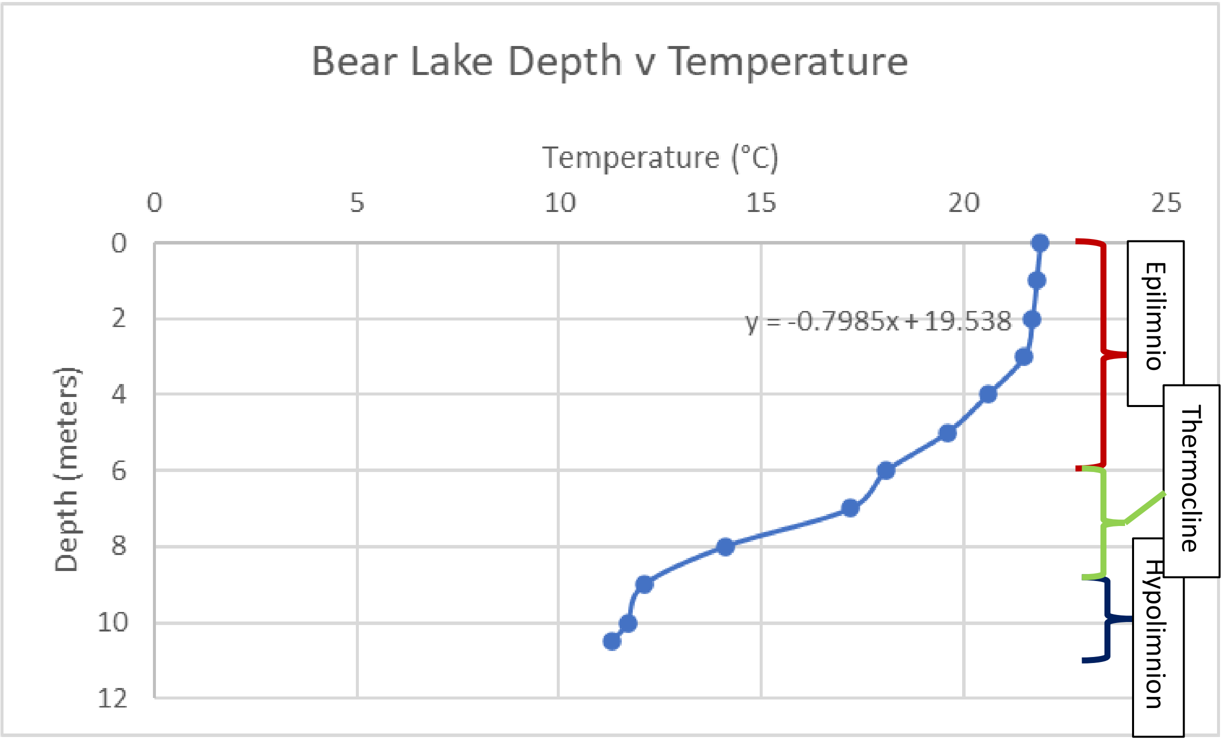


Figure 9: Bear Lake Depth vs Temperature graph showing thermal stratification.

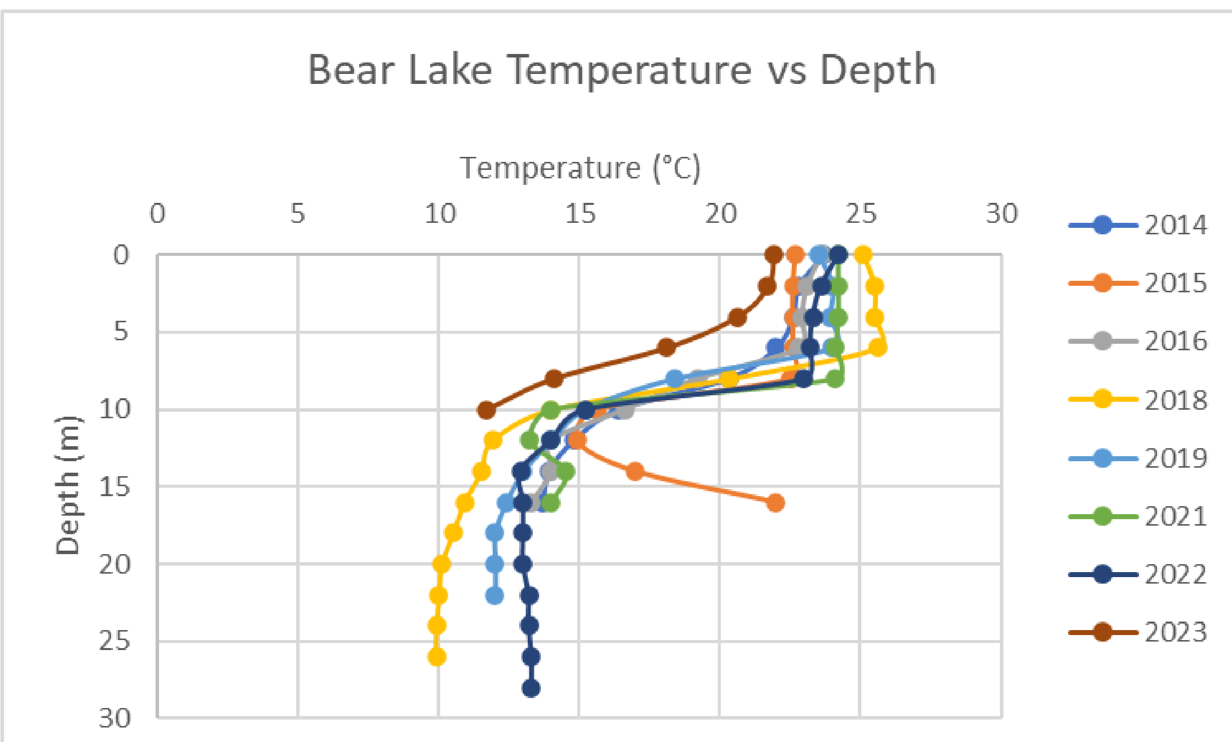


Figure 10: Bear Lake Temperature vs Depth 2014-2016, 2018-2019, 2021-2023.

Dissolved Oxygen:

Figure 11 shows the relationship between depth and dissolved oxygen (DO) in Bear Lake (2023). By looking at the curve you can see that it is inverse to that of **Figure 9** with depth and temperature. This is because dissolved oxygen and temperature are very strongly related. Oxygen dissolves better in colder water, so as the temperature decreases with the depth of the lake, the dissolved oxygen will normally increase. DO is important to the lake's health because it is critical to the survival of fish and other aquatic animals in the lake that need oxygen to breathe. The oxygen in the water comes from the surface exposed to sunlight and the natural photosynthetic activity of phytoplankton and aquatic plants. Low levels of DO at the bottom of the lake (hypolimnion) are bad because they indicate that extreme levels of decomposition are occurring, and that organisms in the hypolimnion are likely not getting enough oxygen to survive. Low DO at the bottom of a lake is a major sign of eutrophication and poor lake health. The data collected from Bear Lake this year shows DO levels as high as 14.3 ppm at the bottom, indicating that the lake is a very well oxygenated and healthy lake. Generally, DO levels of 9-10 ppm are considered particularly good (Dissolved, 2023). When comparing the DO levels at 10 m in Bear Lake with the past, there are lower levels of DO at this depth (**Fig. 12**). However, since this is still an elevated level with only a small decrease of DO at 10 m, there is no reason to be afraid of decreasing DO in the lake. Therefore, Bear Lake is healthy because it has sufficient DO levels to sustain and support aquatic life within the lake.

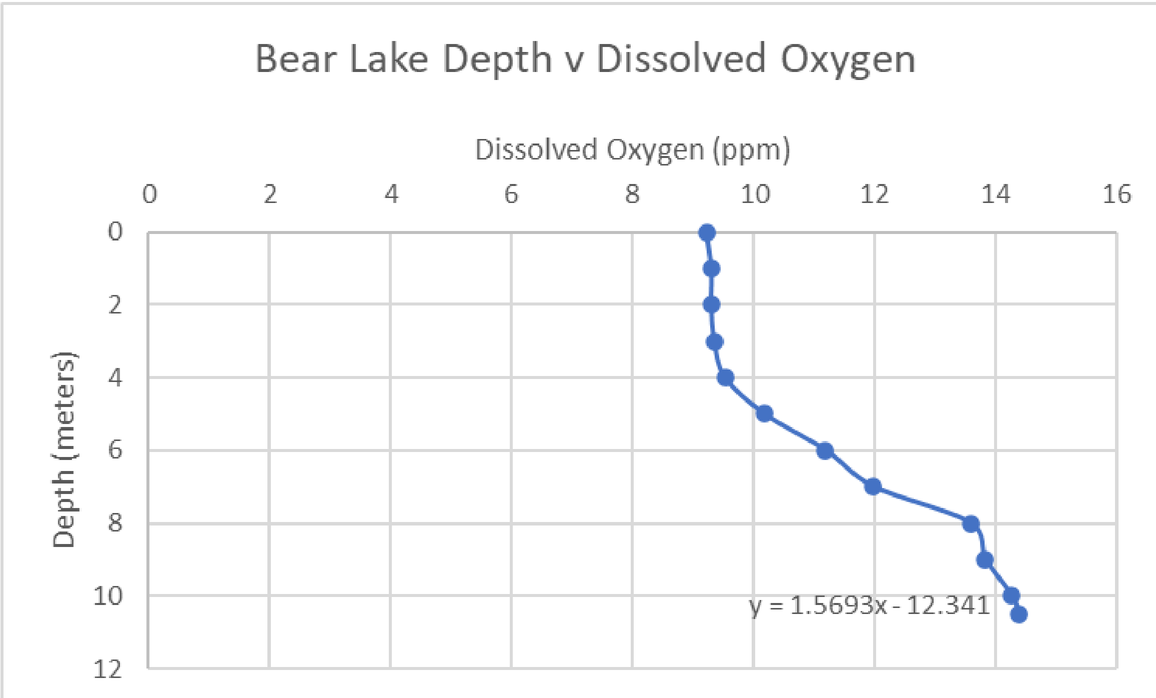


Figure 11: Bear Lake Depth vs Dissolved Oxygen graph showing an increase in dissolved oxygen as depth increases.

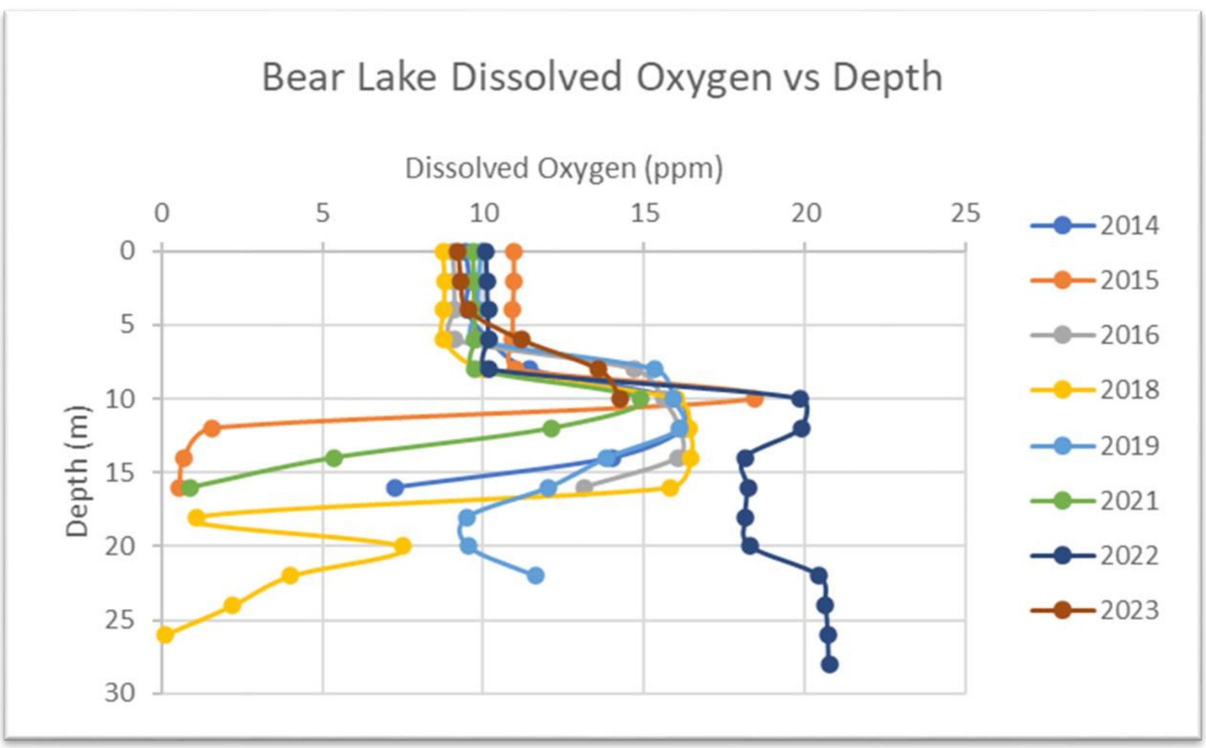


Figure 12: Bear Lake Dissolved Oxygen vs Depth 2014-2016, 2018-2019, 2021-2023.

Light:

Figure 13 shows the relationship between depth and light on Bear Lake (2023). The graph shows a normal logarithmic decrease as depth increases. We only tested the lake up to 10.5 meters deep of the lake, and there were still about 2.4 ft-candles of light measured by the light meter. This means that light is still penetrating the water at this depth. Areas of the lake that are penetrated by at least 1% sunlight are considered to be in the photic zone, meaning that photosynthesis can still take place at this depth. This measurement of light is quantitative as opposed to the relative transparency depth measured by the Secchi disk. While there is not as much light at 10 m compared to previous years (**Fig. 14**), there is still enough light at this depth to promote photosynthesis and support biological activity to keep the lake healthy.

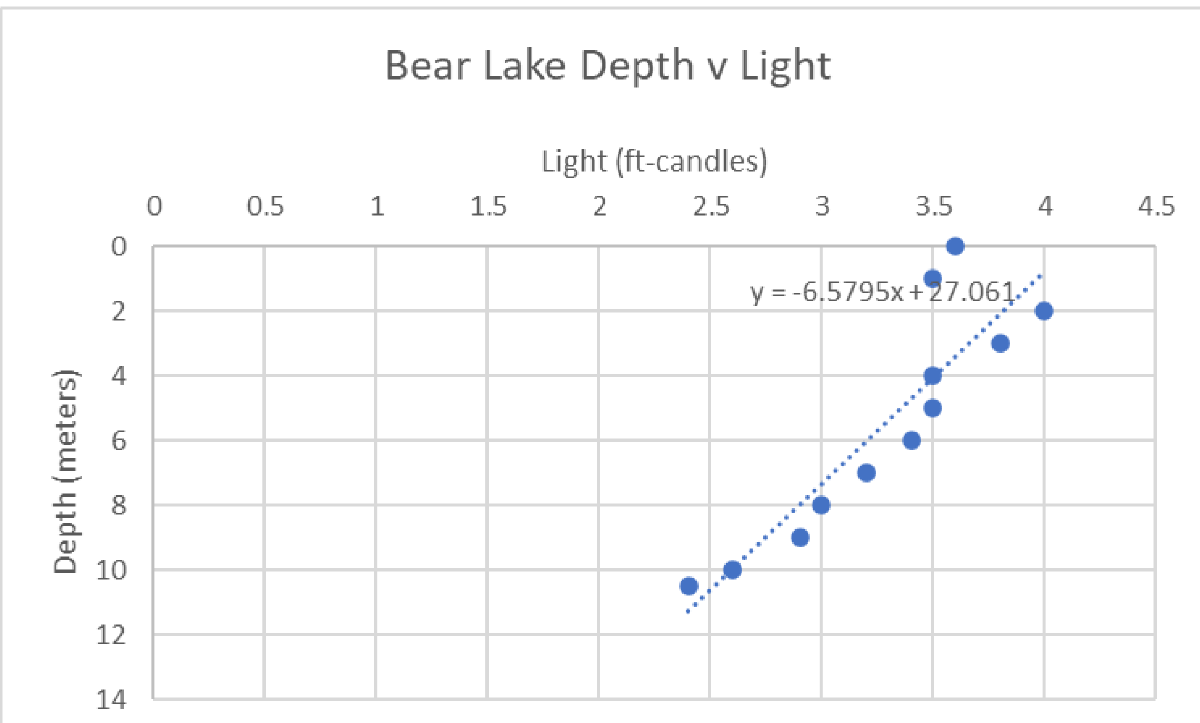


Figure 13: Bear Lake Depth vs Light Graph showing a logarithmic decrease in light as depth increases.

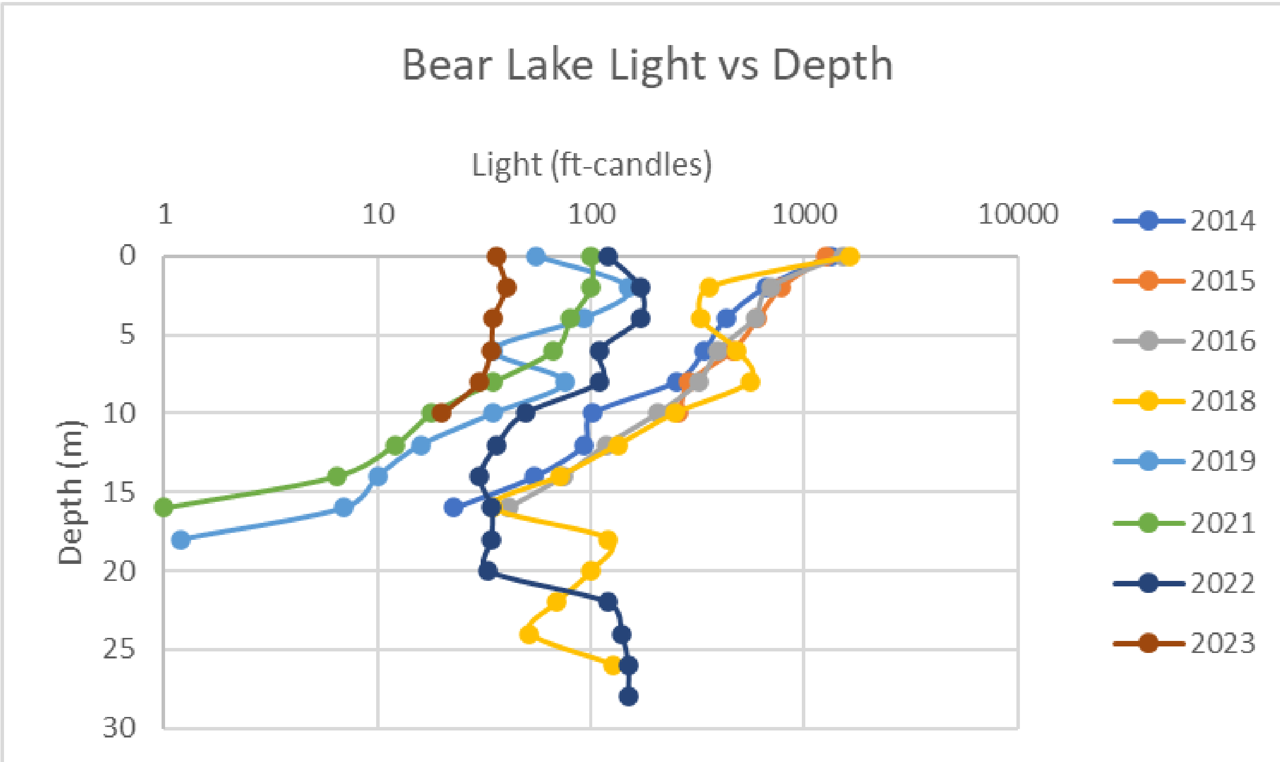


Figure 14: Bear Lake Light vs Depth 2014-2016, 2018-2019, 2021-2023.

Secchi Disk Depth:

This year's testing for Secchi disk depth yielded an 8.5 m relative transparency. This means that with the naked eye, the Secchi disk was visible to 8.5 meters under the water's surface. This is considered highly transparent. More transparency in the water usually means there are less phytoplankton due to less nutrients in the water. Too much algae is not healthy for the lake, but too little can also be a problem because it is the food source for zooplankton, which are the main diet of smaller fish in the lake. **Figure 15** shows the Secchi disk depth at Bear Lake through 2014-2016, 2018-2019, and 2021-2023. Analyzing the Secchi disk depth over the past 10 years shows that Bear Lake is healthy since the depth consistently falls within the oligotrophic (low nutrient load) lake range. Being within the oligotrophic range is a good thing because it indicates that there is a good balance between nutrient levels and algal biomass, which is needed to support a healthy aquatic ecosystem within the lake.

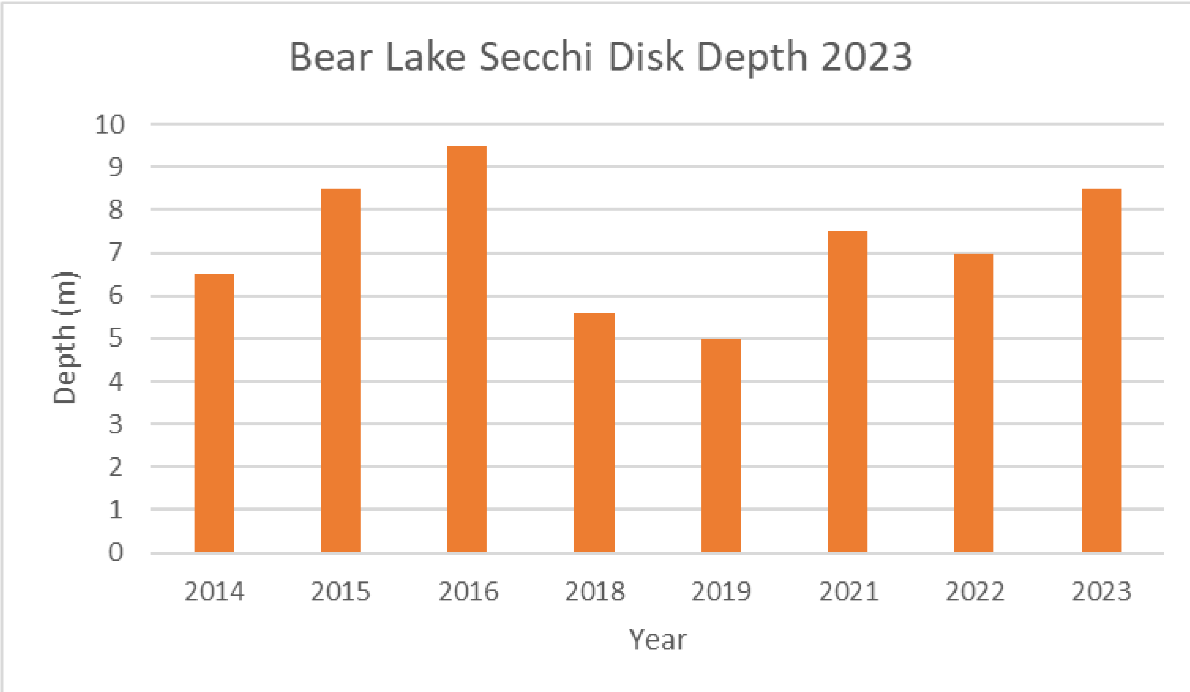


Figure 15: Bear Lake Secchi Disk Depth 2014-2016, 2018-2019, 2021-2023.

Trophic State Index (TSI):

The calculated TSI for 2023 was calculated to be 29.16. A TSI of less than 30 indicates a low nutrient, oligotrophic lake, and Bear Lake seems to be right on that mark, indicating a healthy lake. **Figure 16** shows the Trophic State Index for Bear Lake through 2014-2016, 2018-2019, and 2021-2023. Over the past 10 years Bear Lake, TSI values have fallen within the oligotrophic lake range. Just like the Secchi disk depth, the TSI indicates that there is a healthy balance between nutrient levels and algal biomass within Bear Lake. This healthy balance will allow the lake to thrive and support biological activity. This is a sign that the lake is healthy.

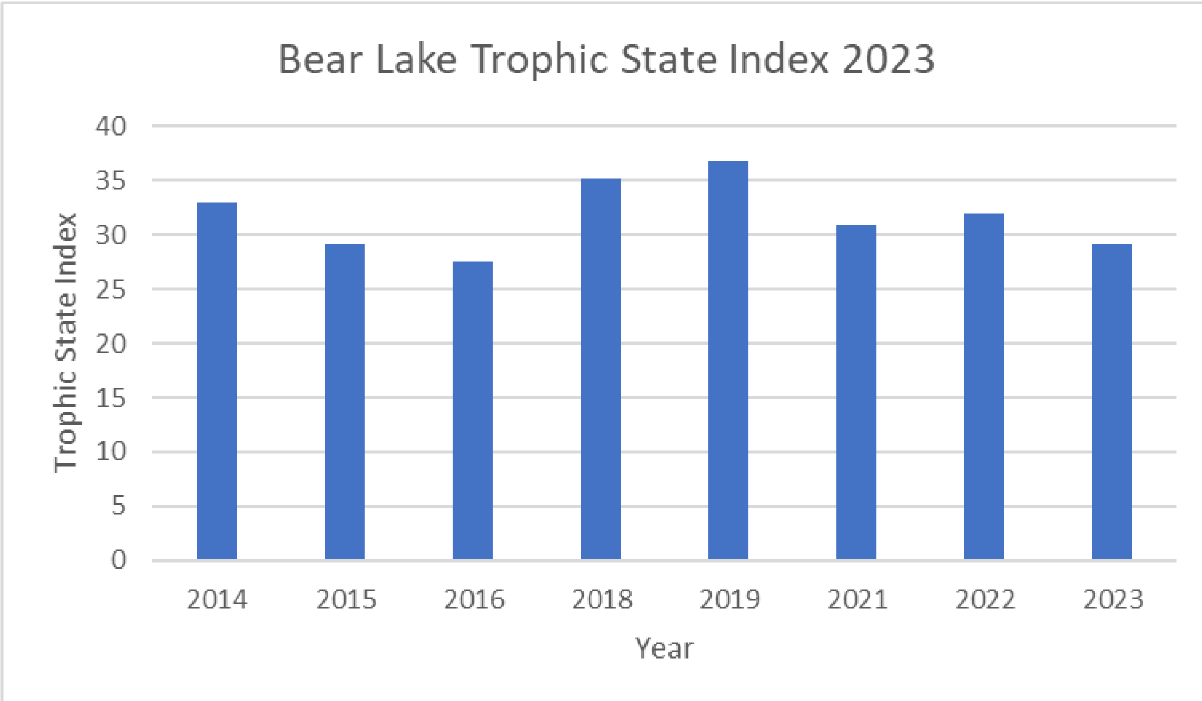


Figure 16: Bear Lake Trophic State Index 2014-2016, 2018-2019, 2021-2023.

Alkalinity:

We measured the alkalinity of Bear Lake to be 114. An acceptable alkalinity reading should be between 100-200 and Bear Lake's reading was within this range. This indicates the lake's resistance to changes in pH, which is a healthy attribute. **Figure 17** shows the alkalinity at Bear Lake through 2014-2016, 2018-2019, and 2021-2023. Analyzing the alkalinity over the past 10 years shows that Bear Lake can sufficiently buffer the water's pH. This means that the lake is healthy because most aquatic organisms cannot survive in water that is too acidic or too basic.

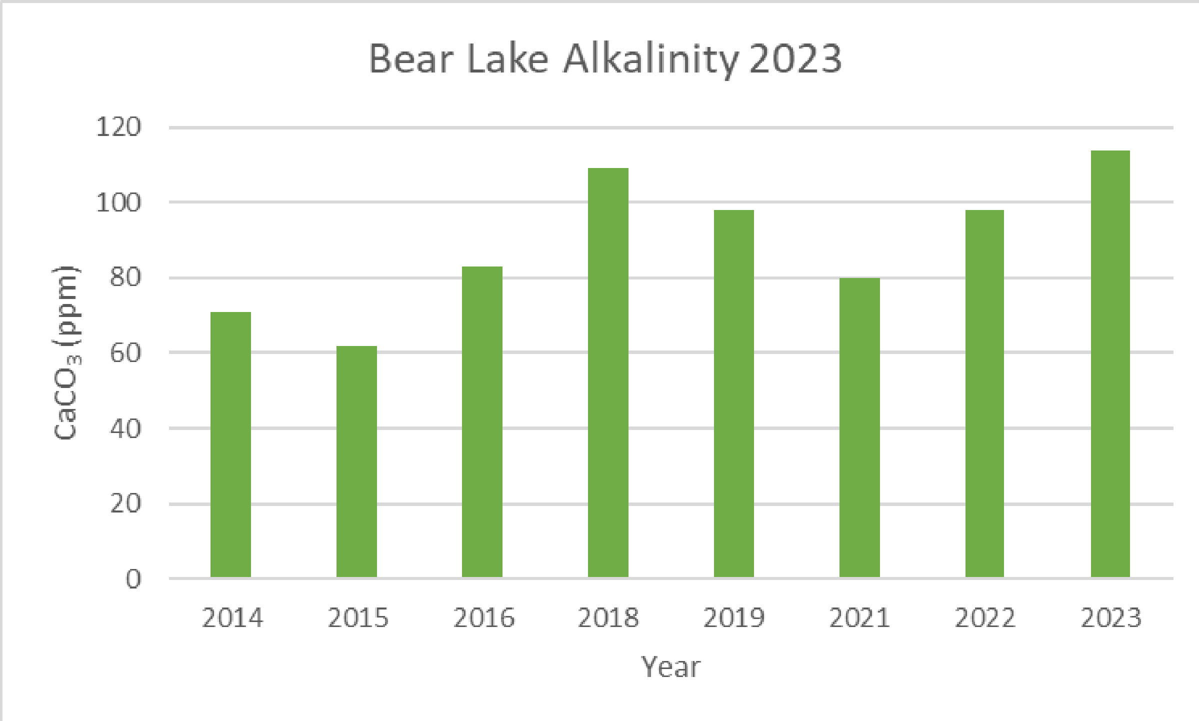


Figure 17: Bear Lake Alkalinity 2014-2016, 2018-2019, 2021-2023.

Hardness:

This year (2023), the hardness of the lake was measured at 102. **Figure 18** shows the hardness at Bear Lake through 2014-2016, 2018-2019, and 2021-2023. Analyzing the hardness over the past 10 years shows that Bear Lake has moderately hard water. Hard water in the lake means it contains dissolved minerals like calcium, magnesium, and other hard metals. Having moderate levels of dissolved minerals is important in a healthy lake because it helps promote growth within the lake since these minerals are needed for phytoplankton and zooplankton.

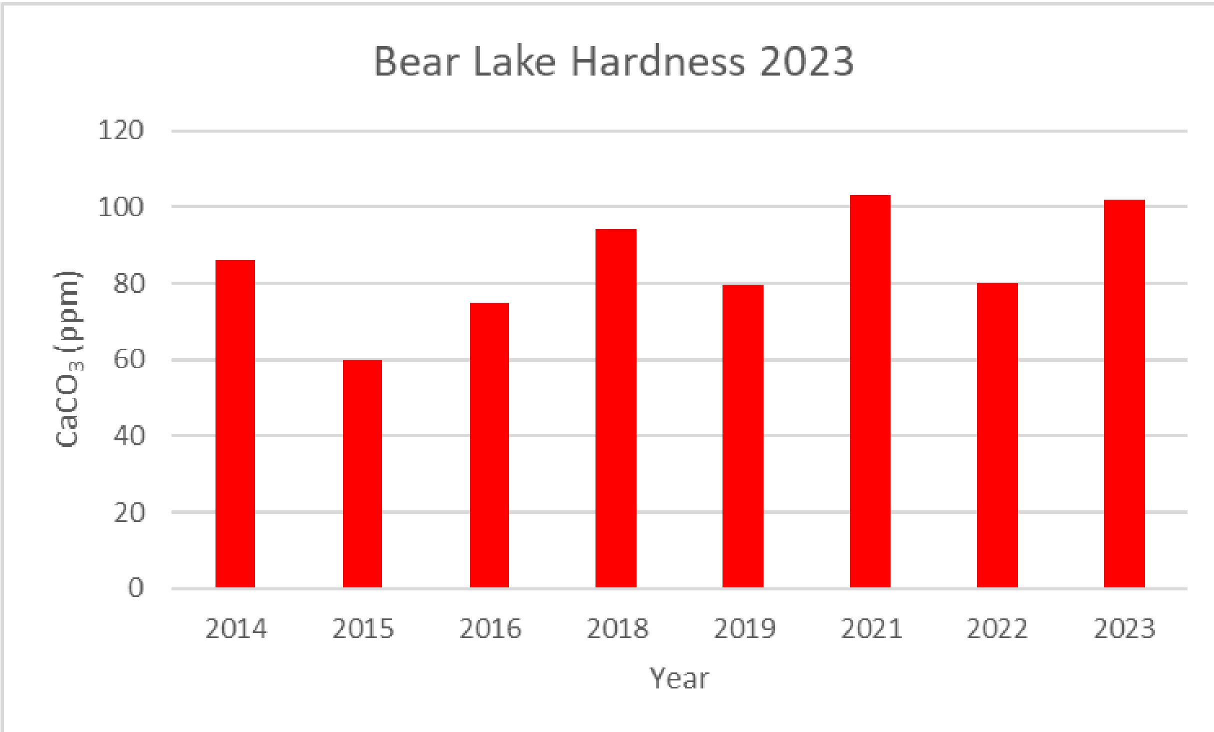


Figure 18: Bear Lake Hardness 2014-2016, 2018-2019, 2021-2023.

pH:

Bear Lake (2023) had a pH of 8.06. This measurement shows the water to be slightly alkaline. **Figure 19** shows the pH at Bear Lake through 2014-2016, 2018-2019, and 2021-2023. Analyzing the pH over the past 10 years shows that Bear Lake has an optimal pH level to support biological activity. Ensuring that the pH range is between 6-9 is very important because most organisms cannot survive in water that is too acidic or too basic. Since a pH of 8.06 is in this range, it can be concluded that the lake is in a healthy and sustainable state.

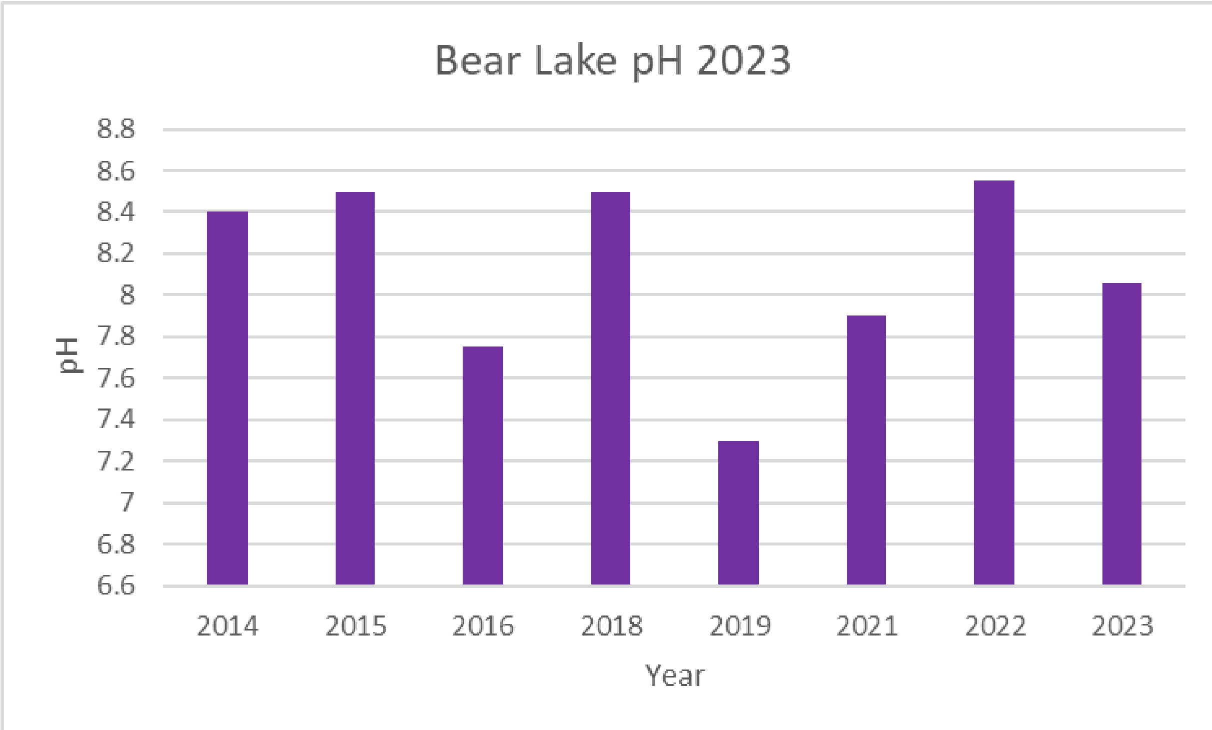


Figure 19: Bear Lake pH 2014-2016, 2018-2019, 2021-2023.

Conductivity:

The conductivity of the water was measured to be 206 this year. **Figure 20** shows the conductivity at Bear Lake through 2014-2016, 2018-2019, and 2021-2023. Analyzing the conductivity over the past 10 years shows that Bear Lake has optimal conductivity for supporting good populations freshwater fish, which is between 150-800 µmhos (Conductivity, 2013). Being able to support good freshwater fish populations shows that the lake is healthy because there are enough nutrients and food to sustain them.

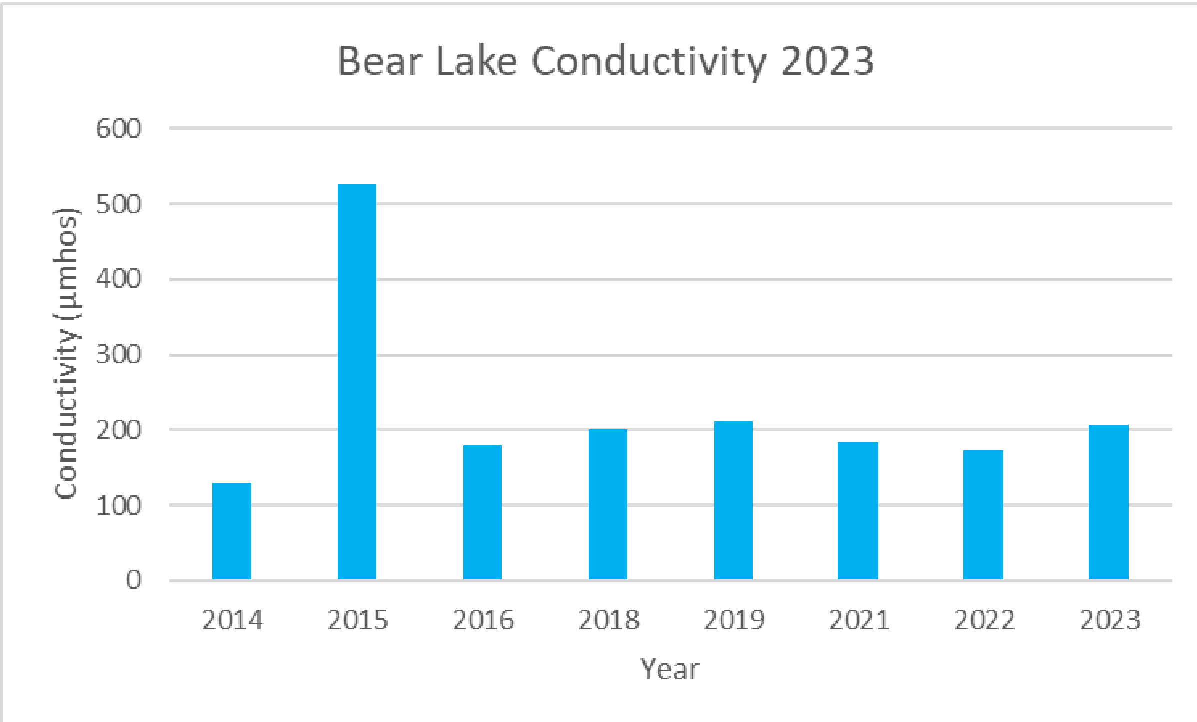


Figure 20: Bear Lake Conductivity 2014-2016, 2018-2019, 2021-2023.

Plankton:

From water samples taken in Bear Lake 2023, we found a variety of both phytoplankton and zooplankton. *Asterionella* (**Fig. 21**), *Cyclotella* (**Fig. 22**), *Navicula* (**Fig. 23**) and *Fragilaria* (**Fig. 24**) were all found in great abundance. These are all freshwater diatoms (phytoplankton) common in low-nutrient Northern lakes and are indicators of a healthy lake. *Ceratium* (**Fig. 25**), a freshwater dinoflagellate (phytoplankton), was found in medium abundance which also indicates a healthy lake. *Daphnia* (**Fig. 26**), a common zooplankton, and *Nauplius larvae* (**Fig. 27**), the larval stage of many crustaceans normally found in freshwater lakes, were found in low abundance. *Asplancha* (**Fig. 28**) and Kellicottia (**Fig. 29**), common rotifers (zooplankton) were also found. These are all characteristic zooplankton of healthy lower-nutrient lakes. *Zygnema* (**Fig. 30**) and *Dinobryon* (**Fig. 31**) were common filamentous algae types (phytoplankton) found in the lake. We also found a single cluster of *Anabaena* (**Fig. 32**), which is a blue-green algae.

Although blue-green algae are often concerning when found in lakes, this find is not concerning because the concentration was so small. Overall, the plankton indicates a healthy lake.

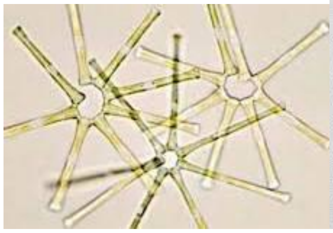
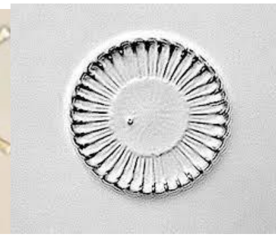
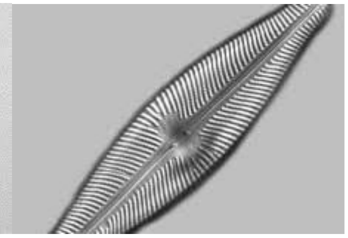




Figure 21: Asterionella **Figure 22:** Cyclotella **Figure 23:** Navicula

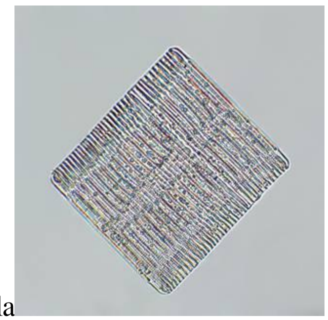
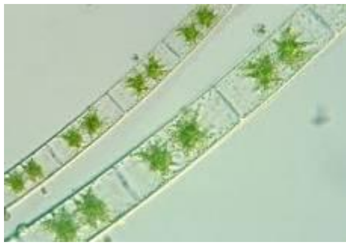



Figure 24: Fragilaria **Figure 25:** Ceratium **Figure 26:** Daphnia



Figure 27: Nauplius Larva **Figure 28: A**splancha **Figure 29:** Kellicotta



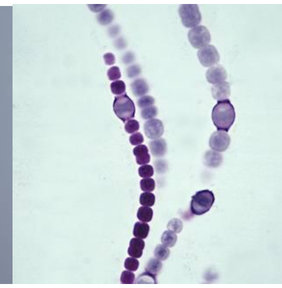
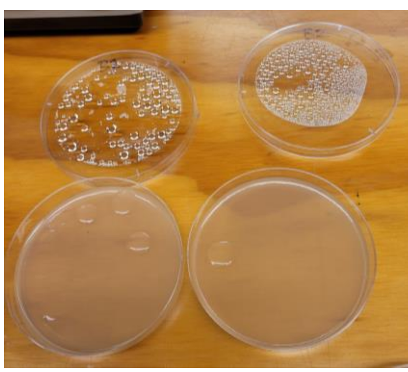
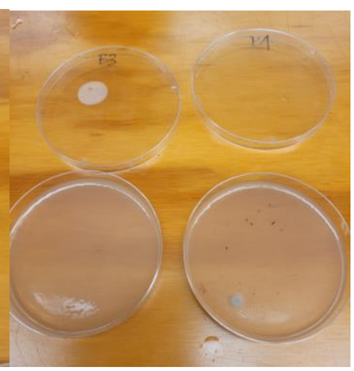


Figure 30: Zygnema **Figure 31:** Dinobryon **Figure 32**: Anabaena

Bacteria:

There was no *Escherichia coli* found on any of the four test sites. We tested areas near the public launch, McCarthy's, Eleanor Bay, and Tuttle Cottages. We chose these sites because they were possible places with contamination. However, none of them showed any reason for concern although they were highly frequented sites. This is a good sign for the lake's health, although these areas should still be monitored in case of future contamination. Note: the spot visible on the McCarthy plate in **Figure 34** is mold, not bacteria growth.

Figures 33 and 34: Bacterial sites - Top left: Tuttle Cottage; Top right: Eleanor Bay; Bottom left: Public launch; Bottom right: McCarthy.

<u>Conclusion</u>

Based on our sampling and analysis of the data, we can say that Bear Lake is a healthy oligotrophic lake. The amount of dissolved oxygen throughout the lake, which is one of the most important qualities in assessing water quality, indicates that there is sufficient oxygen to sustain aquatic life and activity. The Secchi disk depth and Trophic State Index indicate that there is a healthy balance between nutrient levels and algal biomass (phytoplankton and zooplankton) within the lake. After analyzing the distinct species of algae sampled from the lake, we found that there was a high abundance of diatoms (a type of phytoplankton), which is often seen in oligotrophic lakes, and little to no blue-green algae, which is excellent. After analyzing the different bacteria samples taken around Bear Lake, we did not find any signs of fecal coliform bacteria, indicating that Bear Lake is extremely clean.

Our data analysis does not show any concerns or issues about the lake, which indicates that the local homeowners are practicing good management strategies. However, to ensure that Bear Lake stays healthy, the community needs to continue practicing their management strategies, along with other strategies if not currently in place. For example, avoid using fertilizers, especially ones that include phosphorus and other chemicals when maintaining your garden, yard, or other vegetation. Using lake water to water plants is an excellent thing to do. Ensuring that people wash and dry their boat properly to prevent invasive species being introduced to the lake is important. Not using garbage disposals in the kitchen, along with using and maintaining proper septic/sewage tanks, will help keep the lake healthy because it prevents bacteria and excess nutrients from entering the lake.

Another way that the local homeowners can help keep Bear Lake healthy is to decrease the amount of erosion around the lake to prevent excess sediment from entering the lake. Soil erosion adds nutrients like nitrogen or phosphorus, which will increase the growth of algae and plants that will make the lake more eutrophic. The best way to prevent or decrease lakeside erosion is to retain existing or plant new vegetation to keep the soil in place and take up nutrients. Placing rocks on shorelines so that the water hits the rocks instead of the soil is also helpful. Decreasing wake boat erosion by having boats stay in deeper water and having them go slower when near the shore to make smaller waves that will not carry as much sediment as larger waves, are some other ways that they can help keep the lake healthy.

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