2022 Water Quality Report
And
Historical Analysis
Long Lake
Mickey Lake
Ruth Lake

Monitoring Years 1993-2022

Submitted to:
Long Lake Association
Long Lake Foundation
Oleson Foundation
Long Lake Township

Prepared with the assistance of:

Great Lakes Environmental Center
739 Hastings St.
Traverse City, MI 49686

Northwestern Michigan College
Great Lakes Water Studies Institute
1701 E. Front St.
Traverse City, MI 49686

Interns: Kelsey Mills, Sarah Cole
Long Lake Mentors: Barry Lishawa, Len Klein, Peter Doren, Phyllis Laine and Dr. Richard Roeper.

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Reference Information

Figure 1. Water quality sampling sites on Long Lake, 1997-2022

LAKE	SAMPLE SITE	LATITUDE	LONGITUDE
Long Lake	#1	44.70383°	-85.74432°
	#2	44.72473°	-85.75612°
	#3	44.47409°	-85.76453°
Mickey Lake	#1	44.73257°	-85.76640°
	#2	44.73217°	-85.76867°
Ruth Lake	#1	44.69483°	-85.76255°

Table 1. Trophic State Classification (Chapra, 1997)

Variable	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (µg/L)	<10	10-20	>20
Chlorophyll a (µg/L)	<4	4-10	>10
Secchi depth (m)	>4	2-4	<2
Hypolimnion Oxygen (% sat)	>80	10-80	<10

Table 2. Phosphorus Data for Area Lakes and Sediments (GLEC, 2006, p. 12)

Lake	Water Total Phosphorus (µg/L)	Sediment Phosphorus (mg TP/kg DW)
Torch	1.7	86
Burt	2.2	119
Lime	4.4	200
Crystal	4.8	332
North Leelanau	4.8	489
South Leelanau	4.9	398
Glen	5.1	326
Little Traverse	5.1	401
Cedar	5.3	396
Platte	7.7	620

For a comparison of lake quality in Michigan, see: *Water-Quality Characteristics of Michigan's Inland Lakes, 2001–10* https://pubs.usgs.gov/sir/2011/5233/pdf/sir2011-5233_web.pdf

Trophic Status: A measure of lake productivity

Oligotrophic Lakes: Lakes that display lower aquatic plant production and nutrient levels (typically referring to phosphorus levels). Usually deep and clear water. Cool, oxygen-rich bottom waters are home to cold-water fish, including whitefish and trout.

Eutrophic Lakes: Lakes that display high aquatic plant production and nutrient levels. Typically shallow and murky, turbid water. Oxygen-depleted bottom are home to warm water fish, including pike and bass.

Mesotrophic Lakes: Lakes that display characteristics between oligotrophic and eutrophic status. These lakes may be undergoing eutrophication.

<u>Eutrophication</u>: Lakes naturally move from an oligotrophic lake to a eutrophic lake throughout their lifetimes. Most lakes start very large and clear and slowly warm up and fill in with sediment over time. This is a natural process that takes thousands of years.

<u>Cultural Eutrophication</u>: Humans can speed up the eutrophication process by adding excess nutrients and sediments to the lake. It is important to monitor lakes to establish historical trends that will help show if cultural eutrophication is occurring there.

2022 Executive Summary of Results:

The 2022 analysis of data from Long, Mickey, and Ruth lake has shown little change since previous years. In the 2020 season, there wasn't as much data to compare because of pandemic related limitations.

Long Lake parameters were similar to the previous testing season. The *Secchi* average for transparency is slightly higher than last year. *Secchi* depth readings remained within the oligotrophic range. *Phosphorus* levels have slightly increased from last year but remain in an acceptable range for an oligotrophic lake. . *Chlorophyll-a* levels were still within the range of an oligotrophic lake, but have faintly lowered since 2021. *Calcium* levels still remain slightly higher overall, and with the discovery of Zebra Mussels within Long Lake, this needs to be carefully monitored even though levels are not yet at the point where large Zebra Mussel colonies can establish.

Mickey Lake parameters remain within the oligotrophic or mesotrophic levels, other than some eutrophic total phosphorus levels taken at depth. *Calcium* levels have reached the point at which Zebra Mussels have been able to colonize within a laboratory setting and should be closely monitored.

Ruth Lake remains a Eutrophic lake based on total *phosphorus, chlorophyll-a,* and *secchi* measurements. *Calcium* levels have also increased but are not near the level where Zebra Mussels become a threat.

Section I: 2022 Lake Water Quality Assessment on Long Lake, Mickey Lake, and Ruth Lake

The 2022 Lake Monitoring for Long Lake, Mickey Lake, and Ruth Lake was initiated by the Long Lake Association, Long Lake Foundation, Oleson Foundation, and Long Lake Township in partnership with the Great Lakes Environmental Center (GLEC), the Great Lakes Water Studies Institute, and the Cooperative Lake Monitoring Program (CLMP). The Association is now using the CLMP protocols for water quality monitoring, including protocols for monitoring dissolved oxygen and temperature, obtaining secchi disk readings, obtaining *phosphorus* and *chlorophyll-a* samples, identifying exotic aquatic plants, and conducting nearshore habitat assessments. The CLMP works with many lake associations and volunteer lake monitors around the state and has set state-wide standards for water quality monitoring. CLMP requirements included sampling in the early spring (two weeks after ice out) and sampling in the fall after the lakes have turned over. The only exception is *chlorophyll-a* which is sampled twice yearly. The continuation of this lake monitoring program is essential for the assessment of lake water quality across the state, and it facilitates the comparison of data across monitoring years since protocols and meta data match each other across distance and time. This is crucial for establishing trends and taking appropriate actions during lake management.

Physical data collected during the 2022 water quality monitoring season was obtained with a *secchi* disk and a YSI multiparameter water quality probe which was graciously donated to us by the Long Lake Association, Long Lake Foundation, Oleson Foundation, and Long Lake Township. Both of these instruments measure physical water quality parameter levels such as *temperature, dissolved oxygen, pH* and *conductivity.* A plankton net was used again this year, as it was in the past four years, to sample for zooplankton and phytoplankton. Ponar grab/ Ponar dredge was newly implemented during the 2022 summer season. This instrument helped us collect mud from all depths of the lake. Water samples were taken for the analysis of total *phosphorus,* both at the surface and near the bottom of the lakes. *Calcium, chlorophyll a,* and *nitrate/nitrite* levels were also tested.

Long Lake

<u>**Water Chemistry**</u>

Total Phosphorus: Comparing data from 2021 and the 2022 seasons, the surface total phosphorus has increased, while the bottom total phosphorus has decreased. Long Lake remains in the mesotrophic and oligotrophic categories. The overall trend is remaining steady but levels should be carefully monitored. Limited testing during the 2020 season may cause a skew in the data, it has already been noted.

Chlorophyll-a: Chlorophyll-a levels were lower than the 2021 levels in Long Lake, but still falling well within the oligotrophic range. This parameter should still be carefully monitored as an increase in Chlorophyll-a levels is directly tied to the increased presence of lake nutrients.

Secchi Depth: Regular secchi depth measurements were taken this year, and readings remained within the normal range. Secchi depth transparency data shows a slight increase compared to 2021 and 2020.

Calcium: Calcium levels were slightly lower than the 2021 season. The calcium level has been shown to be adequate for zebra mussels to colonize in a laboratory setting, but calcium levels are not yet thought to be high enough for lake colonization based on data focusing on European zebra mussel infestations. Small quantities of zebra mussels have been found in Long Lake.

Nitrogen (Nitrate/Nitrite): Levels have increased compared to 2021, however, remains stable throughout the sampling season and similar to levels from 2005.

Hydrolab (Physical Data)

Temperature and D.O. data shows stratification and seasonal changes as expected. Long Lake is the largest and deepest of the three lakes monitored.

Conclusions and Recommendations

Data collected during the 2022 testing season indicate Long Lake still holds the status of oligotrophic lake. While some parameters trended slightly higher and some slightly lower, most were within similar ranges of last year's data and within the range for oligotrophic status. Some of the data, such as Nitrates and Nitrites are reading the highest numbers they've ever been- we are very unsure if this was human error or accurate readings. This is the 29th year Long Lake has maintained oligotrophic status, based on data collection that began in 1993. As development continues on the lakeshore and within the surrounding watershed it is critical that outreach and education efforts continue and focus on ways property owners can ensure Long Lake continues to be healthy. These include vegetation buffers, limited shoreline development, the emphasis of septic system monitoring and repair, and reduction of nutrient use within the watershed.

Mickey and Ruth Lake

Water Chemistry

Total Phosphorus:

- Mickey Lake: Total phosphorus levels have slightly decreased, with depth readings at site 1 reaching Eutrophic levels. Surface levels remain on the oligotrophic and mesotrophic border.

- Ruth Lake: Total phosphorus levels were uncharacteristically low this year compared to last year and all the previously tested years. It is difficult to decipher why, because of the few times we were able to test on the lake itself.

Chlorophyll a:

- Mickey Lake: Chlorophyll-A levels have increased this year compared to 2021. Measurements remained within the oligotrophic range. Note: data variance each year should be expected as chlorophyll a is highly sensitive to changes in plant life within the lake and the time of year measurements are taken.
- Ruth Lake: Chlorophyll-A levels were in line with previous years measurements. The maximum quantity was slightly low, but not concerningly low.

Secchi Depth:

- Mickey Lake: Average secchi depth remains very close to 2021's average secchi depth, just slightly higher.
- Ruth Lake: Average secchi depth remains very consistent to 2021's depth and other years prior.

Calcium:

- Mickey Lake: Calcium levels ranged between 19.4 and 21.9 mg/L. This is within the range where Zebra Mussel colonies have been able to establish within a laboratory setting. Continued monitoring of this parameter is important.
- Ruth Lake: Calcium levels are much lower than within Long and Mickey Lake and are not within the range where Zebra Mussel colonies can occur.

Nitrogen (Nitrate/Nitrite):

- This year, in our first data collection, the numbers were higher than ever. Then, in our second data collection, the numbers appeared to regain consistent, low readings tantamount to previous years.

Physical Data

Temperature and DO data showed expected temperature and dissolved oxygen relationship in both lakes. Because of their shallow nature, Mickey Lake has a subtle thermocline which Ruth Lake does not have a thermocline.

Conclusions and Recommendations

Mickey Lakes data shows the lake inching closer to mesotrophic status. Ruth Lake is still trending Eutrophic. Even though both are connected to Long Lake the channels connecting them are shallow and vary greatly based on water levels. It is important to continue taking measurements to monitor changes in eutrophication status. Because of their small size and shallow depths, Ruth Lake and Mickey Lake are particularly vulnerable to cultural eutrophication and need to be closely monitored. Long Lake, while larger and deeper, is still vulnerable because of heavy boat traffic and shoreline development. Continued education and outreach programs for property owners and visitors is especially important. The reduction or elimination of fertilizer use, establishment of vegetative shoreline buffers to catch runoff, and proper septic system upkeep are all important factors in reducing the effects of eutrophication that require property owner cooperation.eutrophication process down towards its natural pace. This could preserve the health of the ecosystems in these lakes as well as recreational and property value.

Long Lake Water Chemistry Data

Total Phosphorus (µg/L)

	May 13, 2022	*May 13, 2022*	*September 8, 2022*	*September 8, 2022*
Location	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Surface	3.7	3.7	3.6	17.7
Depth	3.7	4.9	11.6	6.3

Chlorophyll a (µg/L)

	May 13, 2022	*May 13,2022*	*September 8, 2022*	*September 8, 2022*
Location	**Site 1**	**Site 2**	**Site 1**	**Site 2**
	1.84 A	1.31	1.33	1.54 A
	1.92 B			1.50 B

Average Secchi Depth (m)

Long Lake Total Average: 9.3

Calcium (mg/L)

May 13, 2022	*May 13, 2022*	*September 19, 2022*	*September 19, 2022*
Site 1	**Site 2**	**Site 1**	**Site 2**
23.7	23.1	19.5	20.4

Nitrogen (µg/L) (Nitrate/ Nitrite)

	May 13, 2022	*May 13, 2022*	*September 8, 2022*	*September 8, 2022*
Location	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Surface	27.7	27.6	<3.4	<3.4
Depth	27.9	29.5	<3.4	6.2

Mickey Lake Water Chemistry Data

Total Phosphorus (µg/L)

	May 13, 2022	*May 13, 2022*	*September 8, 2022*	*September 8, 2022*
Location	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Surface	6.2	N/A	10.6	N/A
Depth	15.1	N/A	14.1	N/A

Chlorophyll a (µg/L)

	May 13, 2022	*May 13, 2022*	*September 8, 2022*	*September 8, 2022*
Location	**Site 1**	**Site 2**	**Site 1**	**Site 2**
	11.85	N/A	1.68	N/A

Calcium (mg/L)

May 13, 2022	*May 13, 2022*	*September 19, 2022*	*September 19, 2022*
Site 1	**Site 2**	**Site 1**	**Site 2**
21.9	N/A	19.4	N/A

Nitrogen (µg/L) (Nitrate/ Nitrite)

	May 13, 2022	*May 13, 2022*	*September 8, 2022*	*September 8, 2022*
Location	**Site 1**	**Site 2**	**Site 1**	**Site 2**
Surface	24.4	N/A	<3.4	N/A
Depth	35.8	N/A	<3.4	N/A

Average Secchi Depth (m)
Mickey Lake Total Average: 4.72

Ruth Lake Water Chemistry Data

Total Phosphorus (µg/L)

	May 24, 2022	*September 19, 2022*
Location	**Site 1**	**Site 1**
Surface	4.8	20.4
Depth	3.8	24.9

Chlorophyll a (µg/L)

May 24, 2022	*September 19, 2022*
Site 1	**Site 1**
7.20 A	4.65 A
7.34 B	4.58 B

Calcium (mg/L)

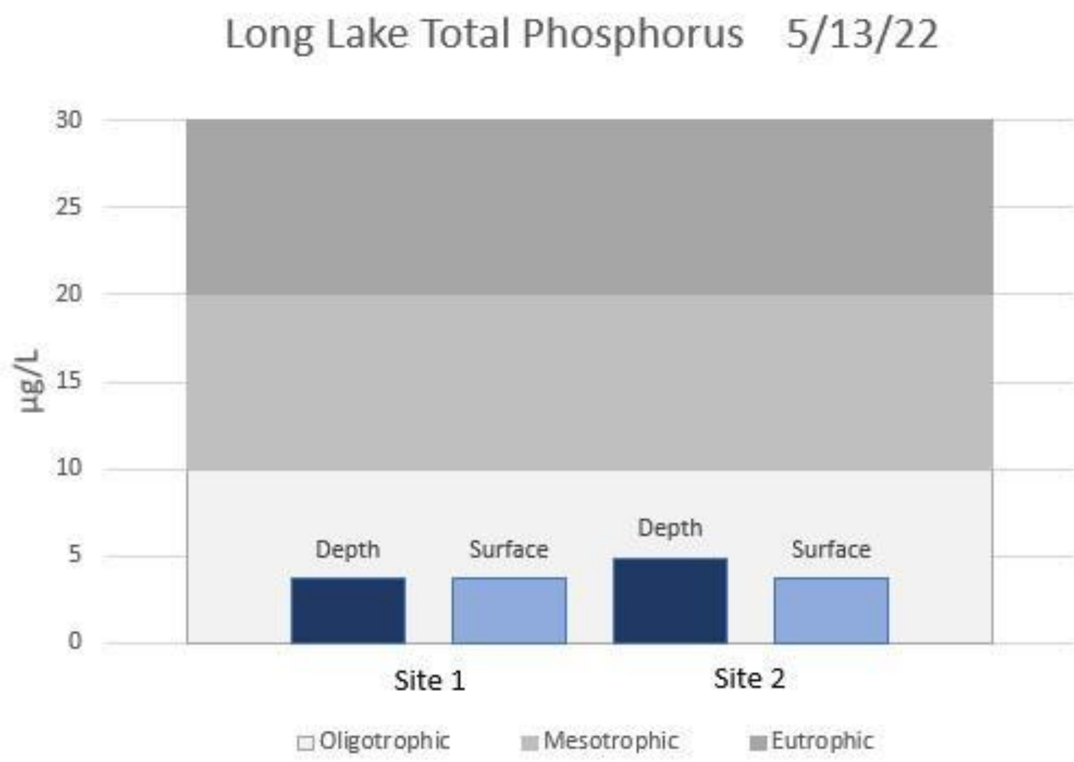
May 24, 2022	*September 19, 2022*
Site 1	**Site 1**
7.4	6.6

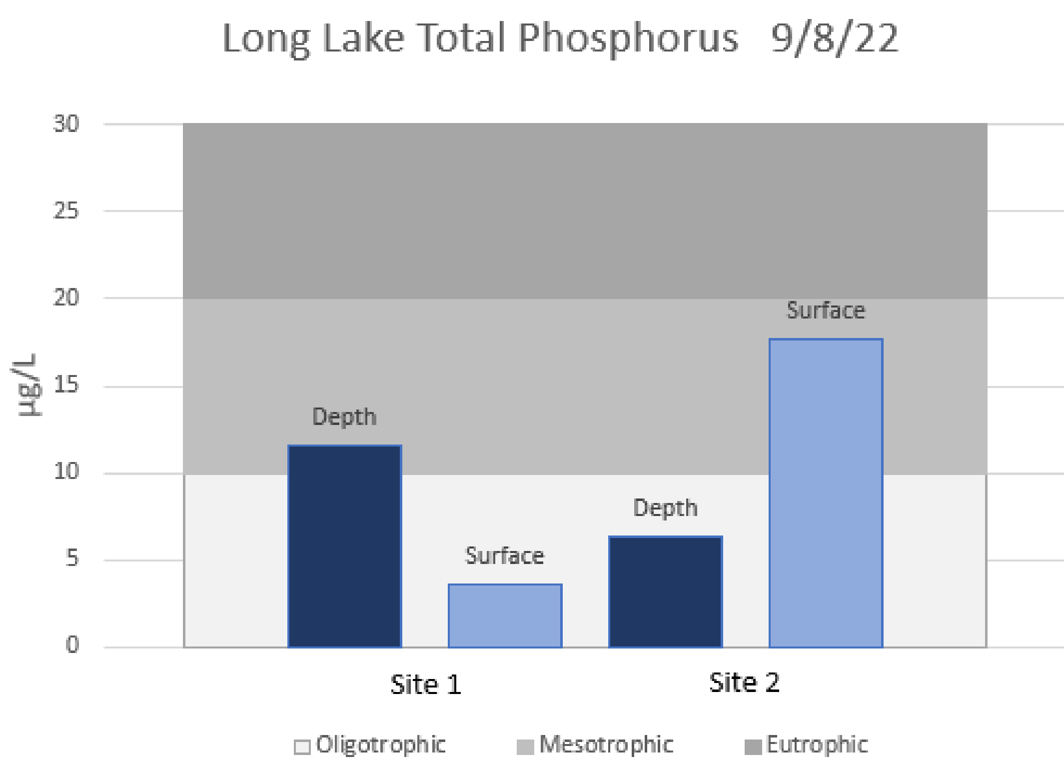
Nitrogen (mg/L) (Nitrate/ Nitrite)

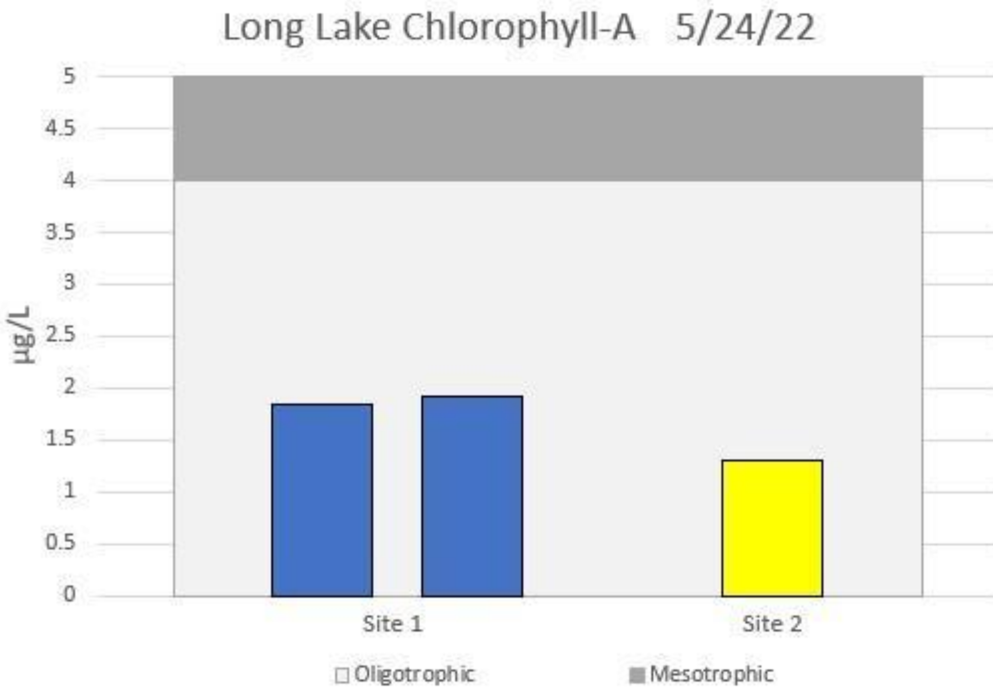
	May 24, 2022	*September 19, 2022*
Location	**Site 1**	**Site 1**
Surface	9.8	<0.0034
Depth	27.6	<0.0034

Average Secchi Depth (m)
Ruth Lake Total Average: 0.91

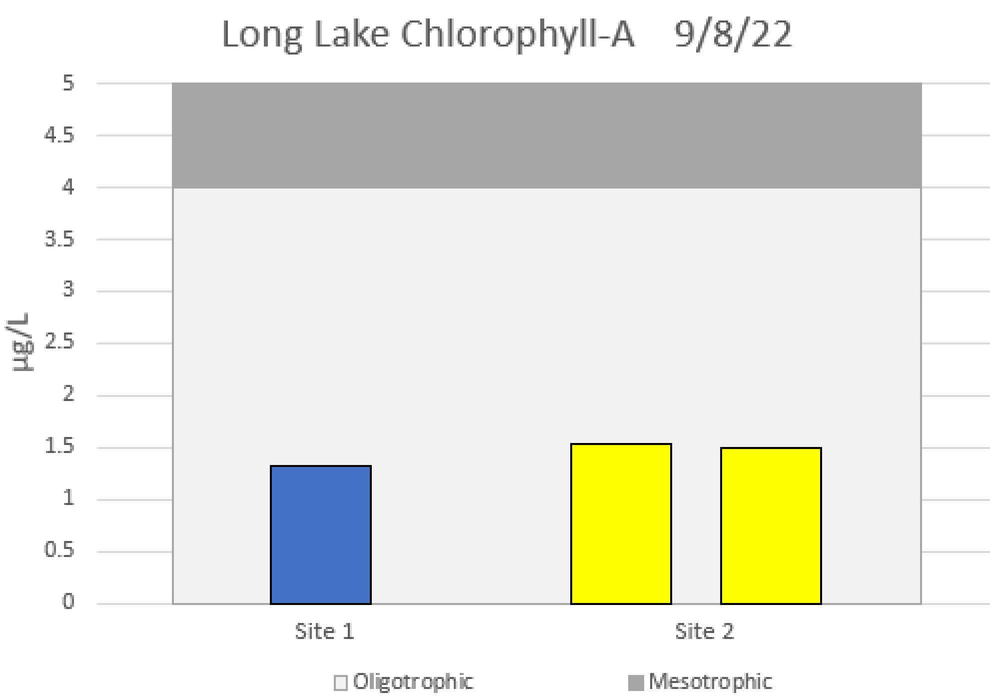
Water Chemistry Data Graphs: Long Lake



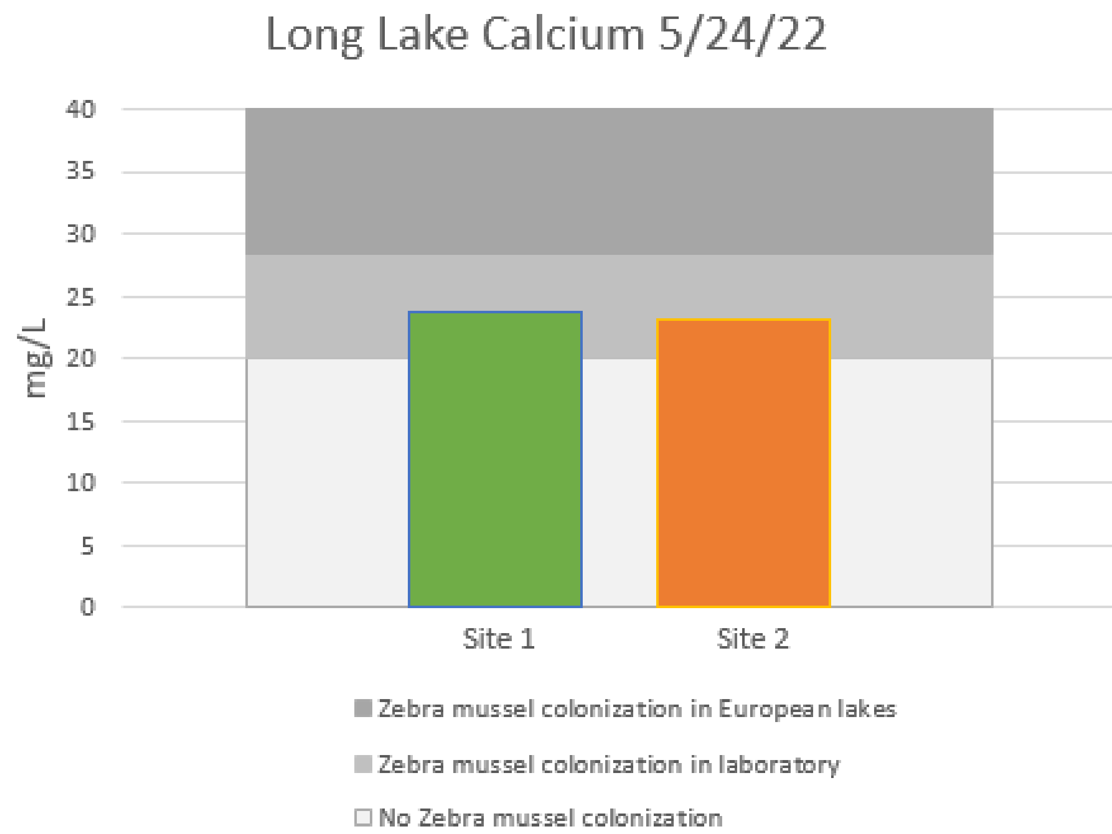


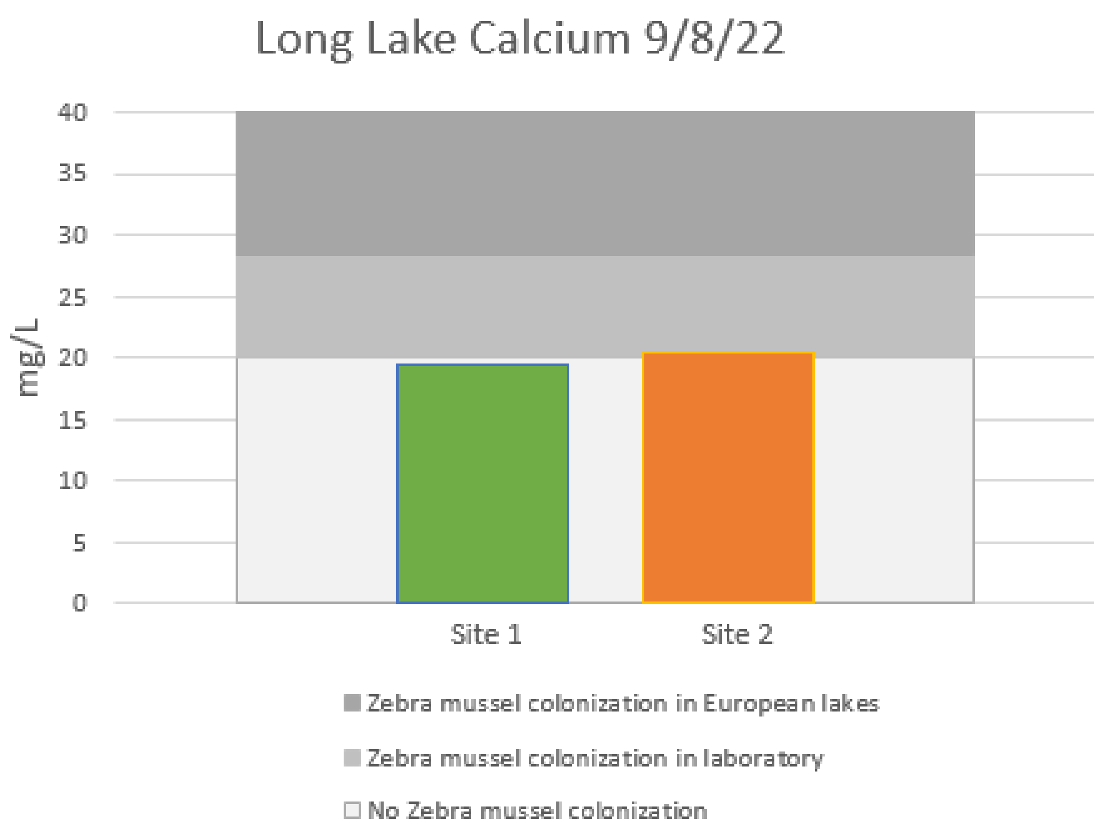


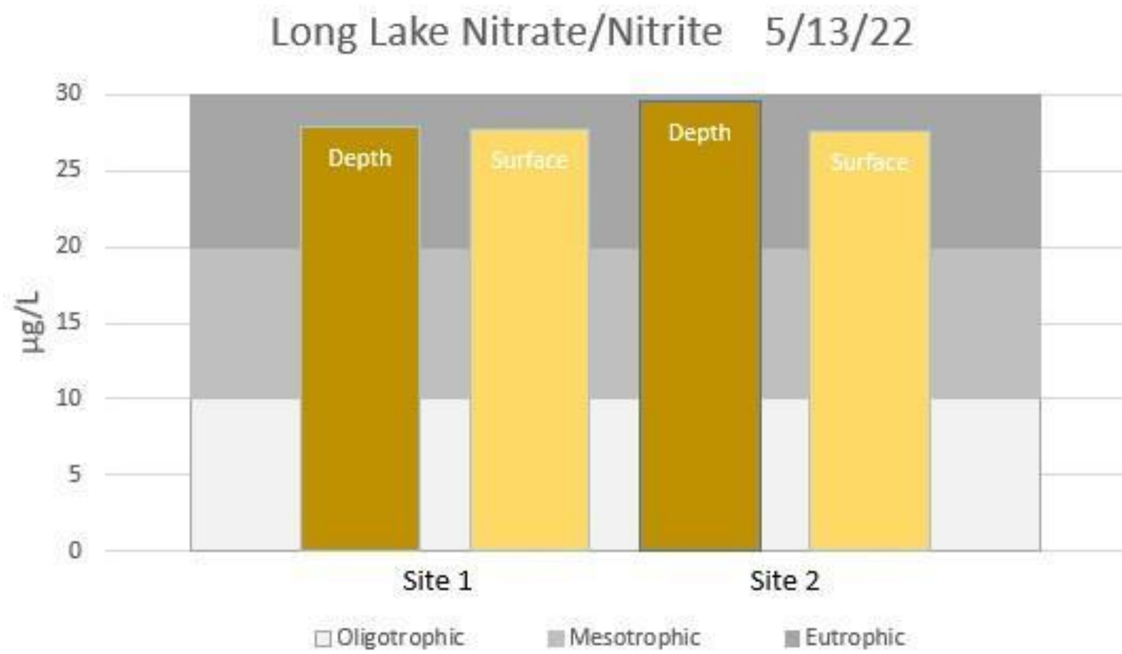
Long Lake Chlorophyll-A 5/24/22
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
µg/L
Site 1
Site 2
Oligotrophic
Mesotrophic

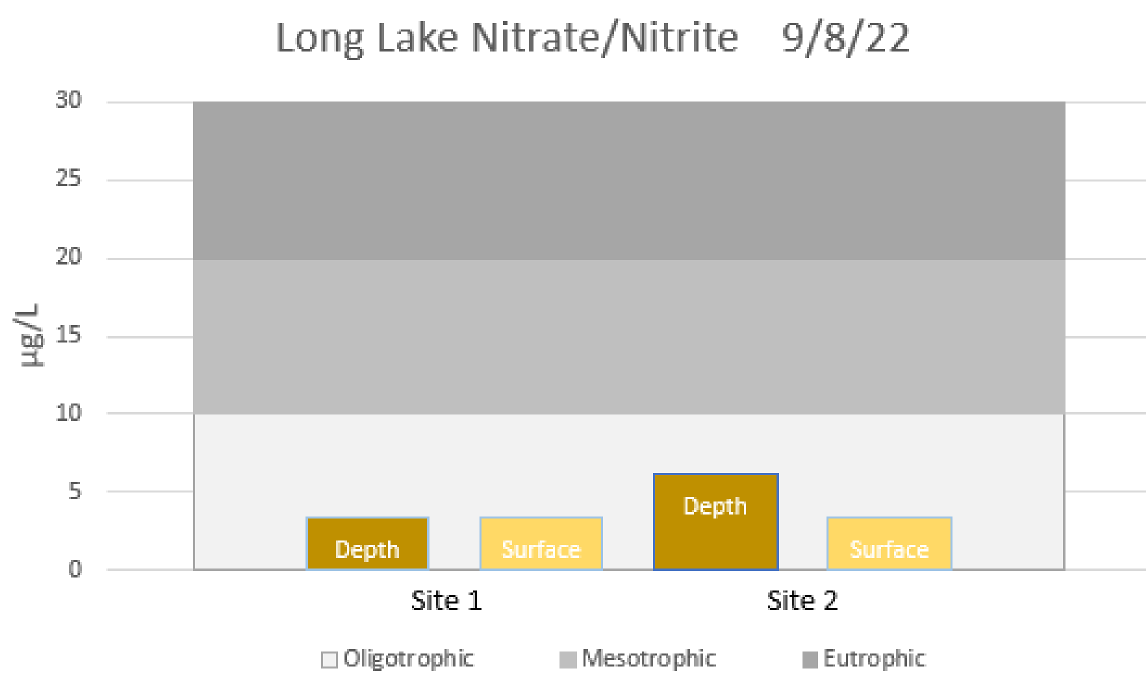


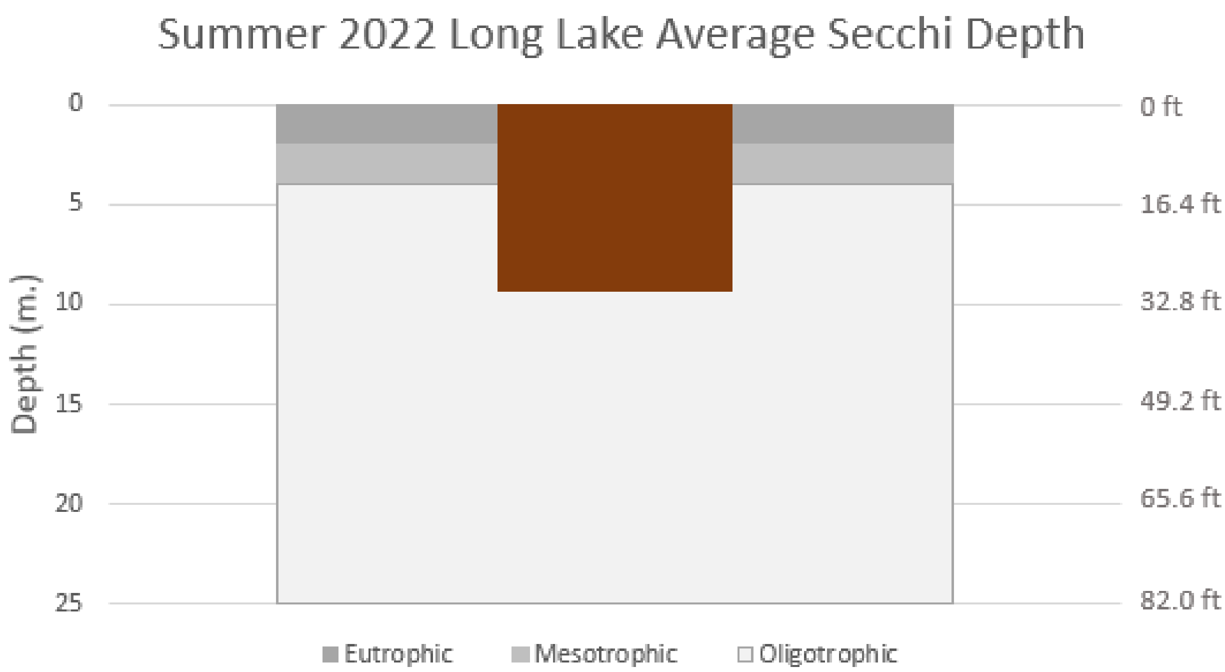
Long Lake Chlorophyll-A 9/8/22
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
µg/L
Site 1
Site 2
Oligotrophic
Mesotrophic


Long Lake Calcium 5/24/22
mg/L
40
35
30
25
20
15
10
5
0
Site 1
Site 2
Zebra mussel colonization in European lakes
Zebra mussel colonization in laboratory
No Zebra mussel colonization

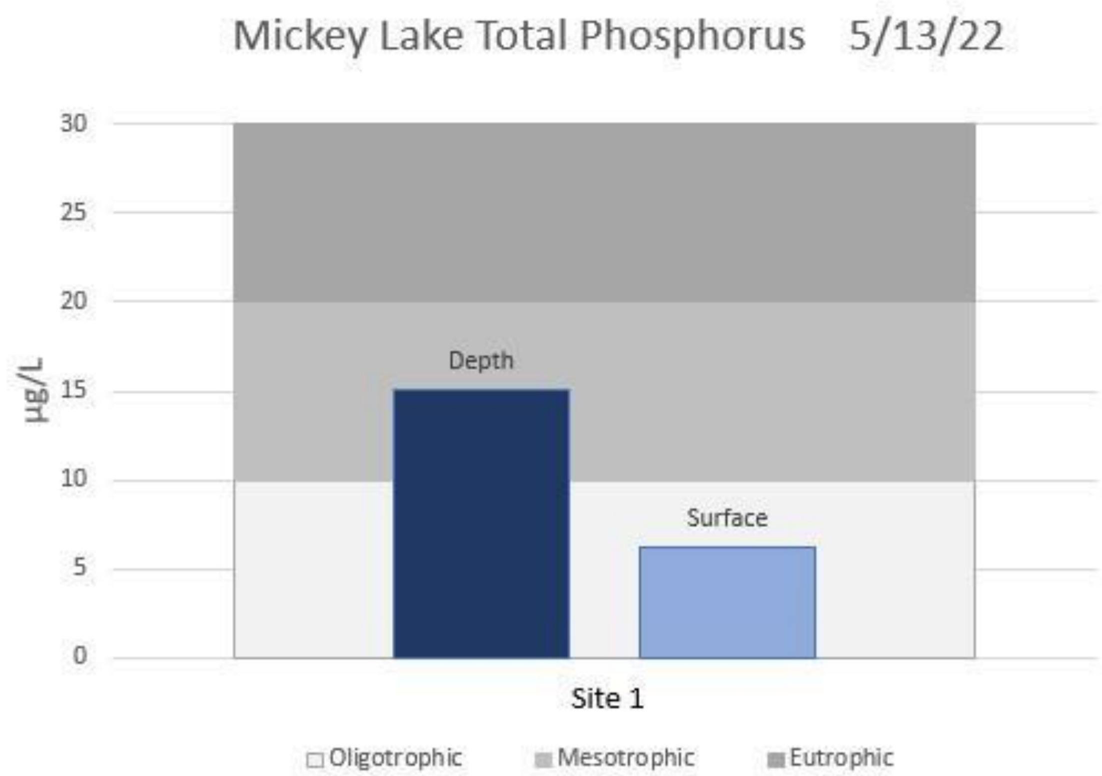

Long Lake Calcium 9/8/22
mg/L
40
35
30
25
20
15
10
5
0
Site 1
Site 2
Zebra mussel colonization in European lakes
Zebra mussel colonization in laboratory
No Zebra mussel colonization

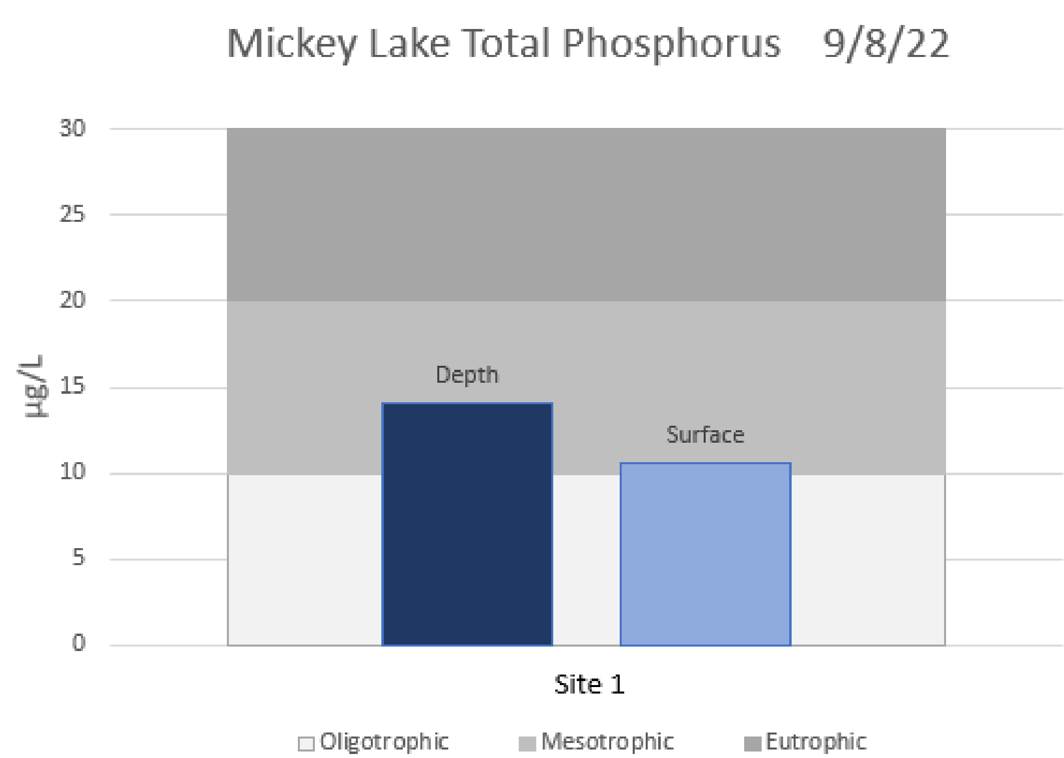

Long Lake Nitrate/Nitrite 5/13/22
30
25
20
15
10
5
0
µg/L
Depth
Surface
Depth
Surface
Site 1
Site 2
Oligotrophic
Mesotrophic
Eutrophic

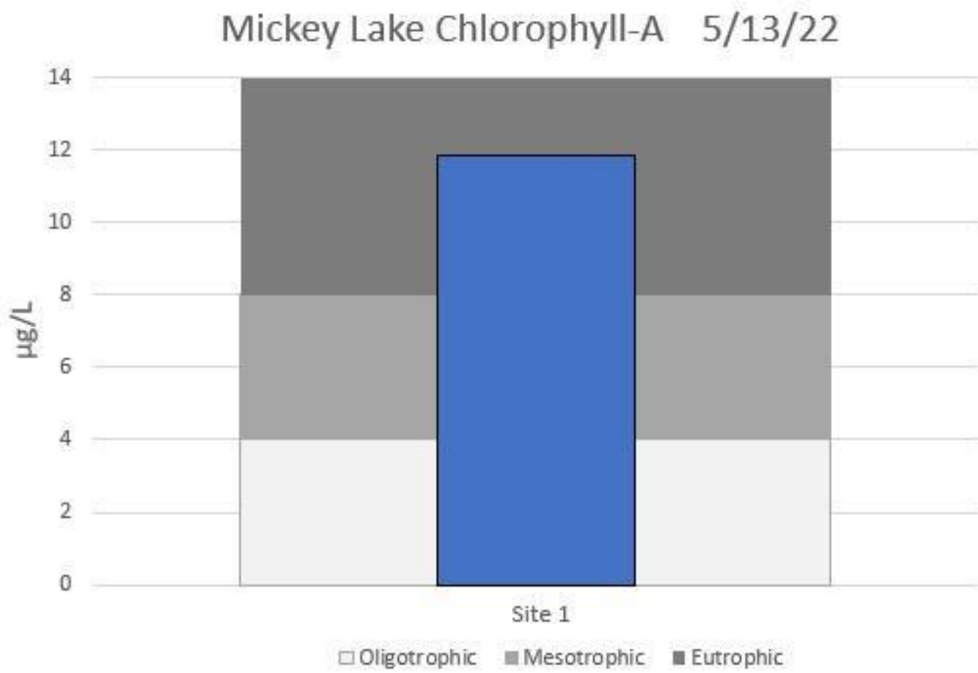

Long Lake Nitrate/Nitrite 9/8/22
30
25
20
15
10
5
0
µg/L
Depth
Surface
Depth
Surface
Site 1
Site 2
Oligotrophic
Mesotrophic
Eutrophic

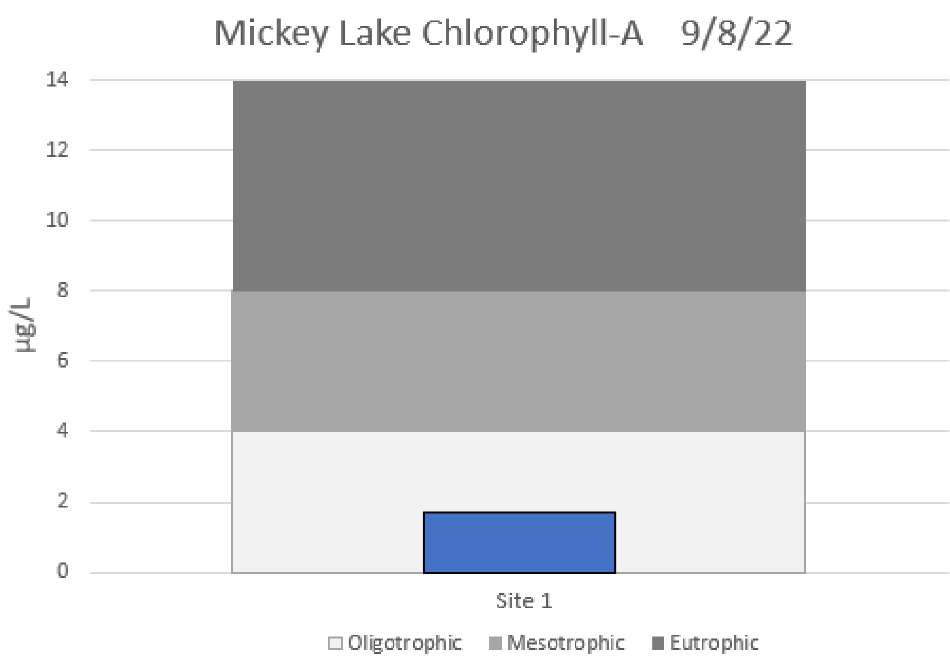

Summer 2022 Long Lake Average Secchi Depth
Depth (m.)
0
5
10
15
20
25
0 ft
16.4 ft
32.8 ft
49.2 ft
65.6 ft
82.0 ft
Eutrophic
Mesotrophic
Oligotrophic

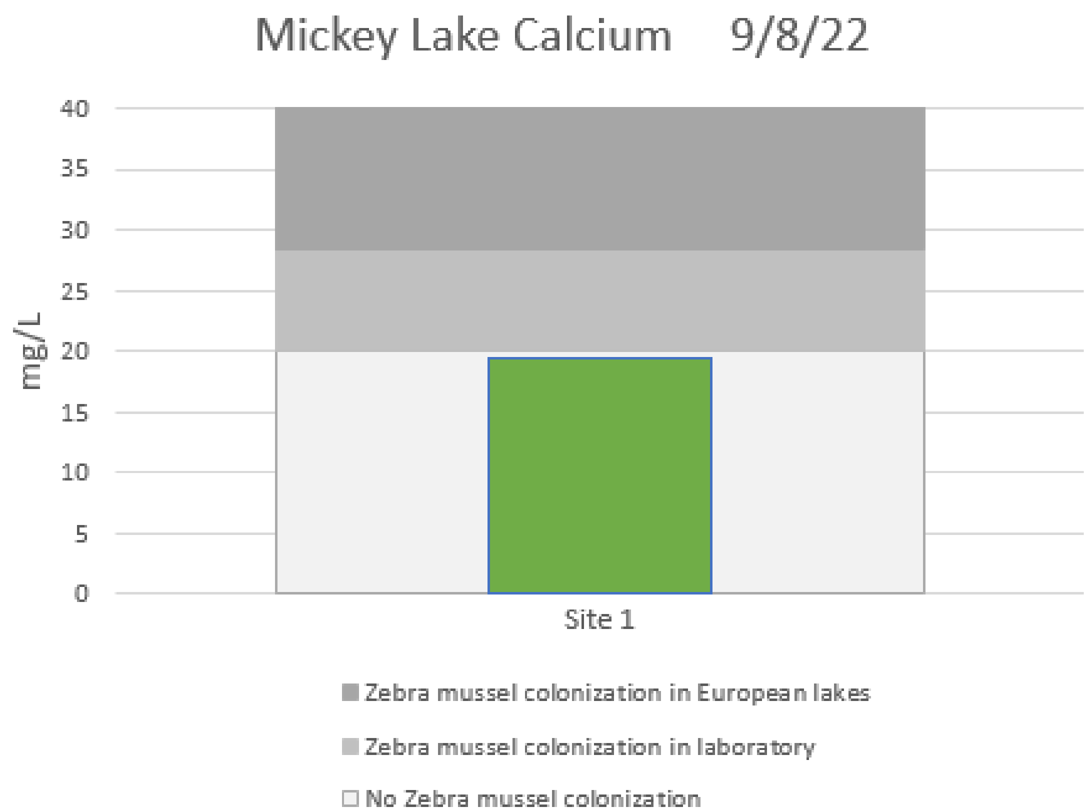
Water Chemistry Data Graphs: Mickey Lake



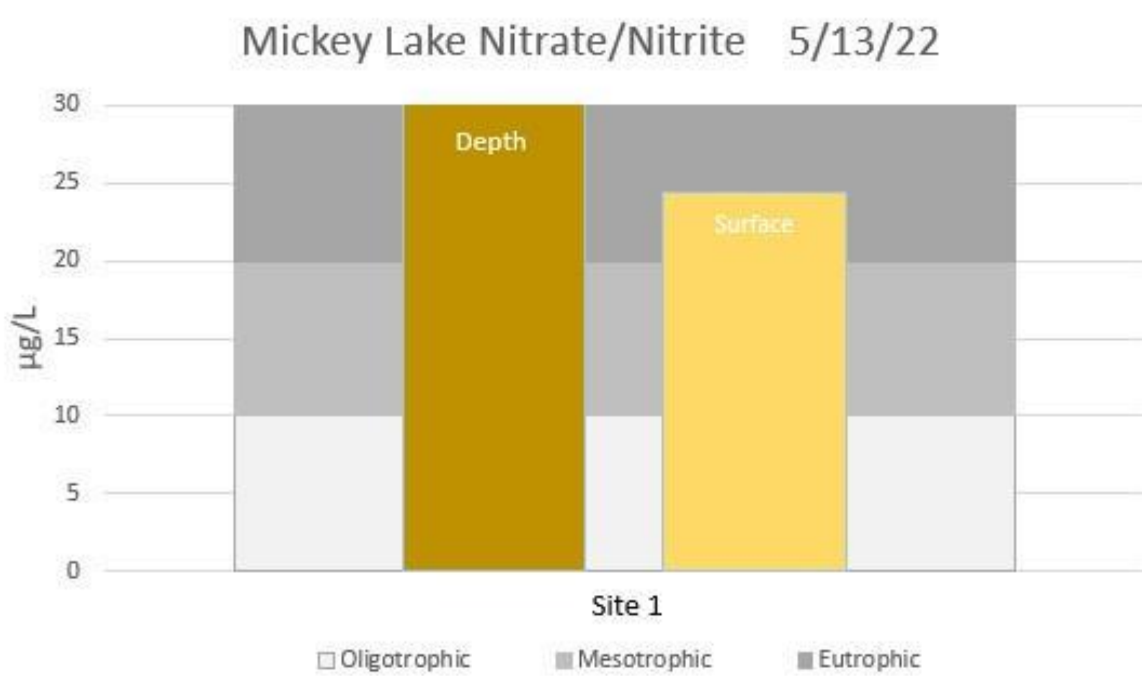



Mickey Lake Chlorophyll-A 5/13/22
14
12
10
8
6
4
2
0
µg/L
Site 1
Oligotrophic
Mesotrophic
Eutrophic

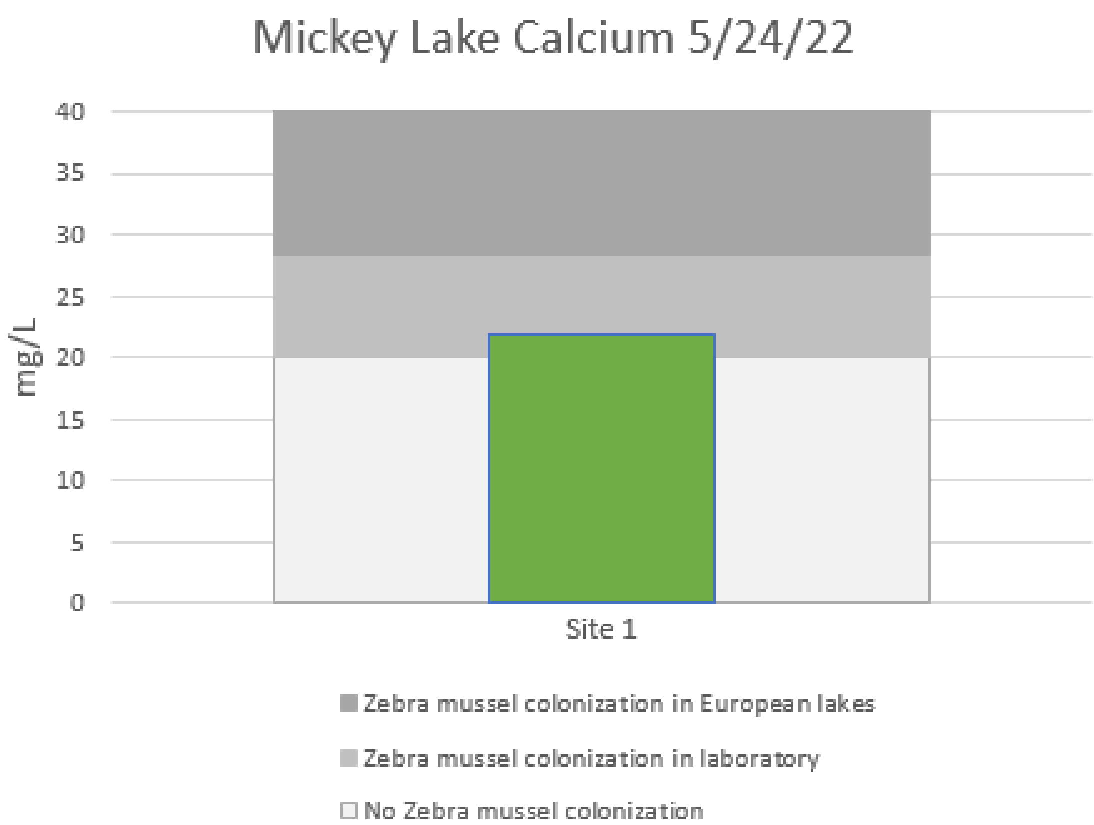

Mickey Lake Chlorophyll-A 9/8/22
14
12
10
8
6
4
2
0
µg/L
Site 1
Oligotrophic
Mesotrophic
Eutrophic



Mickey Lake Calcium 9/8/22
mg/L
40
35
30
25
20
15
10
5
0
Site 1
Zebra mussel colonization in European lakes
Zebra mussel colonization in laboratory
No Zebra mussel colonization



Mickey Lake Nitrate/Nitrite 5/13/22
µg/L
30
25
20
15
10
5
0
Depth
Surface
Site 1
Oligotrophic
Mesotrophic
Eutrophic


Mickey Lake Calcium 5/24/22
mg/L
40
35
30
25
20
15
10
5
0
Site 1
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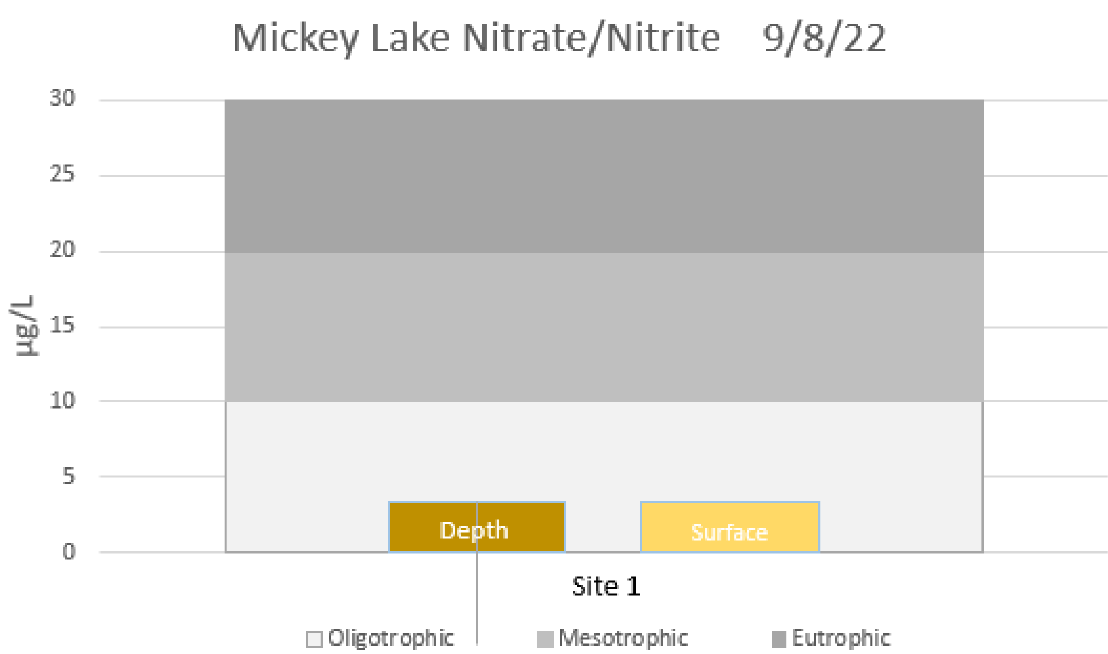
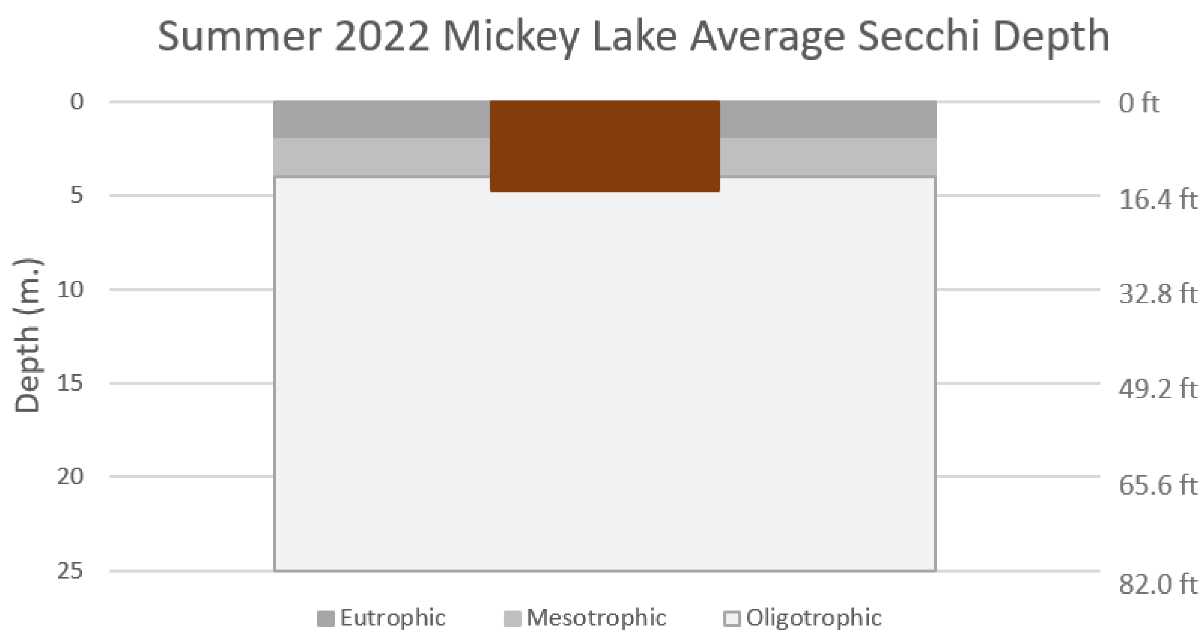
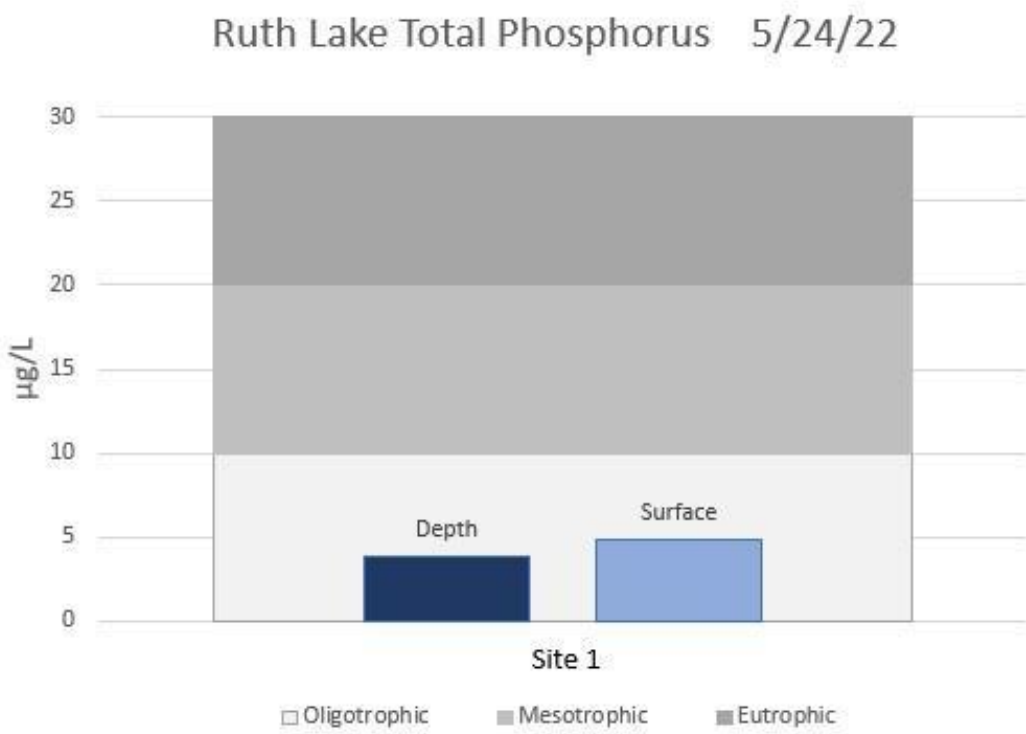
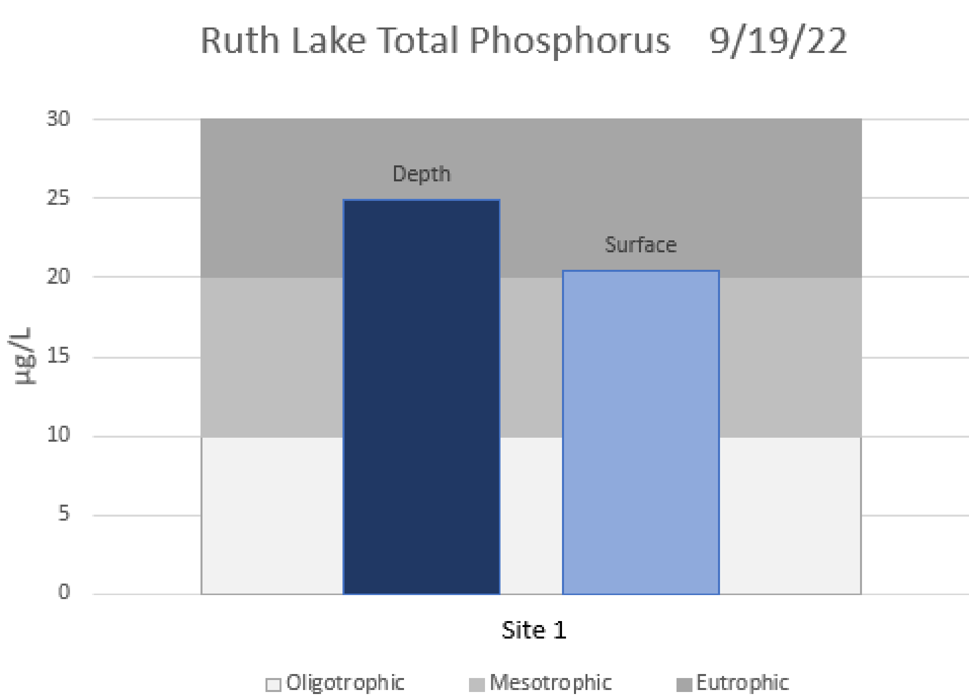
Zebra mussel colonization in laboratory
No Zebra mussel colonization

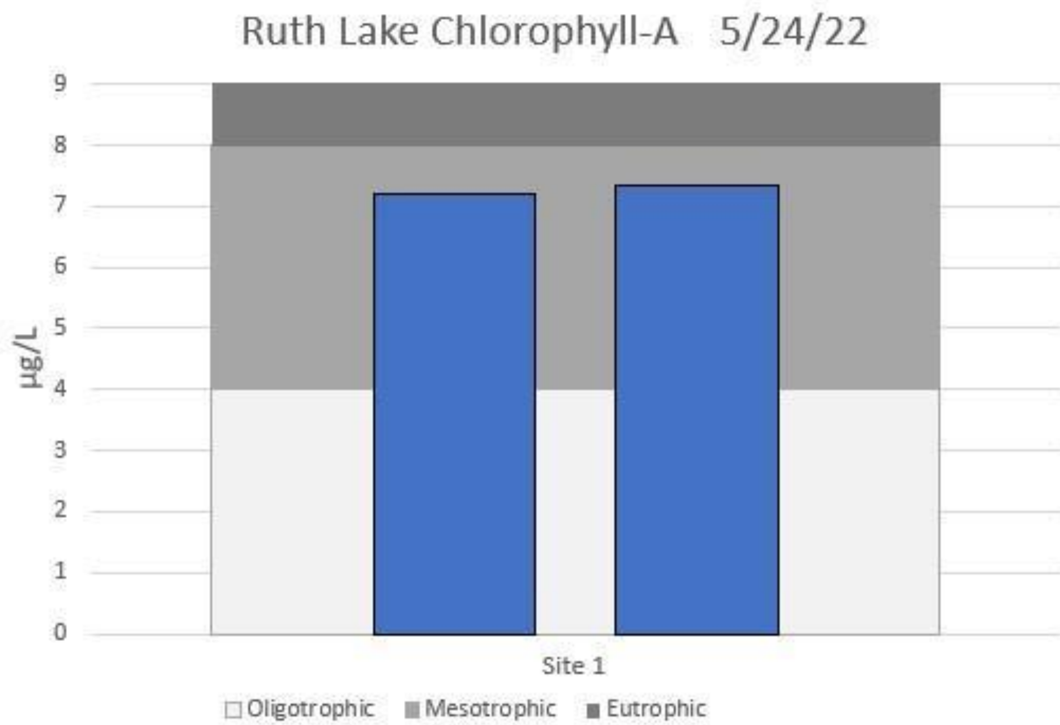

Mickey Lake Nitrate/Nitrite 9/8/22
µg/L
30
25
20
15
10
5
0
Depth
Surface
Site 1
Oligotrophic
Mesotrophic
Eutrophic

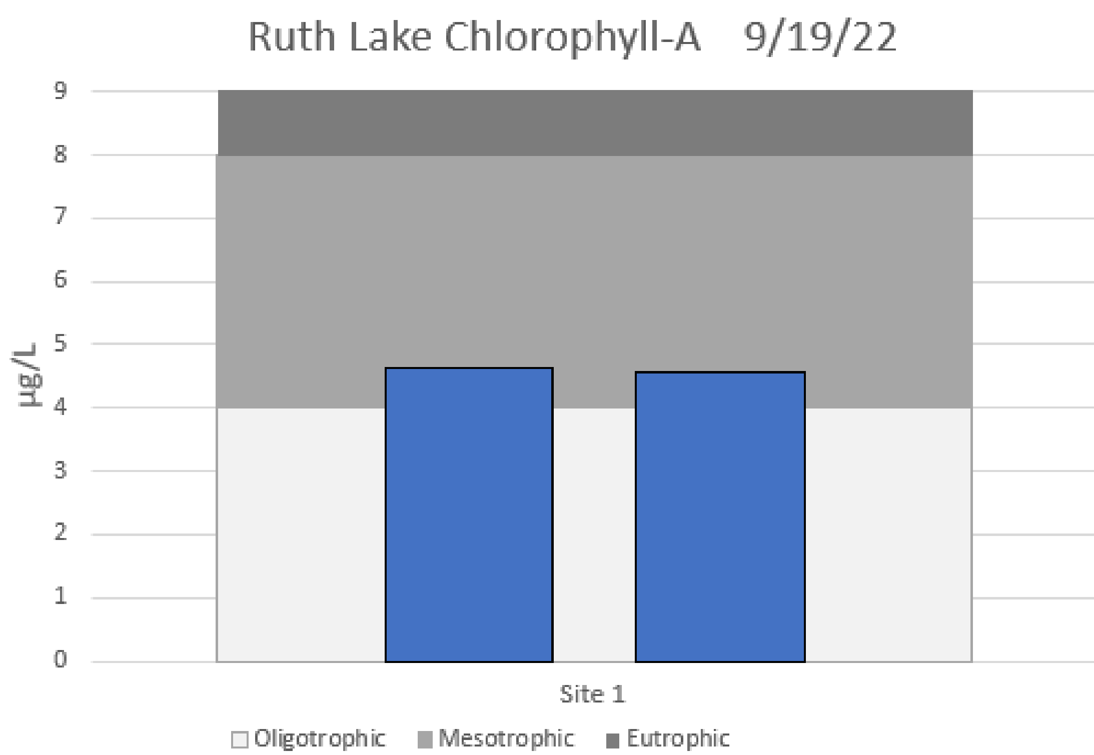

Summer 2022 Mickey Lake Average Secchi Depth
Depth (m.)
0
5
10
15
20
25
0 ft
16.4 ft
32.8 ft
49.2 ft
65.6 ft
82.0 ft
Eutrophic
Mesotrophic
Oligotrophic

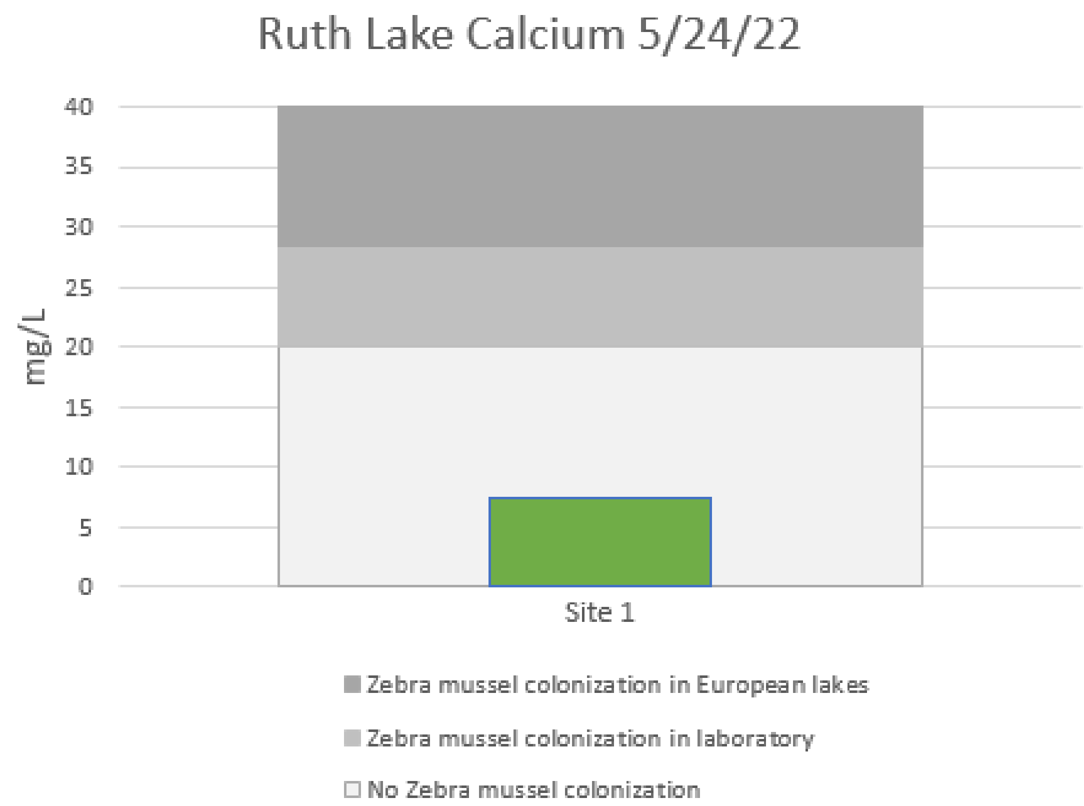
Water Chemistry Data Graphs: Ruth Lake

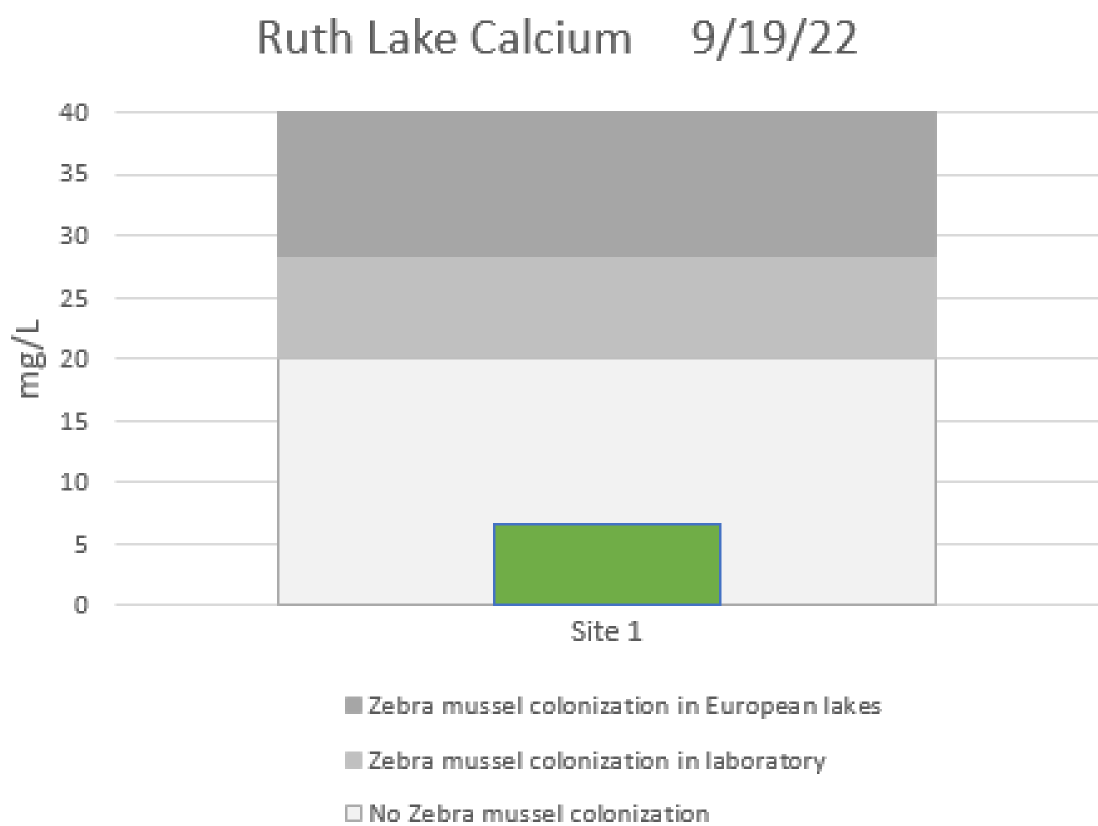


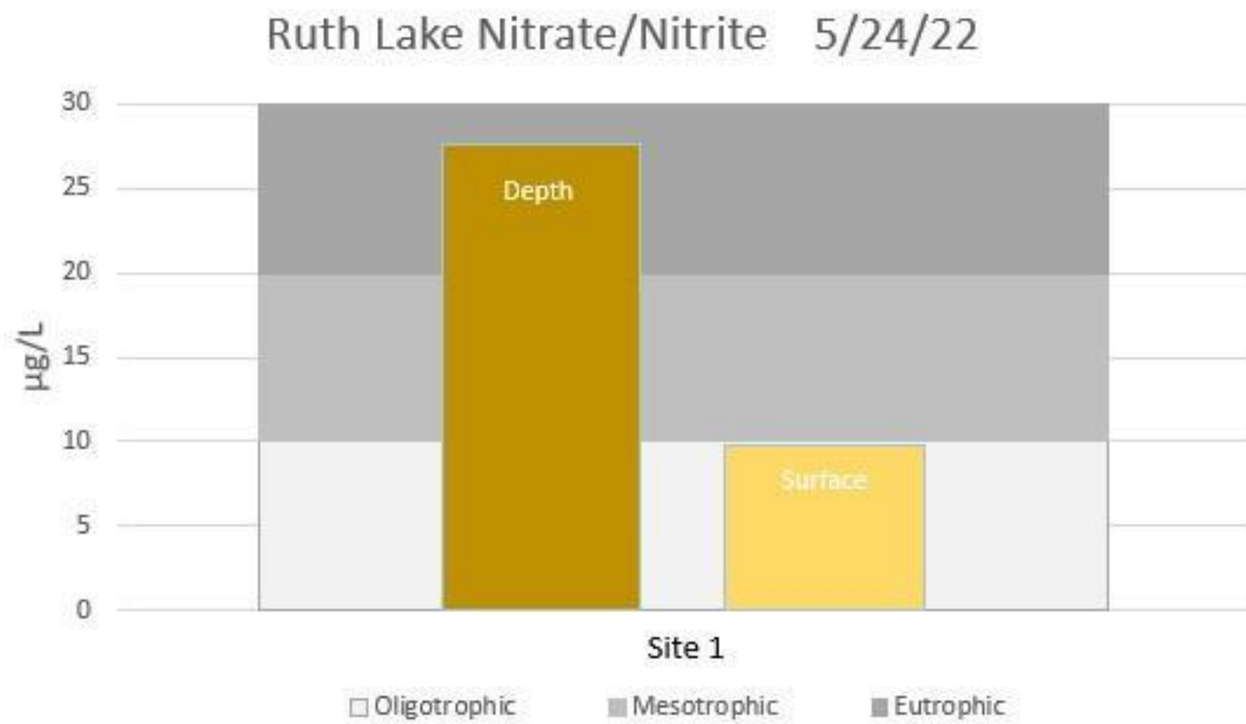


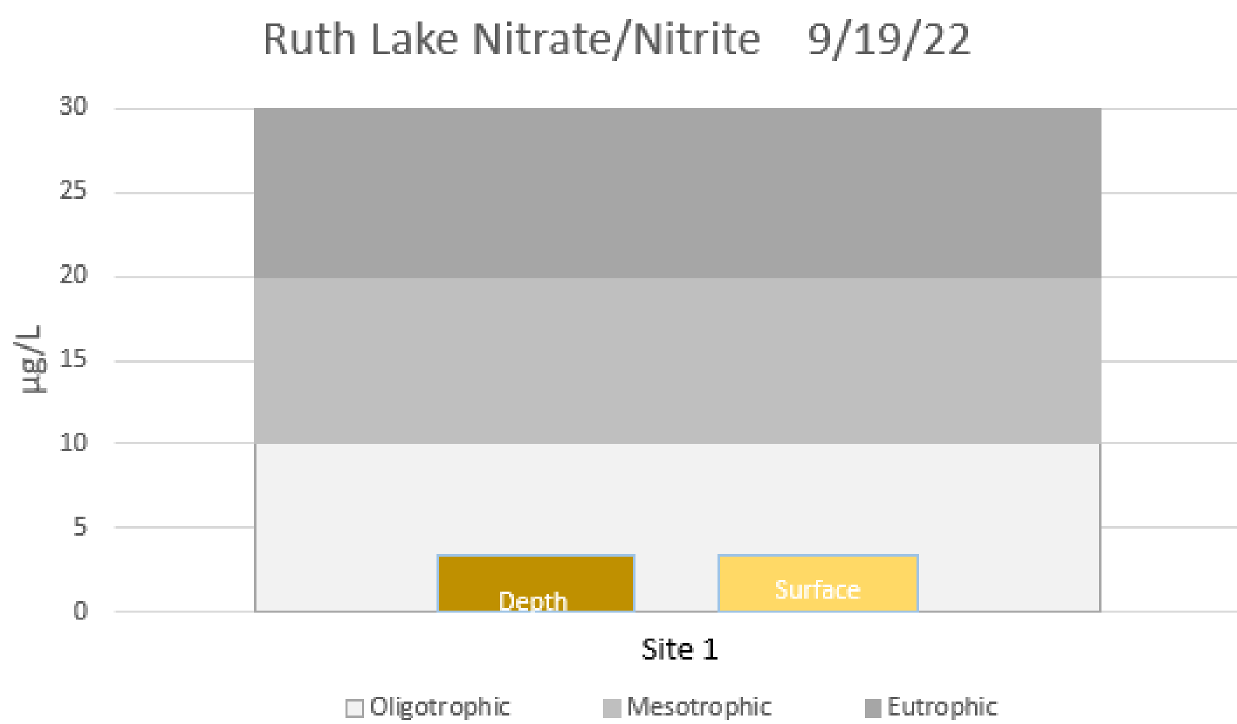

Ruth Lake Chlorophyll-A 5/24/22
9
8
7
6
5
4
3
2
1
0
µg/L
Site 1
Oligotrophic
Mesotrophic
Eutrophic

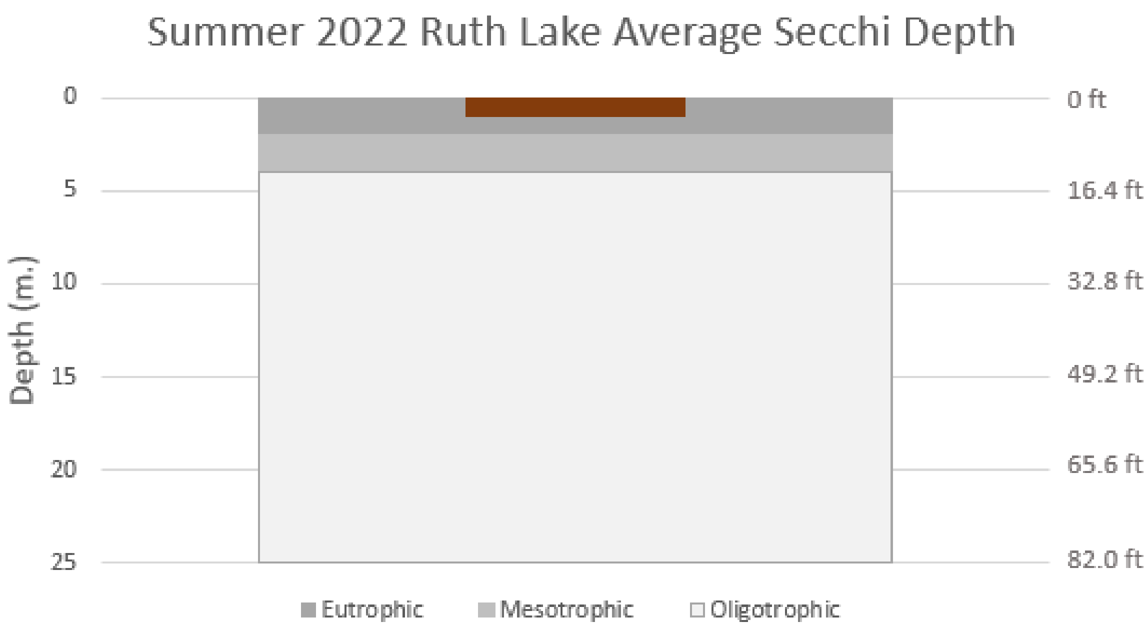

Ruth Lake Chlorophyll-A 9/19/22
9
8
7
6
5
4
3
2
1
0
µg/L
Site 1
Oligotrophic
Mesotrophic
Eutrophic


Ruth Lake Calcium 5/24/22
40
35
30
25
20
15
10
5
0
mg/L
Site 1
Zebra mussel colonization in European lakes
Zebra mussel colonization in laboratory
No Zebra mussel colonization

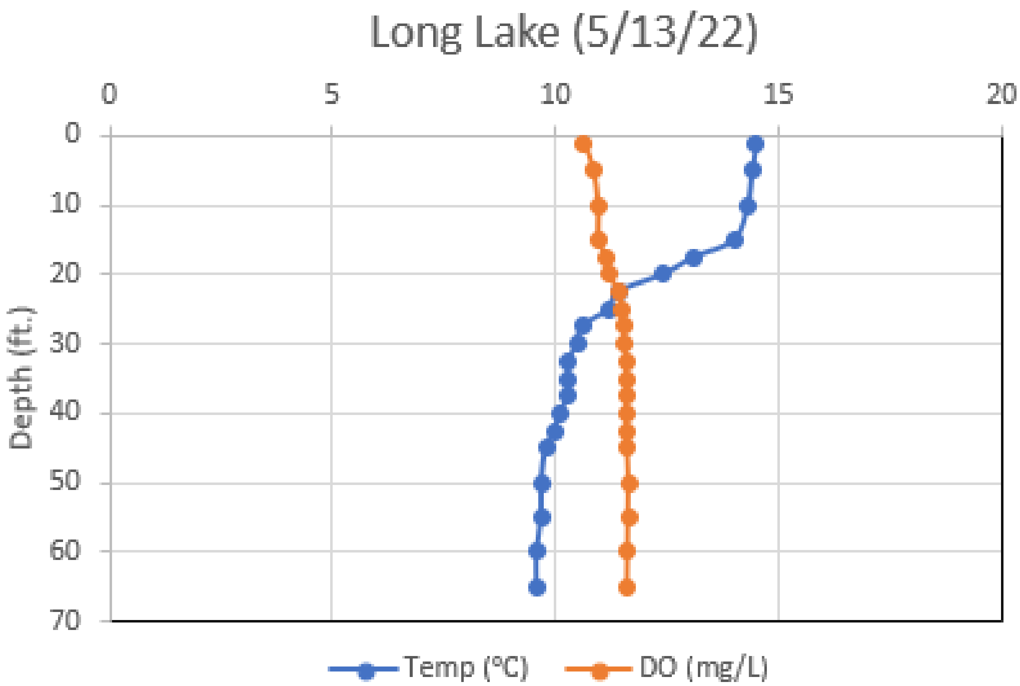

Ruth Lake Calcium 9/19/22
40
35
30
25
20
15
10
5
0
mg/L
Site 1
Zebra mussel colonization in European lakes
Zebra mussel colonization in laboratory
No Zebra mussel colonization

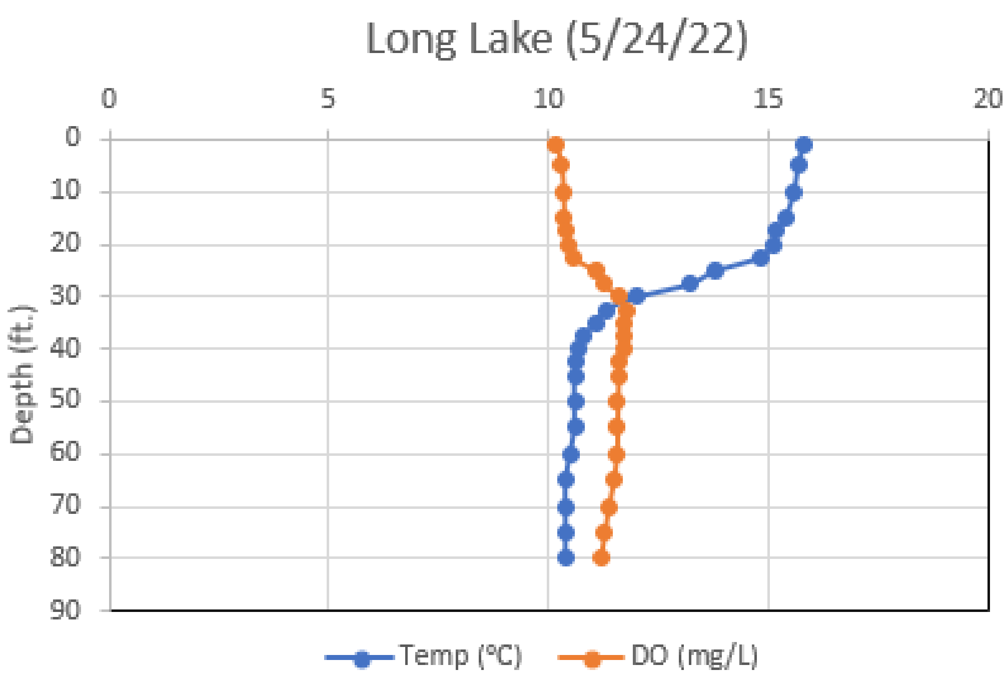

Ruth Lake Nitrate/Nitrite 5/24/22
30
25
20
15
10
5
0
µg/L
Depth
Surface
Site 1
Oligotrophic
Mesotrophic
Eutrophic

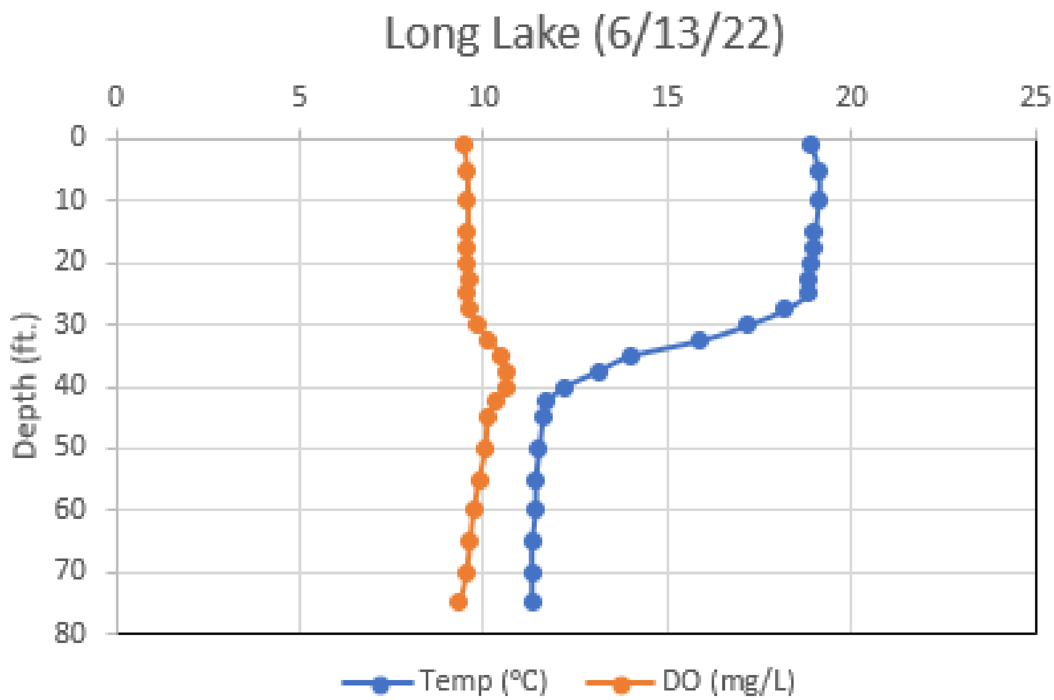

Ruth Lake Nitrate/Nitrite 9/19/22
30
25
20
15
10
5
0
µg/L
Depth
Surface
Site 1
Oligotrophic
Mesotrophic
Eutrophic

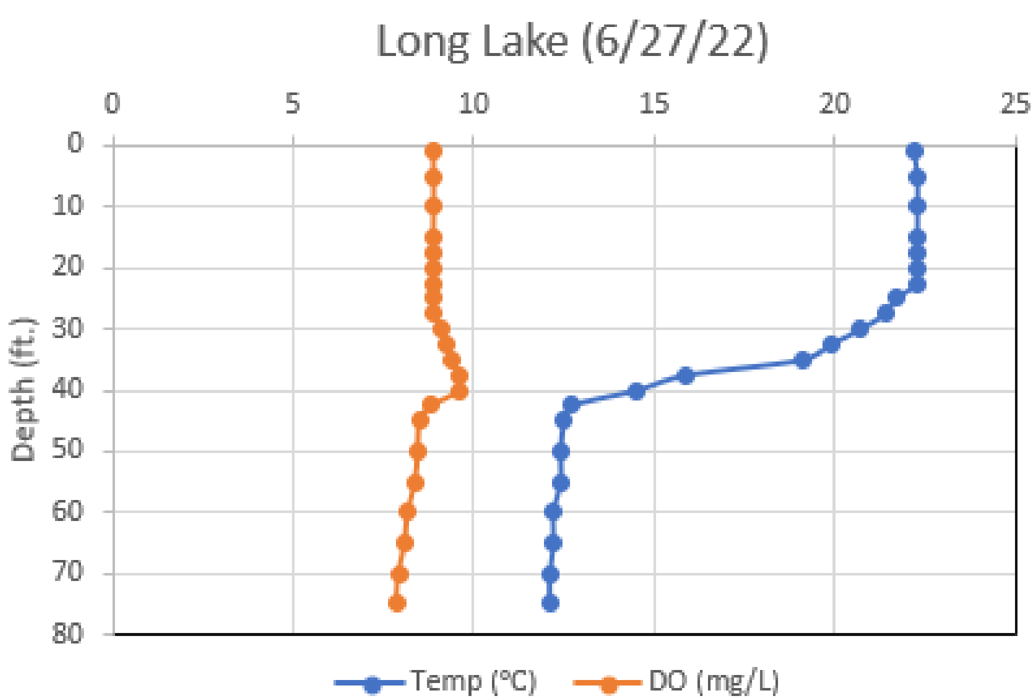

Summer 2022 Ruth Lake Average Secchi Depth
Depth (m.)
0
5
10
15
20
25
0 ft
16.4 ft
32.8 ft
49.2 ft
65.6 ft
82.0 ft
Eutrophic
Mesotrophic
Oligotrophic

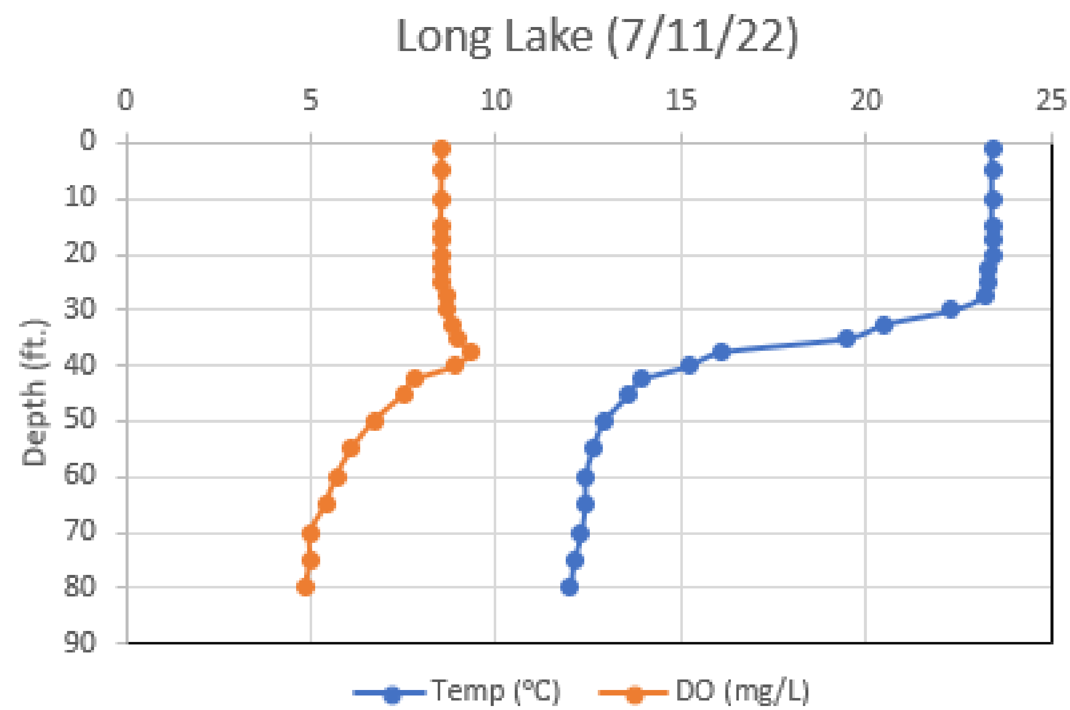
Dissolved Oxygen/Temperature Depth Profiles: Long Lake



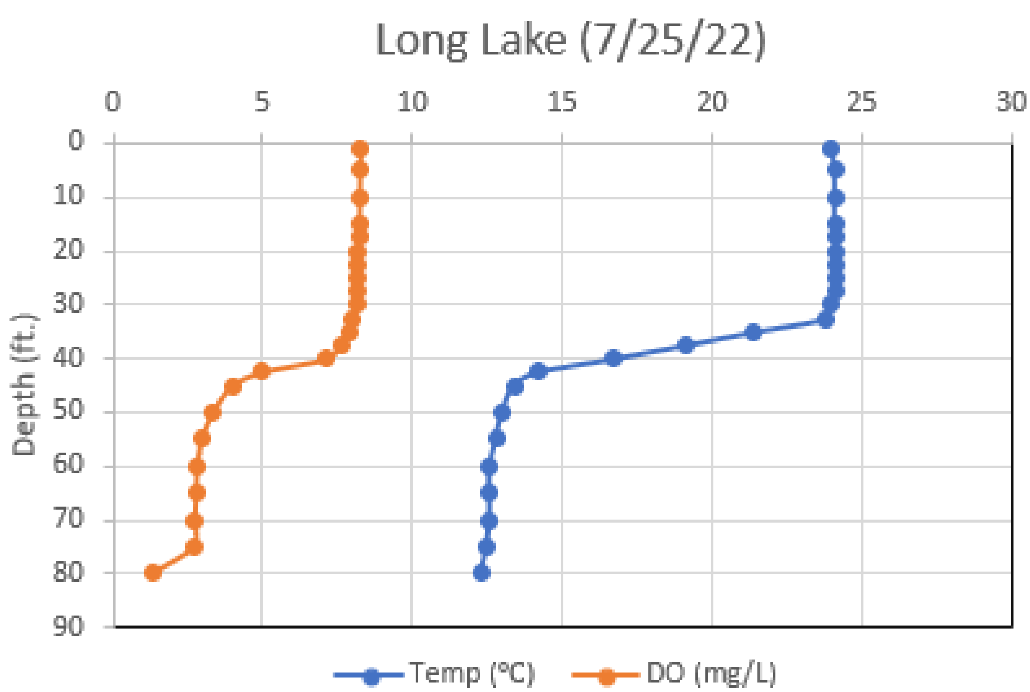



Long Lake (6/13/22)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
Depth (ft.)
Temp (ºC)
DO (mg/L)

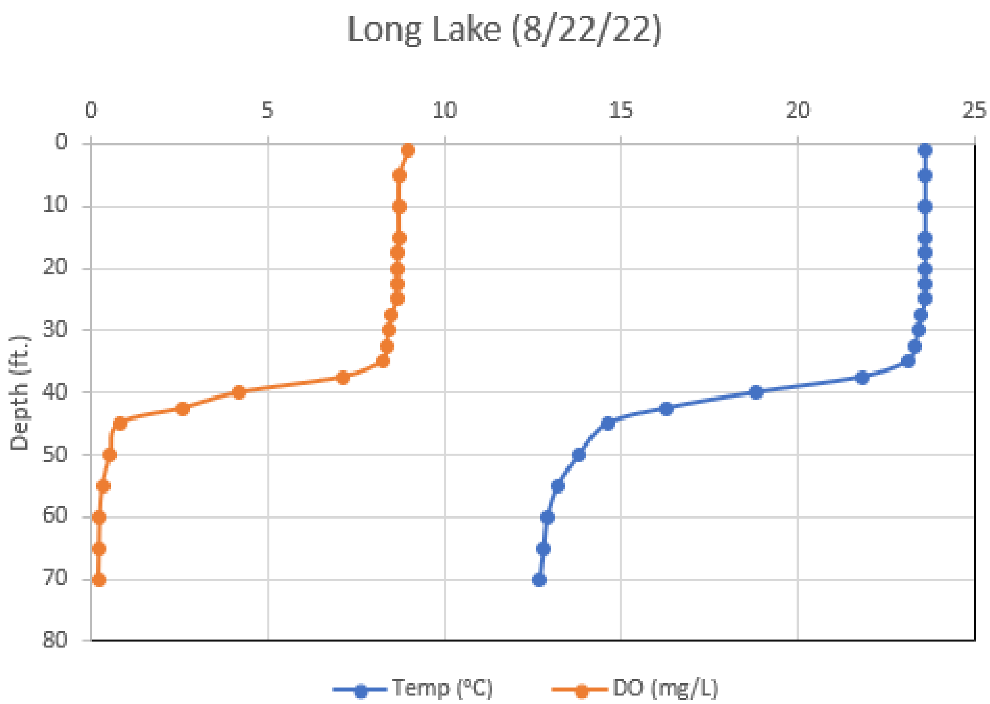

Long Lake (6/27/22)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
Depth (ft.)
Temp (ºC)
DO (mg/L)

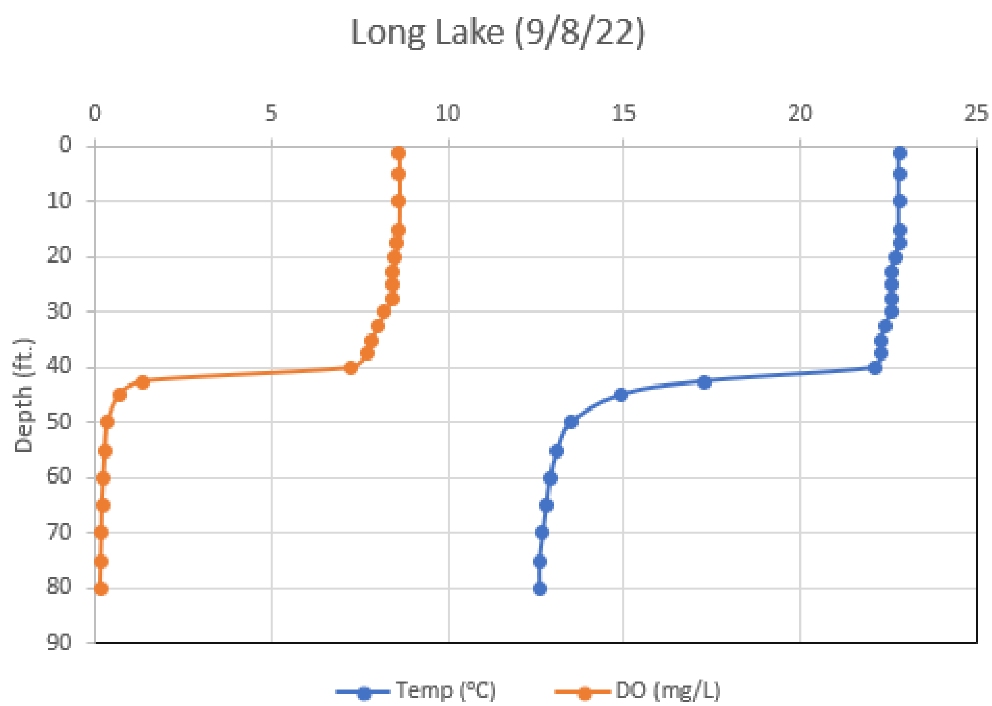


Long Lake (7/11/22)
Depth (ft.)
Temp (°C)
DO (mg/L)

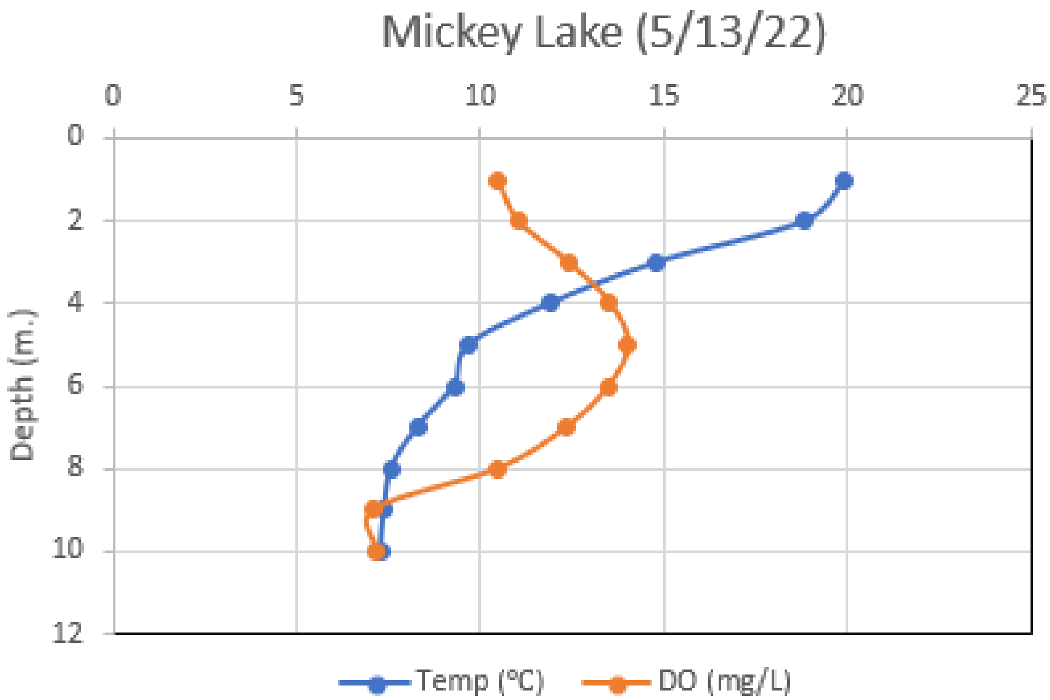


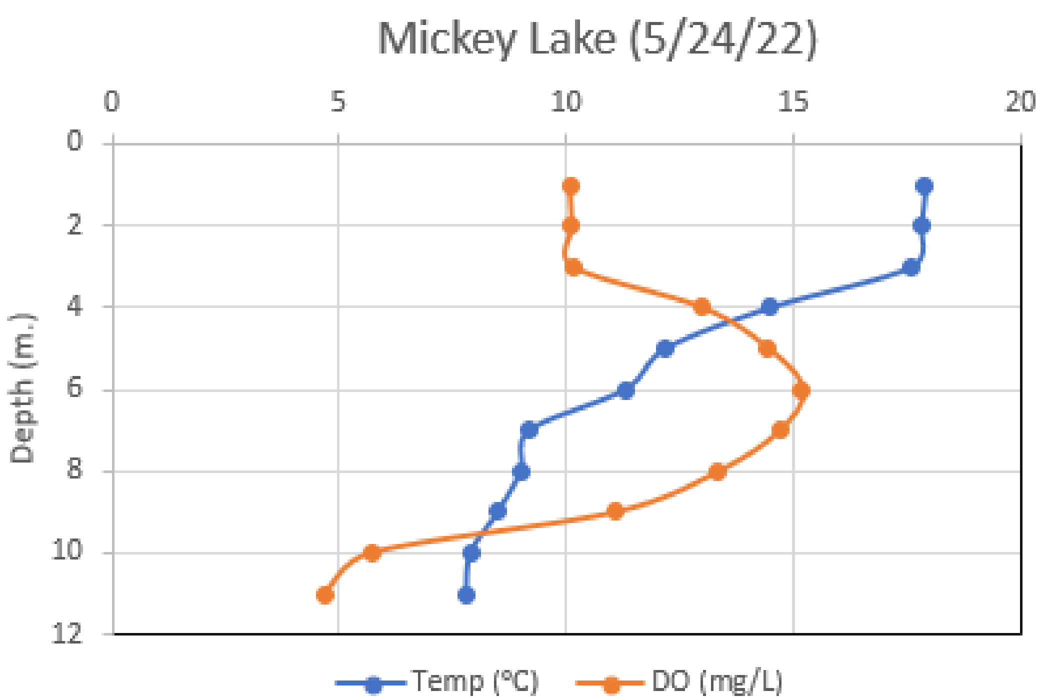
Long Lake (7/25/22)
Depth (ft.)
Temp (°C)
DO (mg/L)

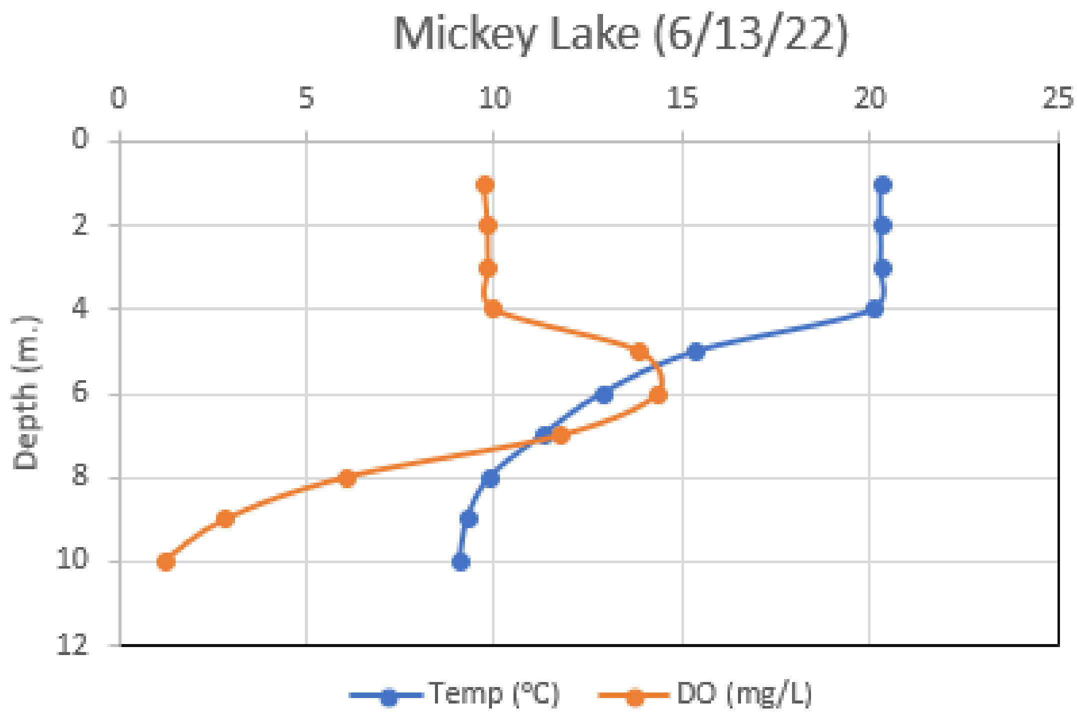

Long Lake (8/22/22)
Depth (ft.)
Temp (°C)
DO (mg/L)

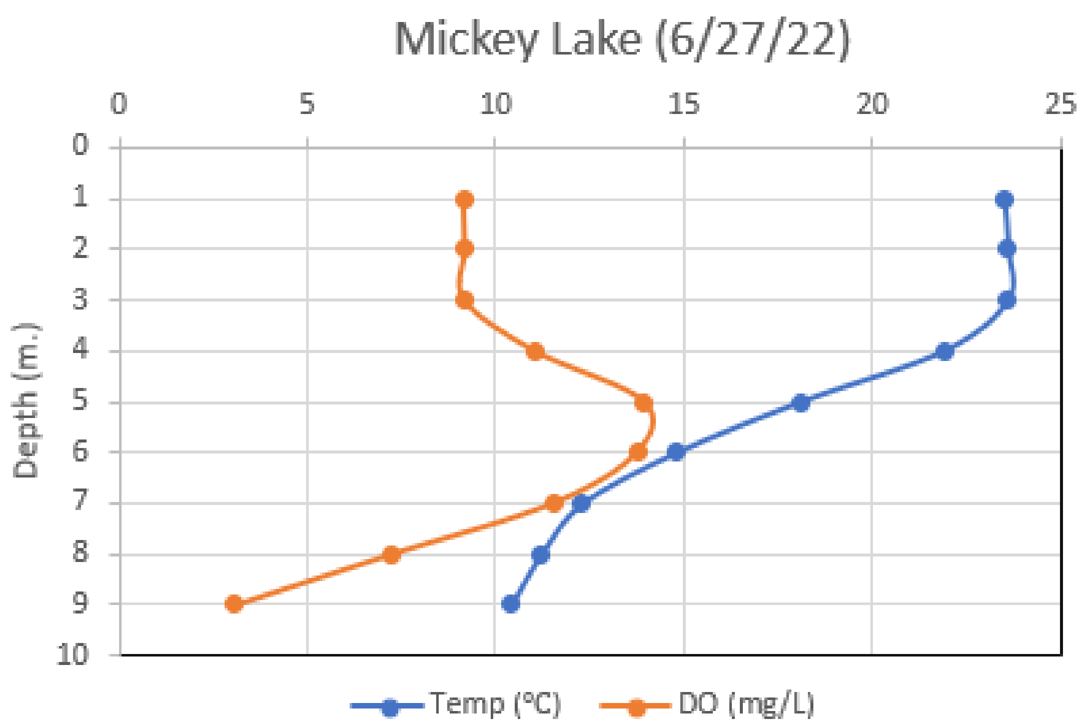

Long Lake (9/8/22)
Depth (ft.)
Temp (°C)
DO (mg/L)

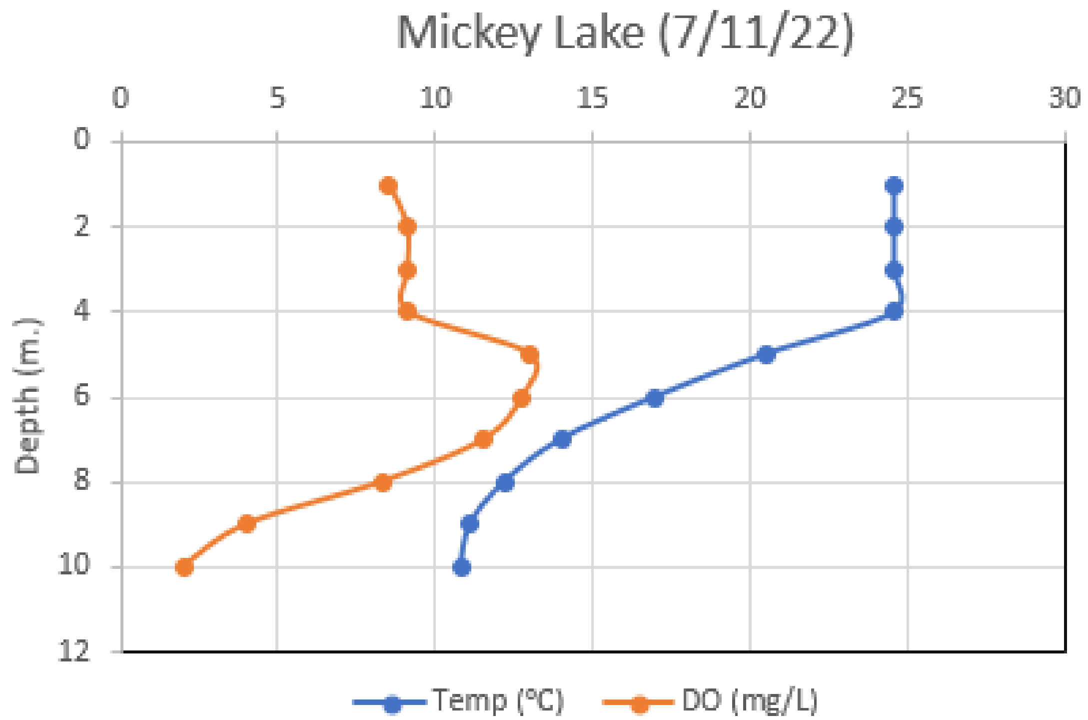
Dissolved Oxygen/Temperature Depth Profiles: Mickey Lake



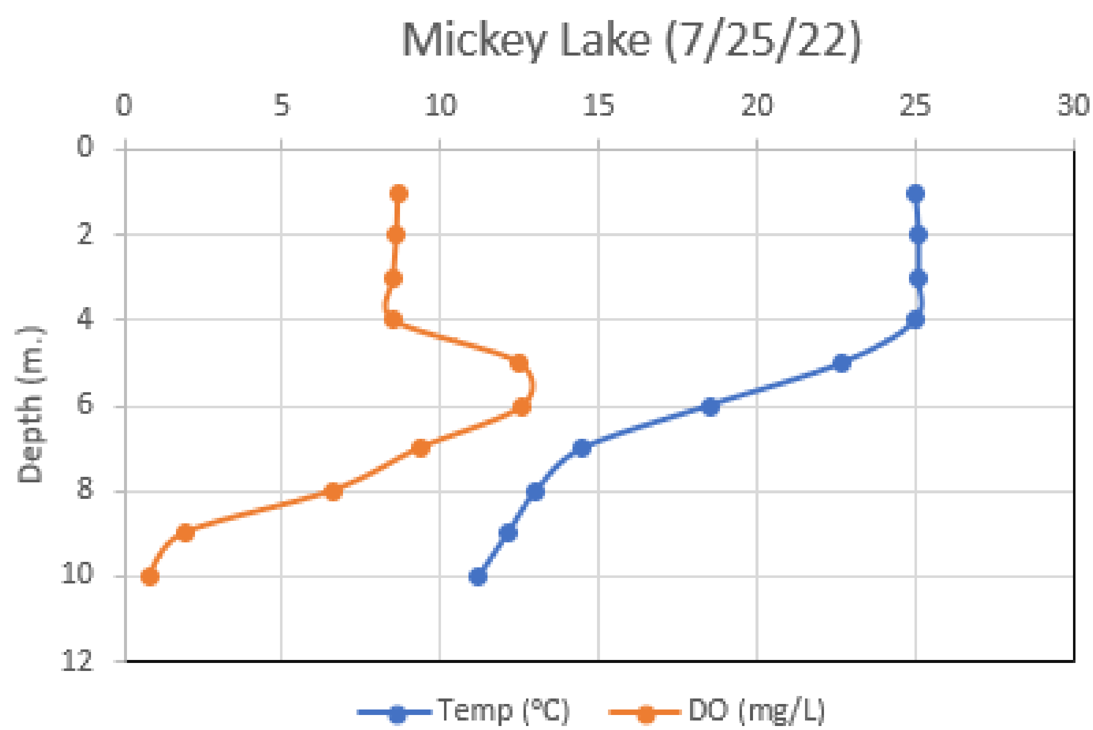



Mickey Lake (6/13/22)
Depth (m.)
Temp (°C)
DO (mg/L)

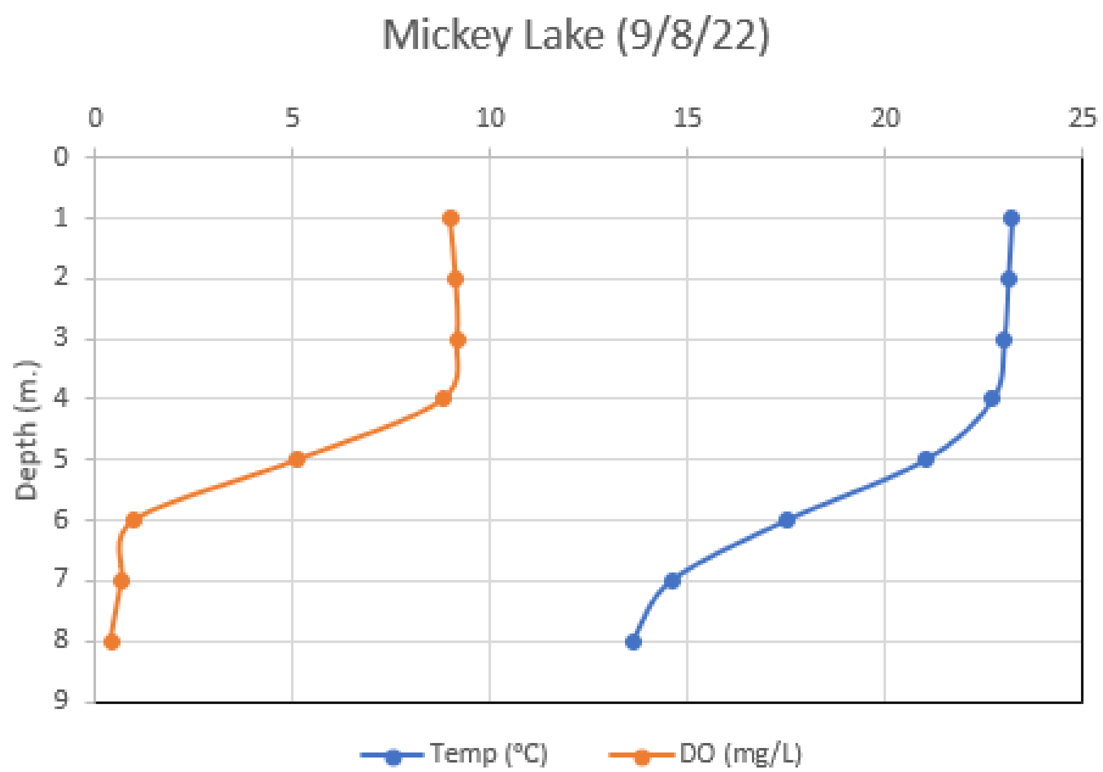

Mickey Lake (6/27/22)
Depth (m.)
Temp (°C)
DO (mg/L)

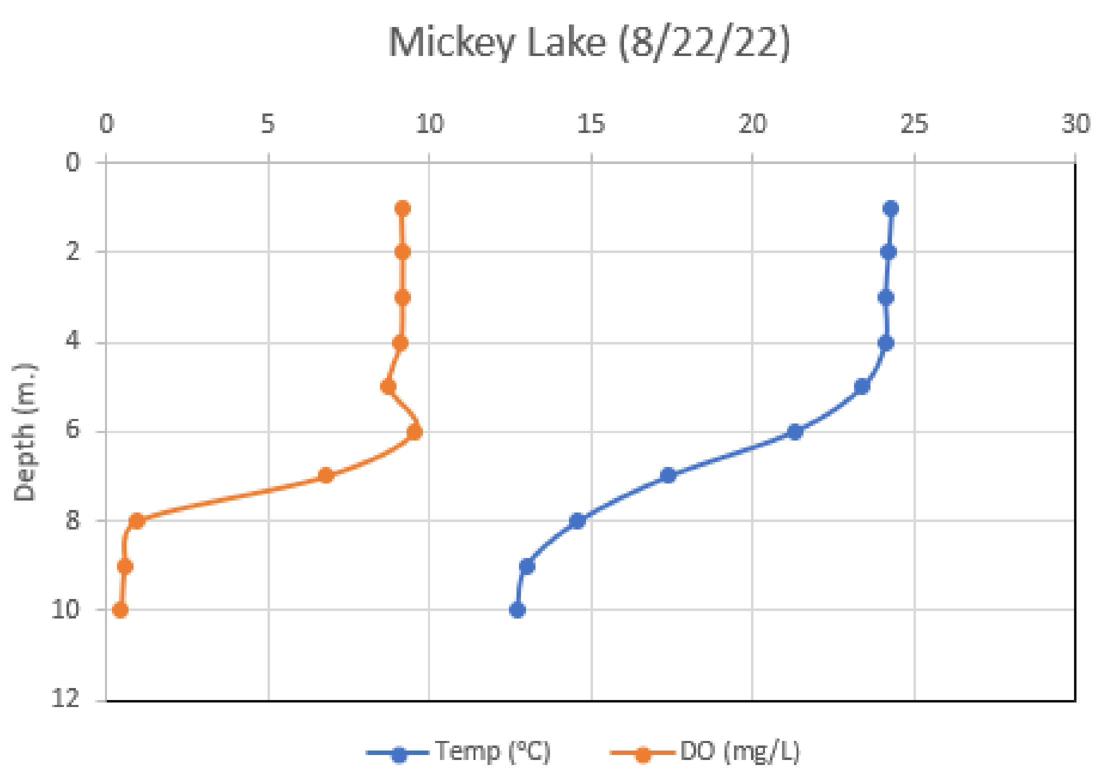


Mickey Lake (7/11/22)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
Depth (m.)
Temp (ºC)
DO (mg/L)

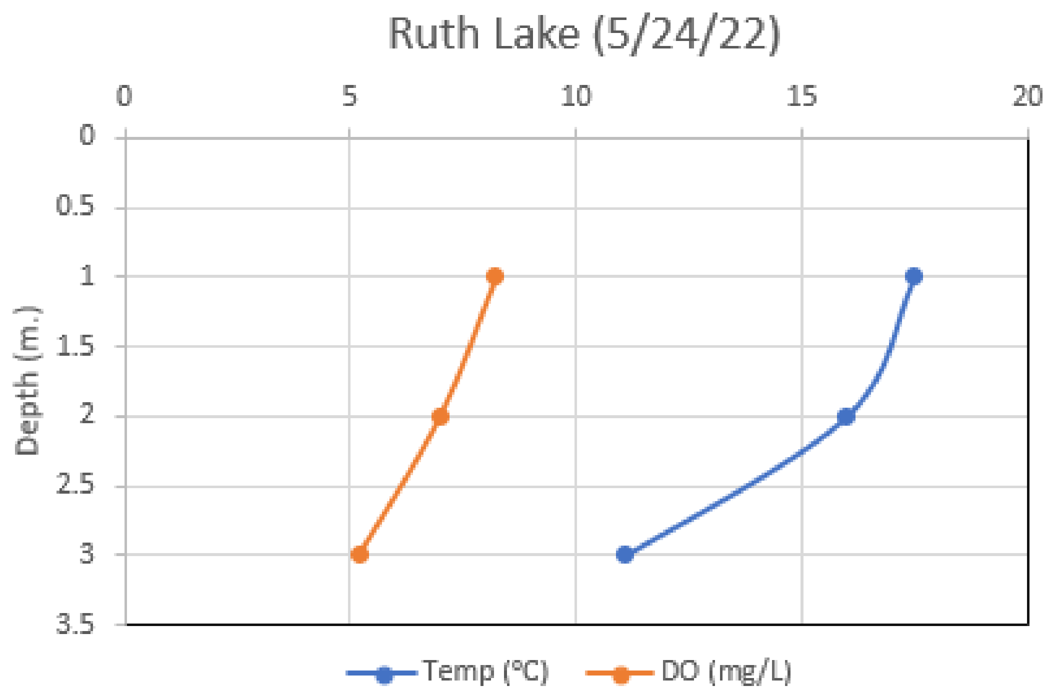


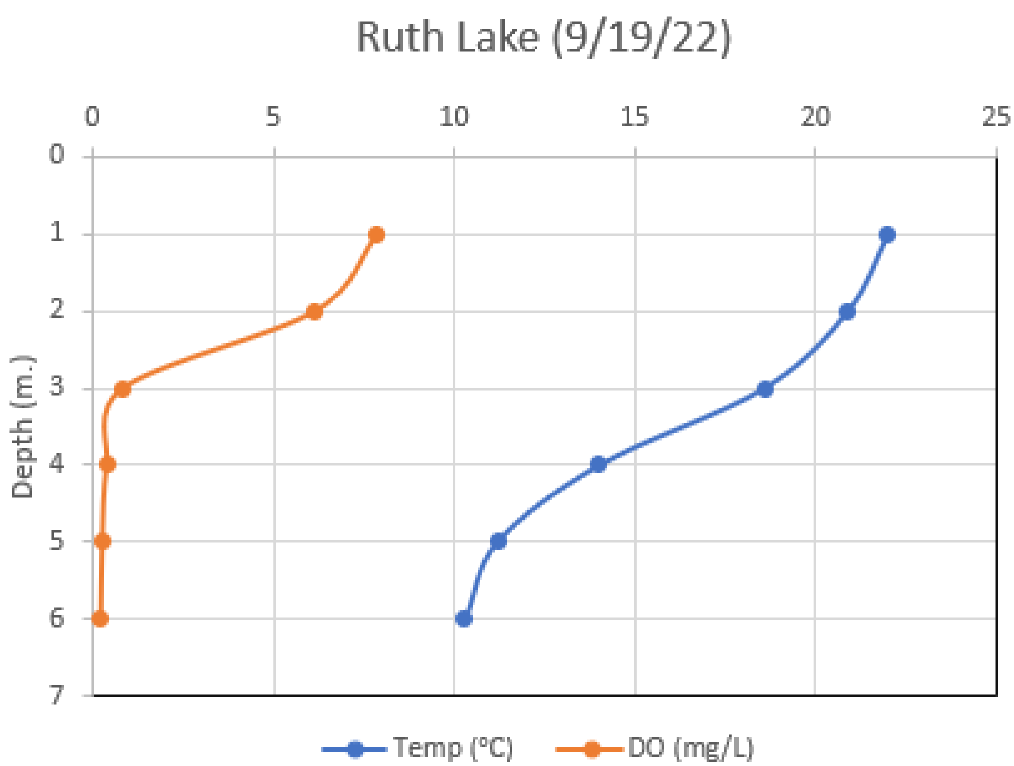
Mickey Lake (7/25/22)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
Depth (m.)
Temp (ºC)
DO (mg/L)


Mickey Lake (9/8/22)
0
5
10
15
20
25
0
1
2
3
4
5
6
7
8
9
Depth (m.)
Temp (°C)
DO (mg/L)


Mickey Lake (8/22/22)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
Depth (m.)
Temp (°C)
DO (mg/L)

Dissolved Oxygen/Temperature Depth Profiles: Ruth Lake





Plankton of Long Lake

Written December 2018,
Dr. Richard A Roeper Professor Emeritus of Biology , Alma College

Introduction and Methods for 2018-2022

Besides using chemical and physical data to analyze the trophic status and health of an inland lake, it is practical to study the biota of the lake. This report looks at one part of the biota consisting of analysis of plankton of Long Lake in Grand Traverse County, Michigan. Plankton is defined as the microscopic algal phytoplankton and the animal zooplankton suspended in the lake's water.

The method involved that samples were collected with a plankton net drawn at a slow speed off a platoon boat. Samples were not fixed, but were chilled and examined within a day of collection. Microscopic mounts consisted of drops of the plankton sample covered by a cover slip and then examined at 100X and 450X of a binocular compound microscope. The observations were made determining the genus of the plankton using several identification sources listed in the bibliography.

Observations were made until no new genera of plankton were observed. Quantitative estimates of observed plankton genera by indicating frequency of observation each genus with a range from one 'x' to three 'xxx'.

From EPA sources and other web sources the trophic level (eutrophic- polluted and oligotrophic-clean) of the plankton were determined.

Results:

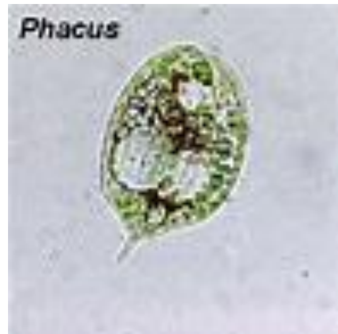
2021 Plankton Data- Long Lake						
	Dates Sampled					
	5/26/2021	6/9/2021	7/9/2021	7/26/2021	9/1/2021	9/8/2021
Phytoplankton						
Blue Green Algae						
Gleotrichia				x		x
Coelosphaerium						
Merismopedia	x			x	x	x
Microcystis					xxx	
Anacystis						x
Anabaena		x				
Diatoms						
Melosira						
Asterionella	x					
Fragillaria	x			xxx	x	
Dinoflagellates						
Ceratium	x					xxx
Chrysophyta						
Dinophyton				xxx	xx	x
Green Algae						
Desmid						
Cosmarium		x				x
Zooplankton						
Rotifers						
Keratella		xx		xx	xx	xx
Kellicotta		xx			xx	
Cladocera						
Bosemina				x		
Nauplius		x		xx		
Coepodia		x		x	xxx	xx

2021 Plankton Data- Mickey Lake					
	Dates Sampled				
	5/26/2021	6/9/2021	7/9/2021	7/26/2021	9/1/21
Phytoplankton					
Blue Green Algae					
Gleotrichia	x	x	x	x	x
Coelosphaerium	x				
Merismopedia			x		
Anacysitis				x	x
Diatoms					
Melosira	x				
Asterionella					
Fragillaria					x
Dinoflagellates					
Ceratium	x		x		
Chrysophyta					
Dinophyton	xx	x	x	x	
Green Algae					
Pediastrum			x		
Cosmarium	x	x			
Zooplankton					
Rotifers					
Keratella	xxx	x	xxx	xx	x
Kellicotta	xxx	x	x		
Cladocera					
Bosemina			x	x	
Nauplius	x	x	x	xx	
Coepodia	xx	xxx	x	x	xx

2020 Plankton Data- Ruth Lake

Dates Sampled		
	9/24/2021	N/A
Phytoplankton		
Blue Green Algae		
Gleotrichia		
Coelosphaerium	x	
Microcystis		
Diatoms		
Asterionella		
Fragillaria		
Dinoflagellates		
Ceratium	xxx	
Chrysophyta		
Dinophyton		
Hydrus		
Green Algae		
Desmid		
Penium	x	
Zooplankton		
Rotifers		
Kellicotta	x	
Keratella	xxx	
Protozoa		
Ciliates		
Cladocera		
Nauplius	xx	
Bosima		
Other		
Coepodia	x	

Representative Algae



Oscillatoria Gleotrichia Phacus

Discussion:

Gloeotrichia is a concern. It is considered a meroplankton. Filaments of Gloeotrichia develop as a ball of cells visible to the naked eye. They start in the sediment of the lake. As the summer progresses, gas vesicles will cause the colony to rise in a late summer bloom. In several lakes in Maine blooms have been observed. Gloeotrichia produces a toxin called microcystin which can cause liver damage if ingested. A swimmers-itch like symptoms have been reported during these late summer blooms.

The presence of Oscillatoria, Phormidium, and Phacus indicate enrichment in Mickey Lake. Desmids may also bloom.

In general, one would conclude the plankton of Long Lake does not represent a eutrophic condition.

Bibliography

Bold, H.C. and M. L. Wynne. 1985 Introduction to the Algae. 2nd Edition . Prentice Hall. 720pp.

Needham, J.G. 1962 Guide to the Study of Fresh Water Biology.

Prescott, G.W. 1970. How to Know the Freshwater Algae 2nd edition 348pp.

Section II:

Historical Data Trends

Data from Dr. Wallace Fusilier's 1993-2005 reports, as well as GLEC's 2005, '08, '11, and '14 reports were used to analyze historical trends for Long Lake, Ruth Lake and Mickey Lake. Water quality data spanning from 2016 to 2022 has been collected by the Long Lake Association's water quality monitoring interns with the support of mentors and local organizations (with the exception of the year 2020 as no interns were hired that year due to pandemic precautions).

Historical analysis can bring to light trends in water quality parameters, both positive and negative. Understanding how the lakes change over time, whether because of a normal eutrophication process or cultural eutrophication, is important for both property owners and lake health specialists. Further analysis can help determine proper treatment plans based on whether the issue is a long term, or sudden development.

Water quality parameters that are included in the historical analysis are total phosphorus (surface and bottom), sediment phosphorus, nitrate and nitrite, secchi depth, chlorophyll a, and calcium. Data collected during the 2022 sampling season is assumed to be accurate unless noted otherwise.

Note: data from the 2020 season will be quite different than surrounding years. This is due to a much lower sample size. 2020 sampling only occurred in late June and mid-September, rather than starting in early spring. Because of the increased level of plant growth that would be present as the summer develops (as well as the smaller overall sample size), the data collected will be skewed.

Historical Charts

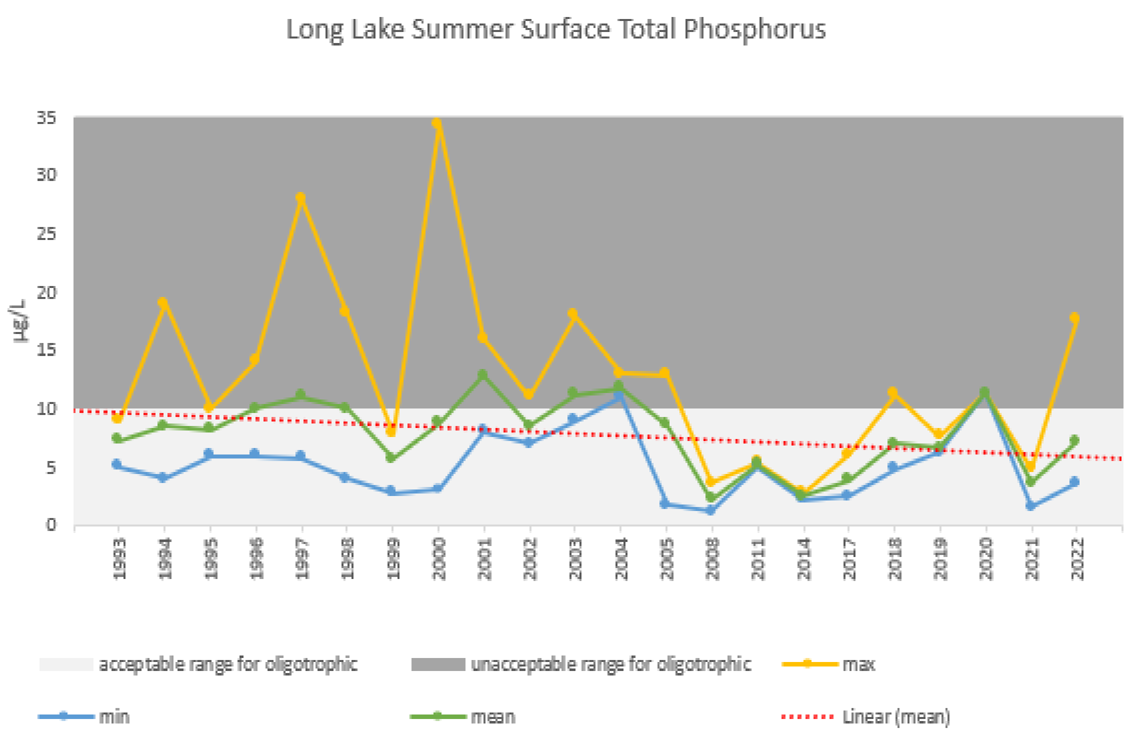
Long Lake

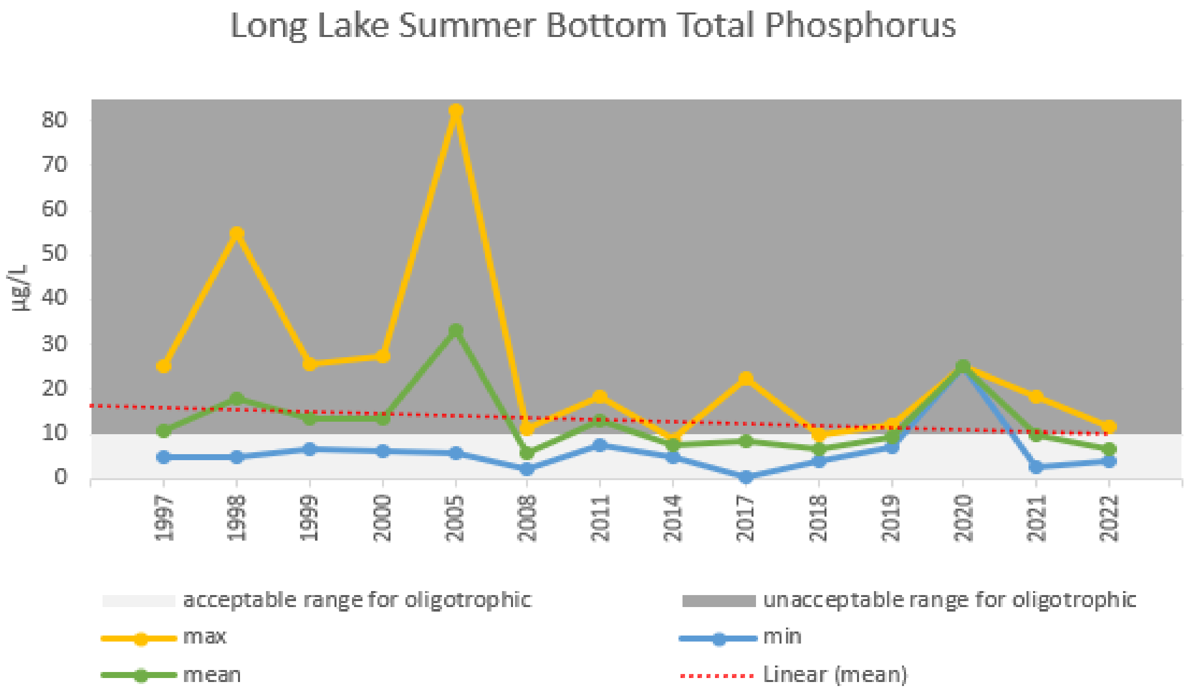
Long Lake

Total Phosphorus (µg/L) SPRING/SUMMER

Year	# samples				min				max				mean			
	Surface	Bottom	Mid-Epi limnion	Mid-Hypo limnion	Surface	Bottom	Mid-Epi limnion	Mid-Hypolim	Surface	Bottom	Mid-Epi limnion	Mid-Hypolimn	Surface	Bottom	Mid-Epi limnion	Mid-Hypolimn
1993	4	---	---	---	5	---	---	---	9	---	---	---	7.25	---	---	---
1994	6	---	---	---	4	---	---	---	19	---	---	---	8.50	---	---	---
1995	4	---	---	---	6	---	---	---	10	---	---	---	8.25	---	---	---
1996	4	---	---	---	6	---	---	---	14	---	---	---	10.00	---	---	---
1997	19	6	---	---	5.8	4.7	---	---	28	24.9	---	---	11.09	10.87	---	---
1998	9	6	---	---	4	4.7	---	---	18.2	55	---	---	9.99	18.1	---	---
1999	6	6	---	---	2.8	6.8	---	---	7.9	25.4	---	---	5.67	13.47	---	---
2000	33	27	22	18	3.1	6.4	3.3	4.2	34.4	27.4	10.6	21	8.77	13.25	7.37	9.92
2001	6	---	---	---	8	---	---	---	16	---	---	---	12.83	---	---	---
2002	6	---	---	---	7	---	---	---	11	---	---	---	8.50	---	---	---
2003	15	---	---	---	9	---	---	---	18	---	---	---	11.27	---	---	---
2004	6	---	---	---	11	---	---	---	13	---	---	---	11.83	---	---	---
2005	6	3	---	---	1.8	5.7	---	---	12.9	82.5*	---	---	8.65	33.17	---	---
2008	3	3	---	---	1.2	1.9	---	---	3.6	11.3	---	---	2.20	5.77	---	---
2011	2	2	---	---	5	7.5	---	---	5.4	18.4	---	---	5.20	12.95	---	---
2014	3	3	---	---	2.2	4.9	---	---	2.8	9.1	---	---	2.47	7.63	---	---
2017	6	7	---	---	2.5	0.3	---	---	6.1	22.3	---	---	3.95	8.53	---	---
2018	6	6	---	---	4.9	3.7	---	---	11.2	9.9	---	---	6.97	6.62	---	---
2019	6	6	---	---	6.3	6.9	---	---	7.7	12.1	---	---	6.68	9.18	---	---
2020^	1	1	---	---	11.3	25.2	---	---	11.3	25.2	---	---	11.30	25.20	---	---
2021	5	4	---	---	<1.6	2.7	---	---	4.9	18.4	---	---	3.64	9.78	---	---
2022	4	4	---	---	3.6	3.7	---	---	17.7	11.6	---	---	7.18	6.63	---	---
			---	---			---	---			---	---			---	---

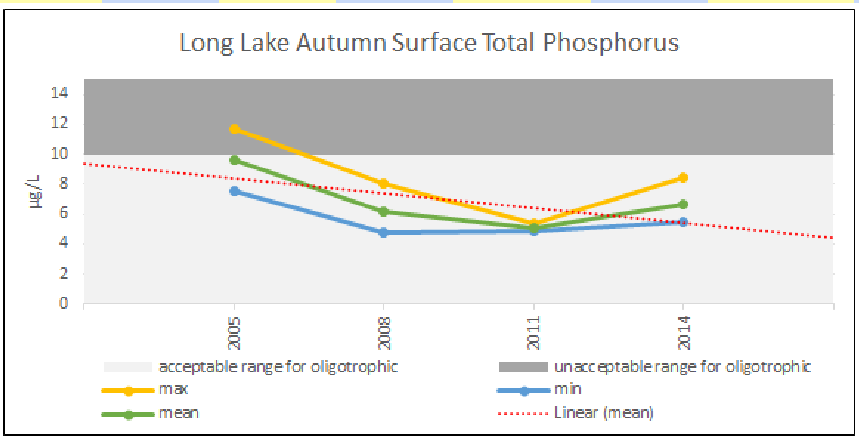
*Possible contamination from bottom sediment ^only one sample date in Sept. due to COVD-19

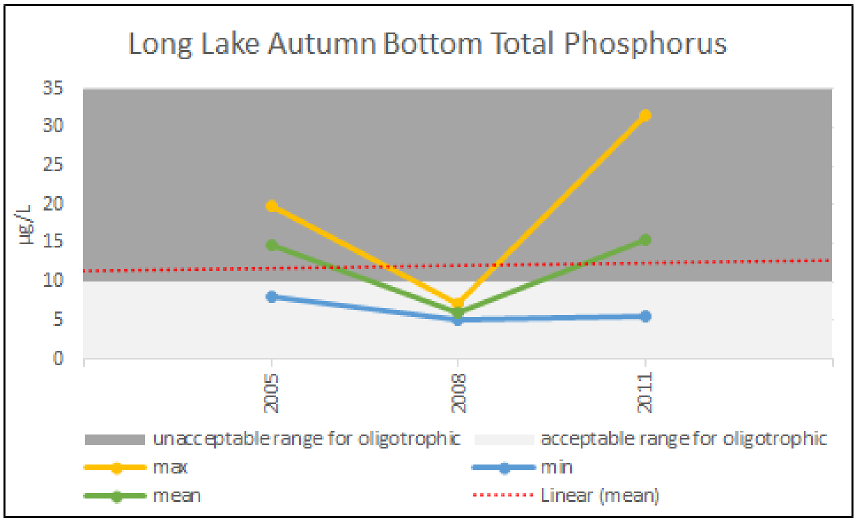




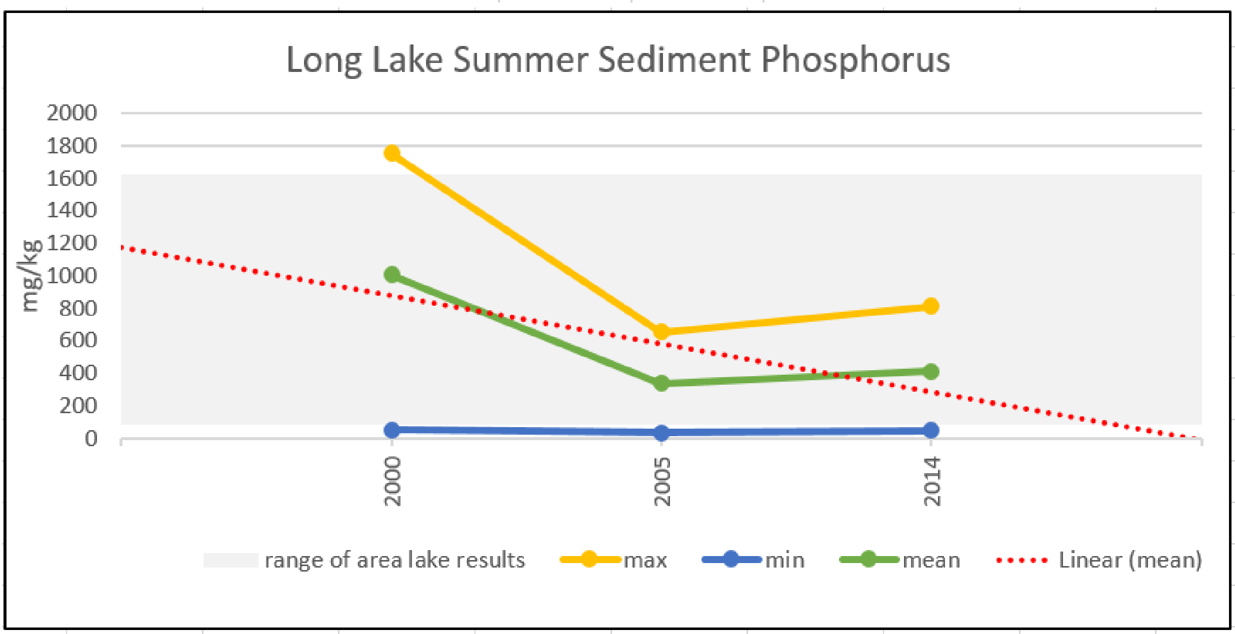
Summary: (see table 1 and 3) * In 2005 there was possible sediment contamination in a sample. This sample was included in the graph, but the overall trend downward is still consistent with what we see in the spring/summer samples. This trend could be slightly more significant if not considering this sample. In 2020 there was only one sampling date which shows high amounts of phosphorus. This is most likely due to the small sample size but it should be watched in the future.

Total Phosphorus (µg/L) AUTUMN								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	---	---	---	---	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---
2001	---	---	---	---	---	---	---	---
2002	---	---	---	---	---	---	---	---
2003	---	---	---	---	---	---	---	---
2004	---	---	---	---	---	---	---	---
2005	3	3	7.5	8.1	11.7	19.9	9.63	14.83
2008	3	3	4.8	5.1	8	7.2	6.13	6.03
2011	3	3	4.9	5.5	5.4	31.7	5.10	15.43
2014	3	3	5.5	6.5	8.4	14.2	6.70	9.10
2017	---	---	---	----	---	---	---	---
2018	---	---	---	----	---	---	---	---
2019	---	---	---	----	---	---	---	---
2020	---	---	---	---	---	---	---	---
2021	---	---	---	---	---	---	---	---
2022	---	---	---	---	---	---	---	---





Sediment Phosphorus (mg/kg) SPRING/SUMMER				
Year	# samples	min	max	mean
2000	3	50.6	1754	1005.30
2005	3	33	654	336.33
2008	---	---	---	---
2011	---	---	---	---
2014	3	48	811	412.67
2017	---	---	---	---
2018	---	---	---	---
2019	---	---	---	---
2020	---	---	---	---
2021	---	---	---	---
2022	---	---	---	---

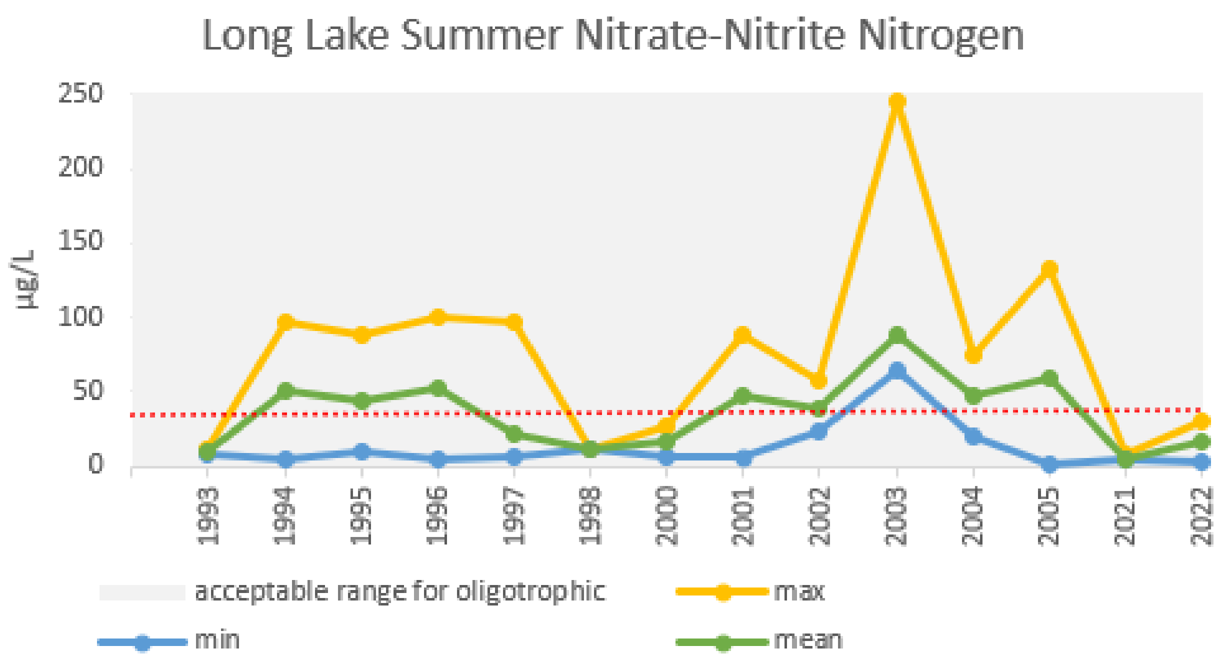


Nitrate-Nitrite Nitrogen (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1993	4	---	8	---	12	---	10.00	---
1994	6	---	5	---	97	---	51.50	---
1995	4	---	9	---	89	---	44.25	---
1996	4	---	4	---	101	---	52.75	---
1997	13	---	6	---	96	---	22.15	---
1998	3	---	11	---	12	---	11.33	---
1999	---	---	---	---	---	---	---	---
2000	6	---	6	---	26	---	16.17	---
2001	6	---	7	---	88	---	47.50	---
2002	6	---	24	---	57	---	39.33	---
2003	15	---	65	---	245	---	87.87	---
2004	6	---	20	---	75	---	47.17	---
2005	6	3	<1.4	<1.4	133	34.1	59.27	16.97
2021	4	4	<4.0	<4.0	7.4	8.2	5.10	5.68
2022	4	4	<3.4	<3.4	27.7	29.5	15.50	16.75

Nitrate-Nitrite Nitrogen (µg/L) AUTUMN								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	---	---	---	---	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---
2001	---	---	---	---	---	---	---	---
2002	---	---	---	---	---	---	---	---
2003	---	---	---	---	---	---	---	---
2004	---	---	---	---	---	---	---	---
2005	3	3	1.5	5.1	6.1	8	4.1	6.6

Nitrogen: Nitrate (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2018	3	---	<1000	---	<1000	---	<1000	---
2019	6	---	<1000	---	<1000	---	<1000	---
2020	1	---	<1000	---	<1000	---	<1000	---

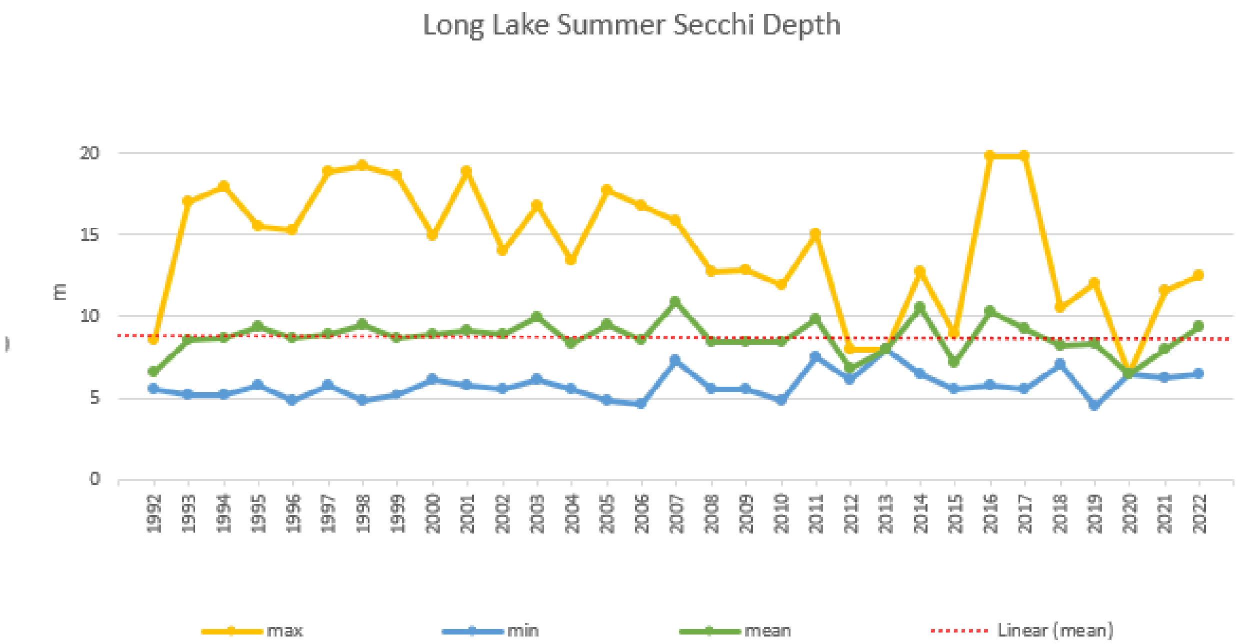
Nitrogen: Nitrite (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2018	3	---	<50	---	<50	---	<50	---
2019	6	---	<50	---	<50	---	<50	---
2020	1	---	<50	---	<50	---	<50	---

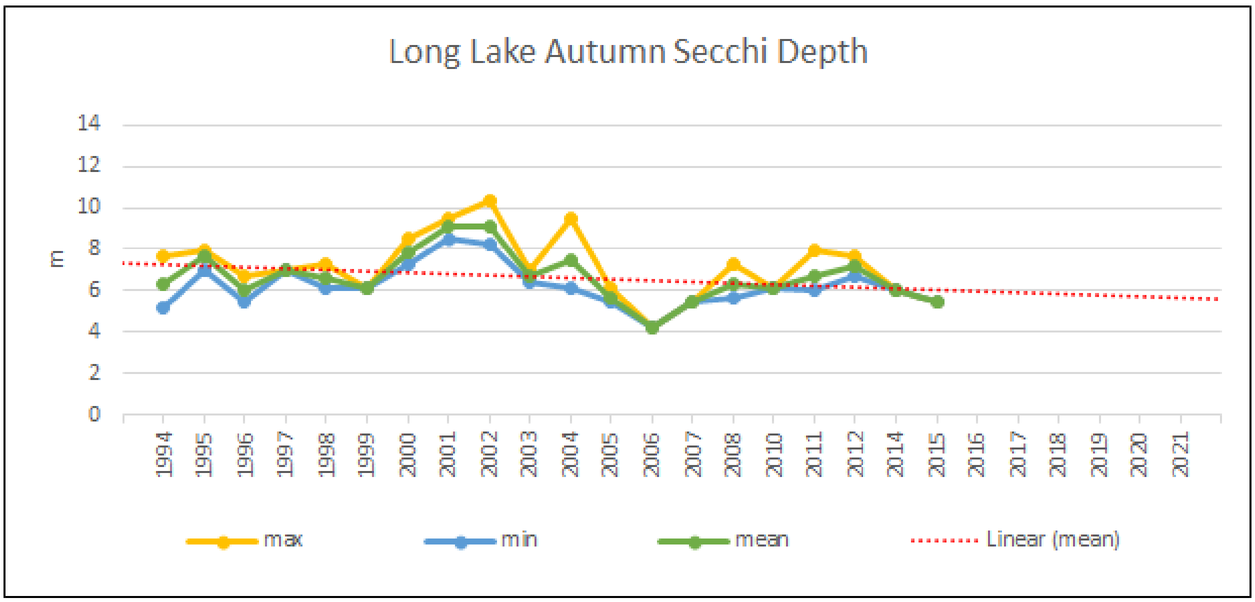


Summary: (see table 2) * There was only 1 bottom sample taken in 2005, so it is not included in the graph. It would have decreased the slope of the trend slightly, but not significantly. The one autumn sample year, 2005, is also not included since no trend could be established. Different nitrogen testing methods were used in both 2018 and 2019, so we are not yet able to compare this data with any historical data.

Secchi Disk (m.)	SPRING/SUMMER			
Year	# samples	min	max	mean
1992	14	5.49	8.53	6.58
1993	25	5.18	17.07	8.56
1994	27	5.18	17.98	8.69
1995	28	5.79	15.54	9.30
1996	25	4.88	15.24	8.66
1997	33	5.79	18.9	8.87
1998	61	4.88	19.2	9.45
1999	24	5.18	18.59	8.65
2000	38	6.1	14.94	8.90
2001	30	5.79	18.9	9.08
2002	30	5.49	14.02	8.86
2003	32	6.1	16.76	9.88
2004	30	5.49	13.41	8.30
2005	27	4.88	17.68	9.42
2006	24	4.57	16.76	8.55
2007	6	7.32	15.85	10.87
2008	10	5.49	12.74	8.37
2009	7	5.49	12.8	8.40
2010	7	4.88	11.89	8.45
2011	4	7.5	15	9.79
2012	3	6.1	7.92	6.81
2013	1	7.92	7.92	7.92
2014	5	6.4	12.74	10.51
2015	2	5.49	8.84	7.17
2016	10	5.79	19.81	10.30
2017	8	5.5	19.81	9.29
2018	7	7	10.5	8.24
2019	25	4.42	12.04	8.32
2020	5	5.75	18.9	9.00
2021	17	6.25	11.6	7.98
2022	18	6.4	12.5	9.3

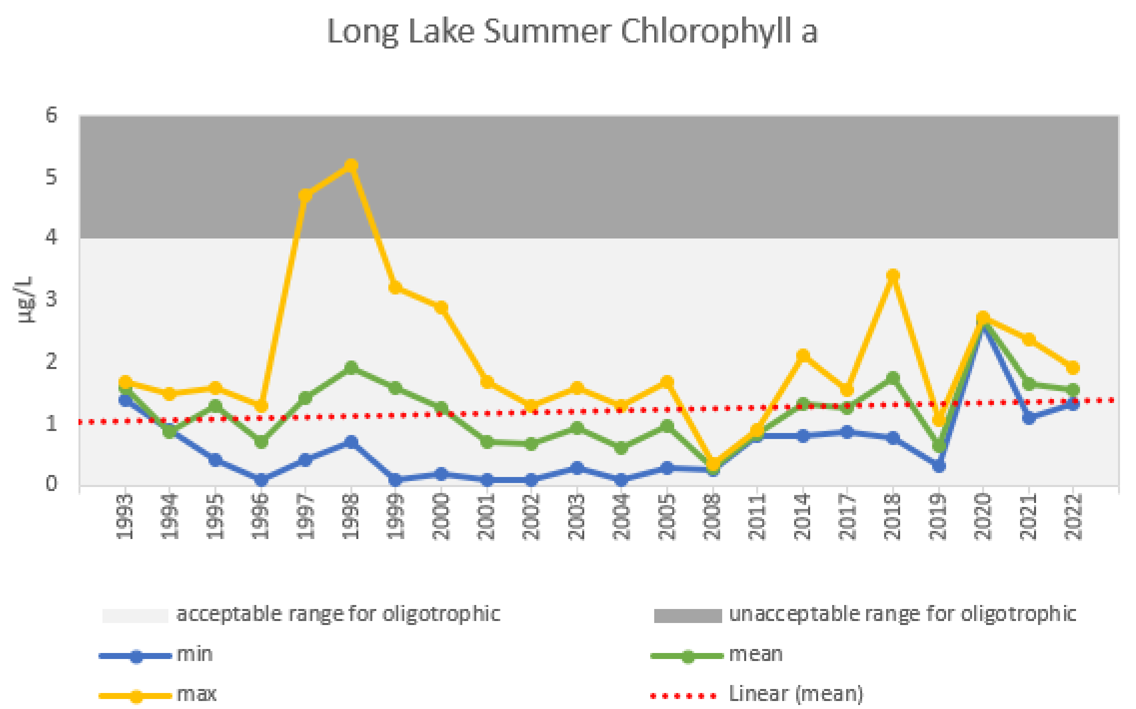
Secchi Disk (m.)	AUTUMN			
Year	# samples	min	max	mean
1992	---	---	---	---
1993	---	---	---	---
1994	4	5.18	7.62	6.33
1995	4	7.01	7.92	7.62
1996	4	5.49	6.71	6.02
1997	1	7.01	7.01	7.01
1998	4	6.1	7.32	6.63
1999	3	6.1	6.1	6.10
2000	3	7.32	8.53	7.82
2001	3	8.53	9.45	9.14
2002	4	8.23	10.36	9.14
2003	2	6.4	7.01	6.71
2004	5	6.1	9.45	7.44
2005	5	5.49	6.1	5.70
2006	1	4.27	4.27	4.27
2007	1	5.49	5.49	5.49
2008	4	5.64	7.32	6.31
2009	---	---	---	---
2010	1	6.1	6.1	6.10
2011	4	6	7.92	6.73
2012	2	6.71	7.62	7.17
2013	---	---	---	---
2014	3	6	6	6.00
2015	1	5.49	5.49	5.49
2016	---	---	---	---
2017	---	---	---	---
2018	---	---	---	---
2019	---	---	---	---
2020	---	---	---	---
2021	---	---	---	---
2022	---	---	---	---

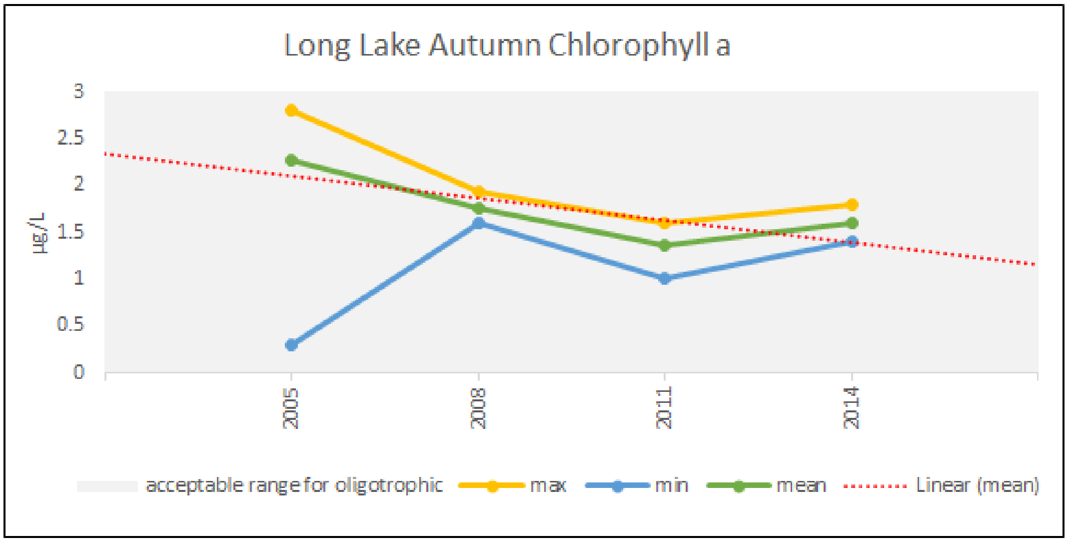

Long Lake Summer Secchi Depth
20
15
10
5
0
m
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
max
min
mean
Linear (mean)


Long Lake Autumn Secchi Depth
14
12
10
8
6
4
2
0
m
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
2021
max
min
mean
Linear (mean)

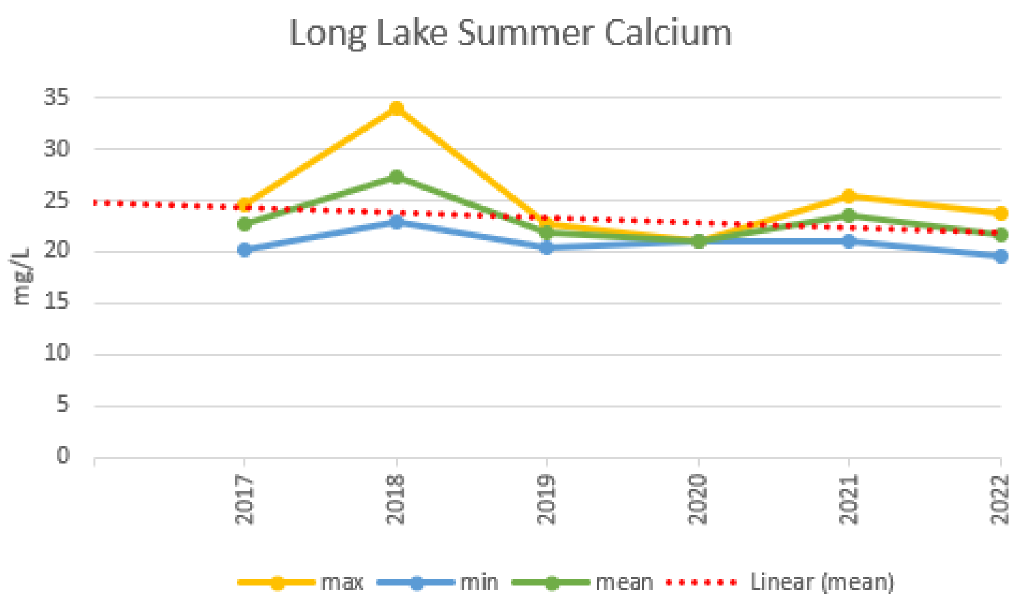
Chlorophyll a (µg/L)		SPRING/SUMMER		
Year	# samples	min	max	mean
1993	4	1.4	1.7	1.58
1994	6	0.9	1.5	0.88
1995	4	0.4	1.6	1.28
1996	4	0.1	1.3	0.70
1997	6	0.4	4.7	1.43
1998	5	0.7	5.2	1.92
1999	6	0.1	3.2	1.60
2000	12	0.2	2.9	1.26
2001	6	0.1	1.7	0.72
2002	6	0.1	1.3	0.68
2003	6	0.3	1.6	0.92
2004	6	0.1	1.3	0.60
2005	6	0.3	1.7	0.97
2008	3	0.25	0.35	0.30
2011	2	0.8	0.9	0.85
2014	3	0.8	2.1	1.33
2017	7	0.86	1.57	1.25
2018	8	0.78	3.4	1.76
2019	8	0.33	1.05	0.65
2020	2	2.64	2.74	2.69
2021	5	1.09	2.36	1.636
2022	6	1.31	1.92	1.57

Chlorophyll a (µg/L)		AUTUMN		
Year	# samples	min	max	mean
1993	---	---	---	---
1994	---	---	---	---
1995	---	---	---	---
1996	---	---	---	---
1997	---	---	---	---
1998	---	---	---	---
1999	---	---	---	---
2000	---	---	---	---
2001	---	---	---	---
2002	---	---	---	---
2003	---	---	---	---
2004	---	---	---	---
2005	3	0.3	2.8	2.27
2008	3	1.61	1.93	1.75
2011	3	1	1.6	1.37
2014	3	1.4	1.8	1.60
2017	---	---	---	---
2018	---	---	---	---
2019	---	---	---	---
2022	---	---	---	---





Calcium (mg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2017	6	20.2	24.6	22.70
2018	6	22.9	34	27.32
2019	6	20.5	22.7	21.85
2020	1	21	21	21
2021	4	22.1	25.5	23.6
2022	4	19.5	23.7	21.7



Bacterial Testing (per 100mL) Summer			
Year	Beach	Total Coliform	E. coli
2018	Taylor Park	307.6	3.1
2018	Gilbert Park	770.1	8.6

Recommended Safe Body Contact	E. coli count per 100 milliliters
Full body contact	0-299
Partial body contact (waist down)	300-999
No body contact	1,000+

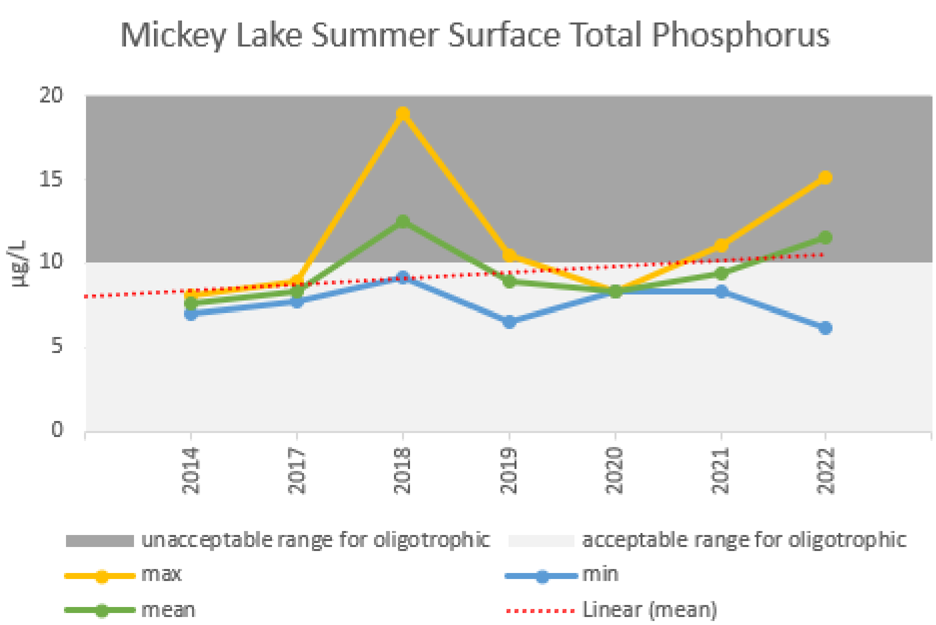
*Michigan EGLE standards (Michigan Department of Environment, Great Lakes, and Energy, 2019)

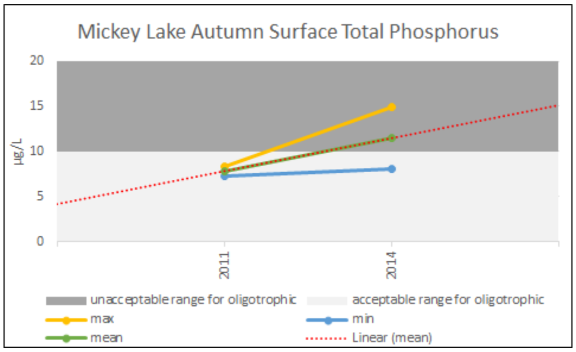
Mickey Lake

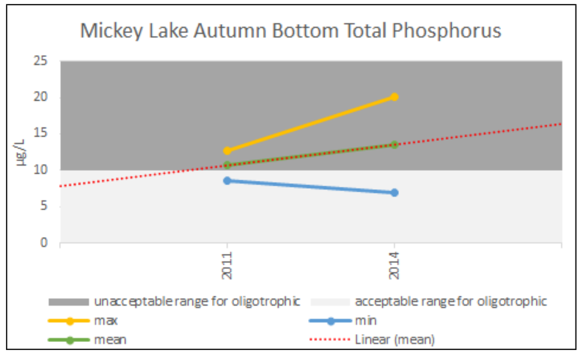
Total Phosphorus (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2011	---	---	---	---	---	---	---	---
2014	2	2	7	7.6	8.1	18	7.55	12.80
2017	5	4	7.71	6.5	8.9	28.1*	8.30	14.43
2018	3	2	9.1	10.4	18.9	15.4	12.50	12.90
2019	4	4	6.5	7.5	10.5	17.6	8.88	12.70
2020	1	1	8.3	21.8	8.3	21.8	8.30	21.80
2021	4	4	8.3	11.3	11.1	25.4	9.43	18.88
2022	2	2	6.2	14.1	10.6	15.1	8.40	14.60

*Possible contamination from bottom sediment

Total Phosphorus (µg/L) AUTUMN								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2011	2	2	7.3	8.6	8.4	12.7	7.85	10.65
2014	2	2	8.1	6.9	14.9	20.1	11.50	13.50







Sediment Phosphorus (mg/kg)		SPRING/SUMMER		
Year	# samples	min	max	mean
2014	2	879	1625	1252

Summary: There is only one sample year, so no trend could be established.

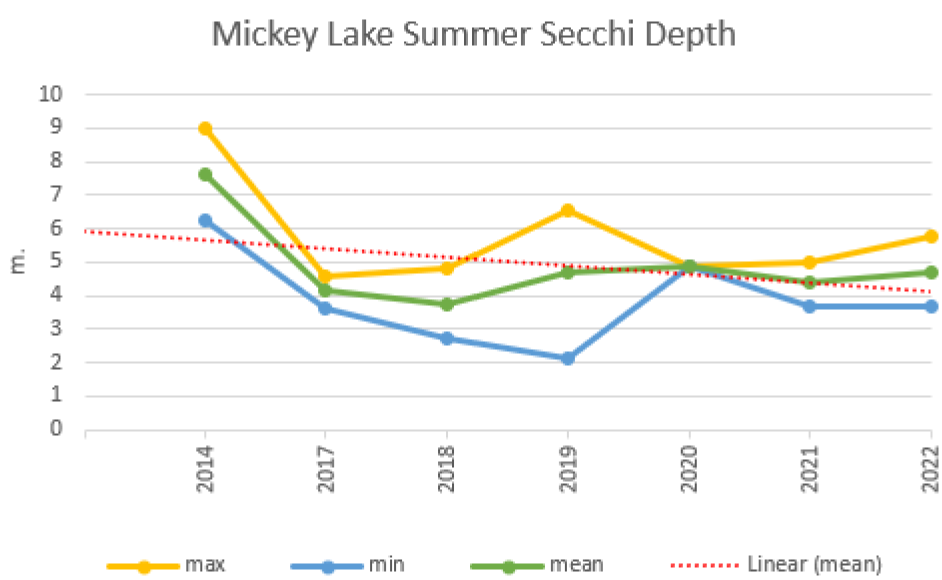
Nitrogen: Nitrate (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2018	1	---	<1000	---	<1000	---	<1000	---
2019	4	---	<1000	---	<1000	---	<1000	---

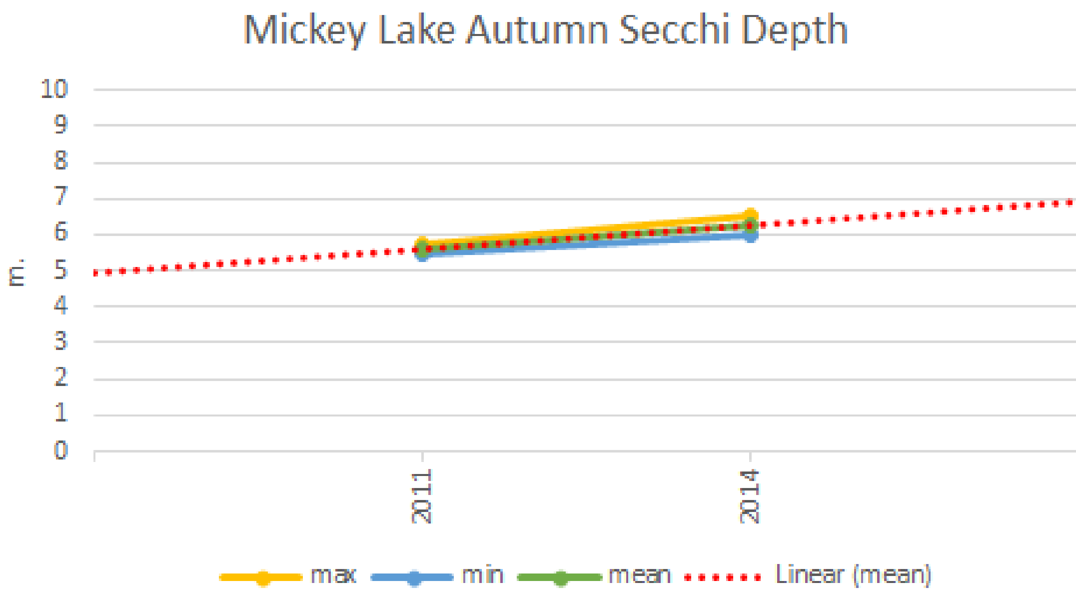
Nitrogen: Nitrite (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2018	1	---	<50	---	<50	---	<50	---
2019	4	---	<50	---	<50	---	<50	---

Summary: 2018 and 2019 used two different measuring techniques so a trend cannot yet be established as they are not comparable. Samples were not taken in 2020. For 2021 and 2022, Nitrates and Nitrites were calculated together, so we do not know the values separately.

Secchi Disk (m.) SPRING/SUMMER				
Year	# samples	min	max	mean
2011	---	---	---	---
2014	2	6.25	8.99	7.62
2017	4	3.6	4.6	4.15
2018	4	2.7	4.8	3.74
2019	6	2.13	6.55	4.72
2020	1	4.9	4.9	4.90
2021	9	3.7	5	4.38
2022	15	3.7	5.8	4.72

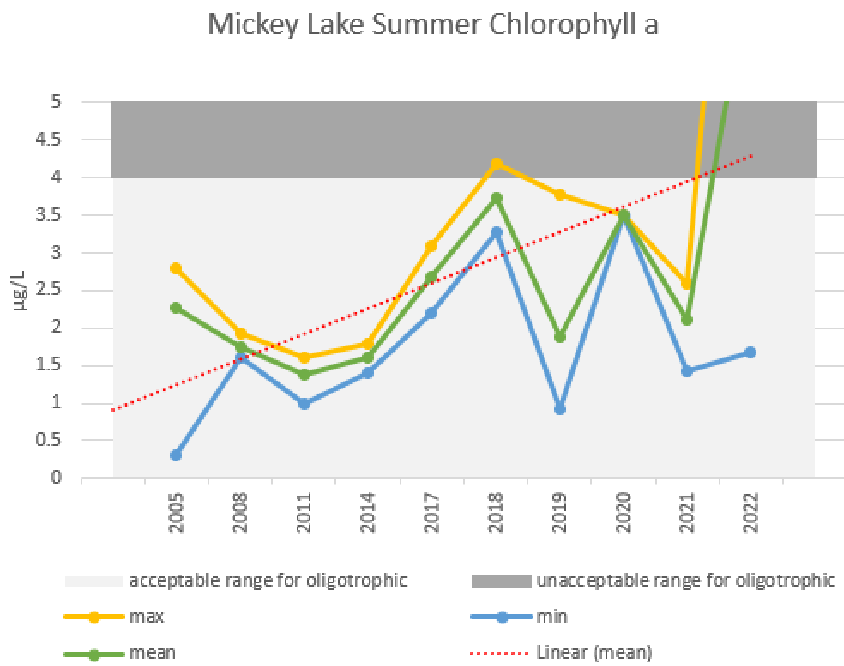
Secchi Disk (m.) AUTUMN				
Year	# samples	min	max	mean
2011	2	5.49	5.7	5.60
2014	2	6	6.49	6.25

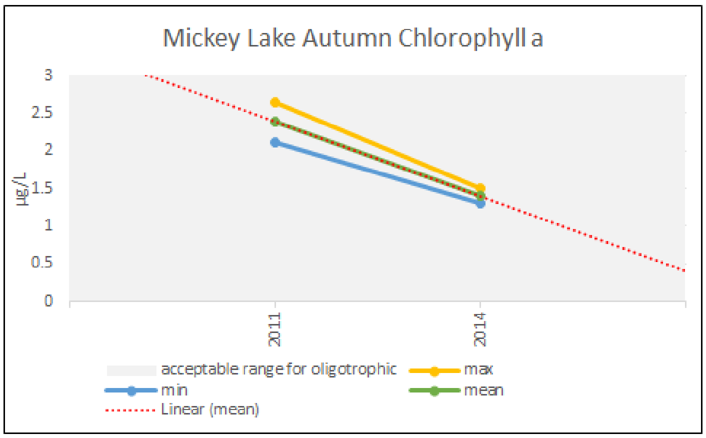




Chlorophyll a (µg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2011	---	---	---	---
2014	2	2	5.2	3.6
2017	2	2.2	3.1	2.69
2018	2	3.27	4.19	3.73
2019	3	0.92	3.78	1.873
2020	1	3.5	3.5	3.50
2021	5	1.43	2.59	2.116
2022	2	1.68	11.85	6.765

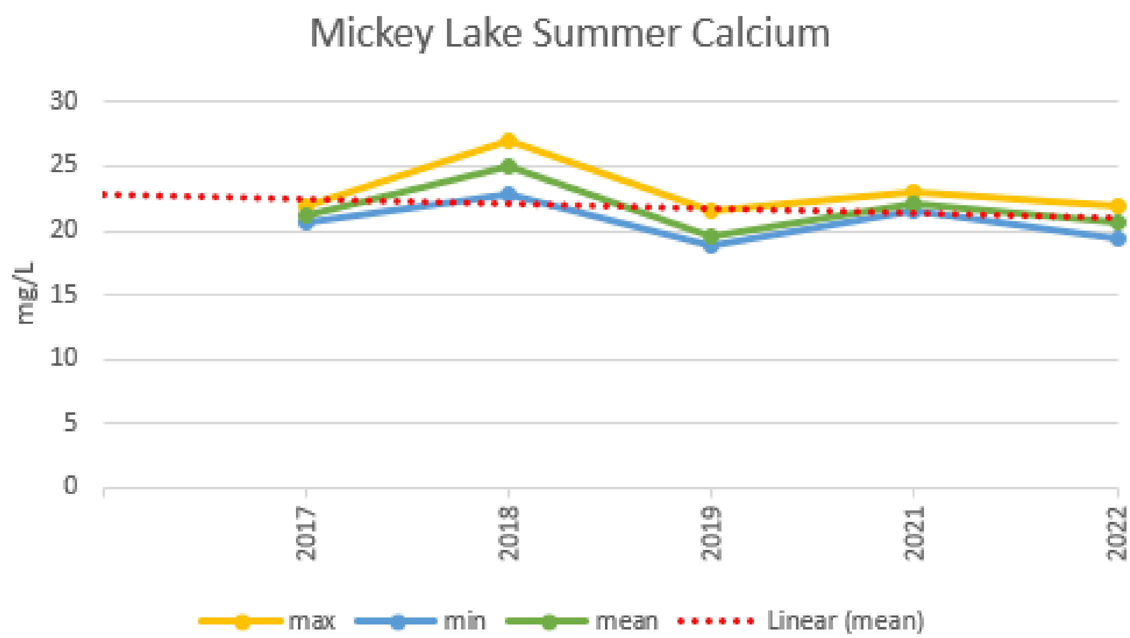
Chlorophyll a (µg/L) AUTUMN				
Year	# samples	min	max	mean
2011	2	2.12	2.65	2.39
2014	2	1.3	1.5	1.4





Calcium (mg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2017	3	20.6	21.9	21.17
2018	3	22.9	27	24.95
2019	4	18.8	21.6	19.575
2020	---	---	---	---
2021	4	21.5	23	22.175
2022	2	19.4	21.9	20.65

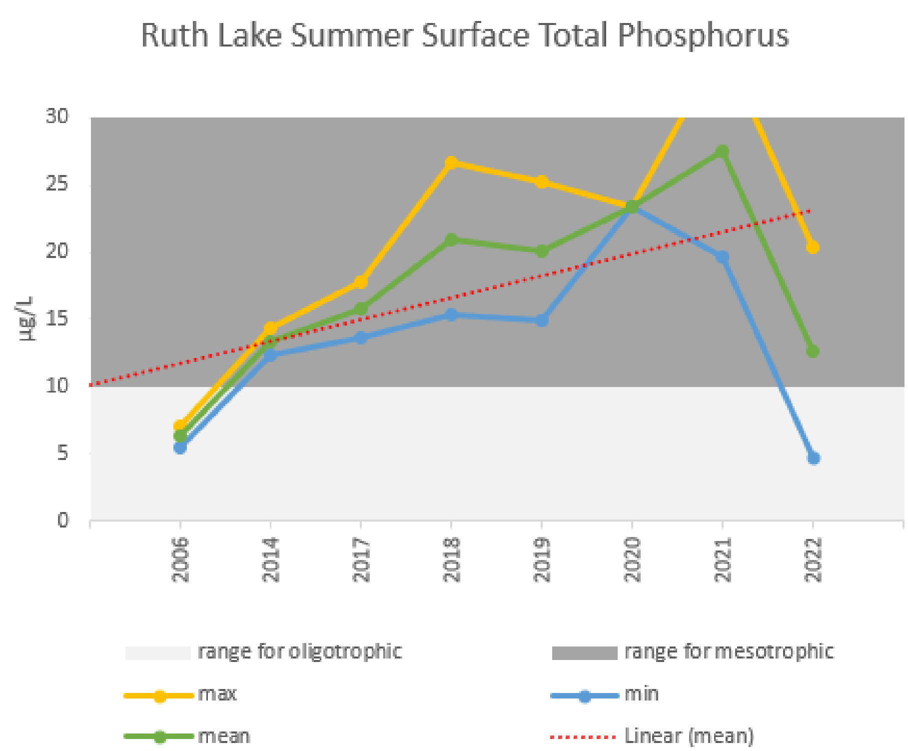
*Calcium was not tested in 2020

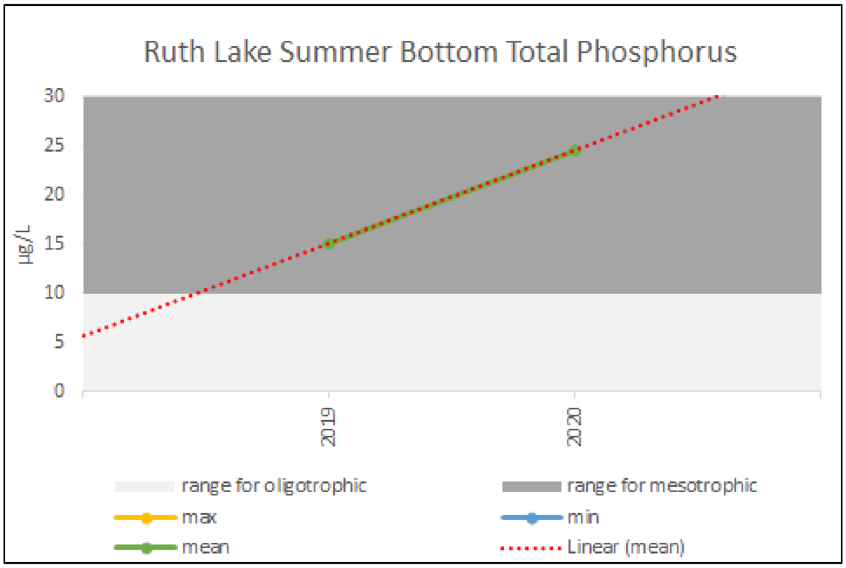

Mickey Lake Summer Calcium
mg/L
30
25
20
15
10
5
0
2017
2018
2019
2021
2022
max
min
mean
Linear (mean)

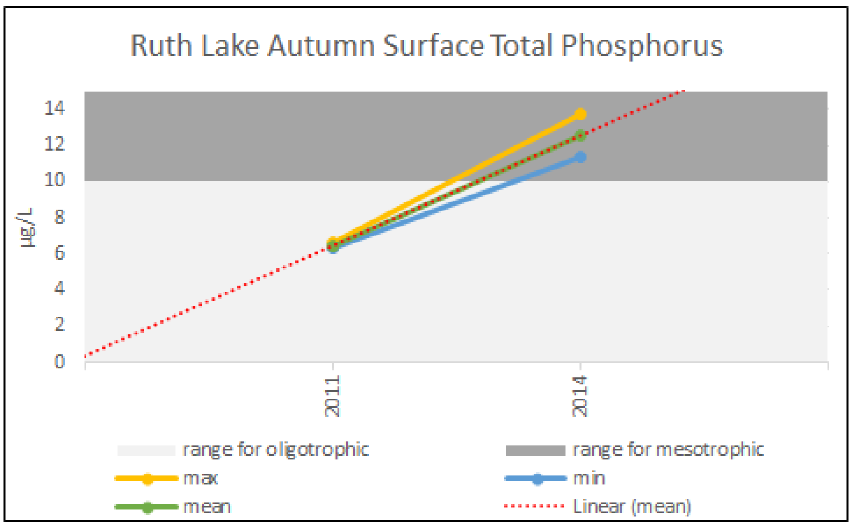
Ruth Lake

Total Phosphorus (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2006	2	---	5.5	---	7.1	---	6.30	---
2011	---	---	---	---	---	---	---	---
2014	2	---	12.4	---	14.4	---	13.40	---
2017	2	---	13.7	---	17.8	---	15.75	---
2018	2	---	15.4	---	26.6	---	21.00	---
2019	2	1	14.9	15.1	25.2	15.1	20.05	15.10
2020	1	1	23.4	24.6	23.4	24.6	23.40	24.60
2021	2	---	19.6	---	35.4	---	27.50	---
2022	2	2	4.8	3.8	20.4	24.9	12.60	14.35

Total Phosphorus (µg/L) AUTUMN								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2006	---	---	---	---	---	---	---	---
2011	2	---	6.3	---	6.6	---	6.45	---
2014	2	---	11.4	---	13.7	---	12.55	---







Sediment Phosphorus (mg/kg) SPRING/SUMMER				
Year	# samples	min	max	mean
2014	2	445	461	451

Summary: There is only one sample year, so no trend could be established.

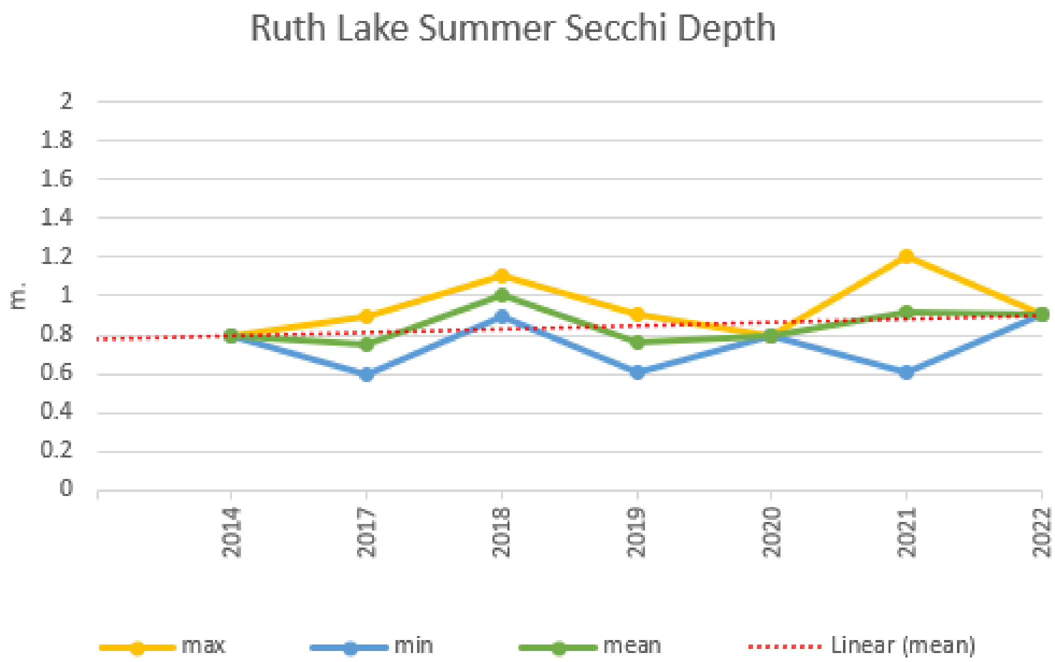
Nitrogen: Nitrate (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2018	1	---	<1000	---	<1000	---	<1000	---
2019	2	---	<1000	---	<1000	---	<1000	---

Nitrogen: Nitrite (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2018	1	---	<50	---	<50	---	<50	---
2019	2	---	<50	---	<100	---	<75	---

Summary: 2018 and 2019 used two different measuring techniques so a trend cannot yet be established as they are not comparable. Samples were not taken in 2020. For 2021 and 2022, Nitrates and Nitrites were calculated together, so we do not know the values separately.

Secchi Disk (m.) SPRING/SUMMER				
Year	# samples	min	max	mean
2014	2	0.79	0.79	0.79
2017	2	0.6	0.9	0.75
2018	2	0.9	1.1	1
2019	2	0.61	0.91	0.76
2020	1	0.8	0.8	0.8
2021	2	0.61	1.2	0.92
2022	2	0.91	0.91	0.91

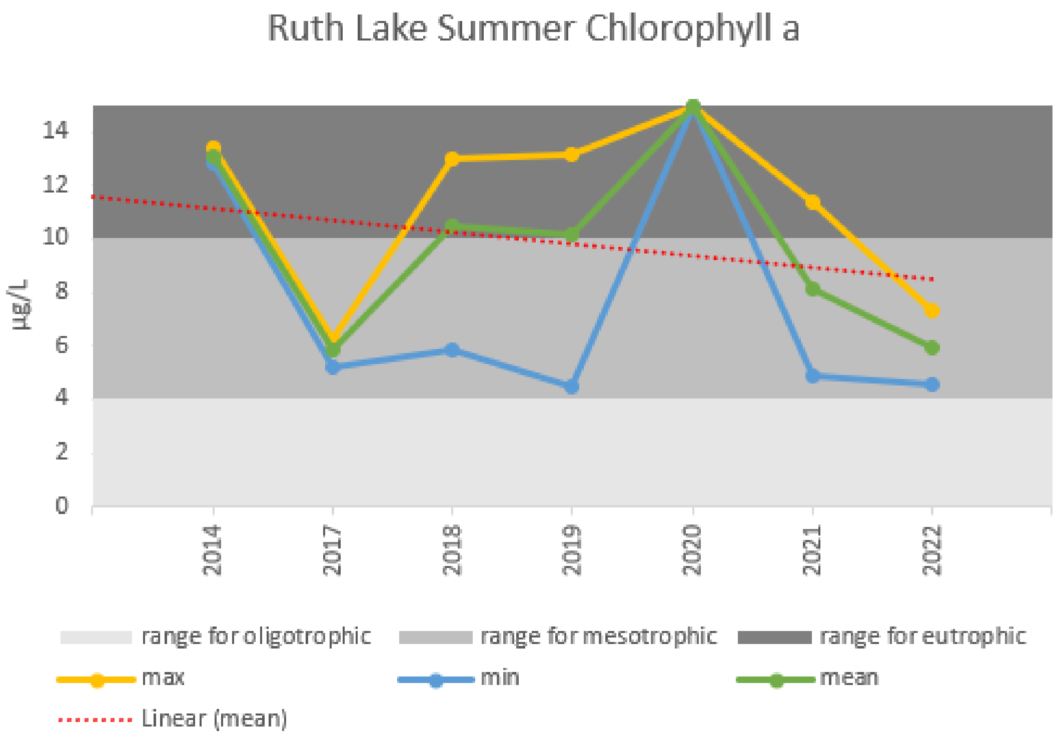
Secchi Disk (m.) AUTUMN				
Year	# samples	min	max	mean
2014	2	1.01	1.01	1.01



Summary: There is only one sample year for Autumn, so no trend could be established.

Chlorophyll a (µg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2014	2	12.8	13.4	13.1
2017	3	5.17	6.27	5.86
2018	3	5.82	13	10.50
2019	3	4.51	13.15	10.18
2020	1	14.95	14.95	14.95
2021	2	4.88	11.37	8.125
2022	4	4.58	7.34	5.94

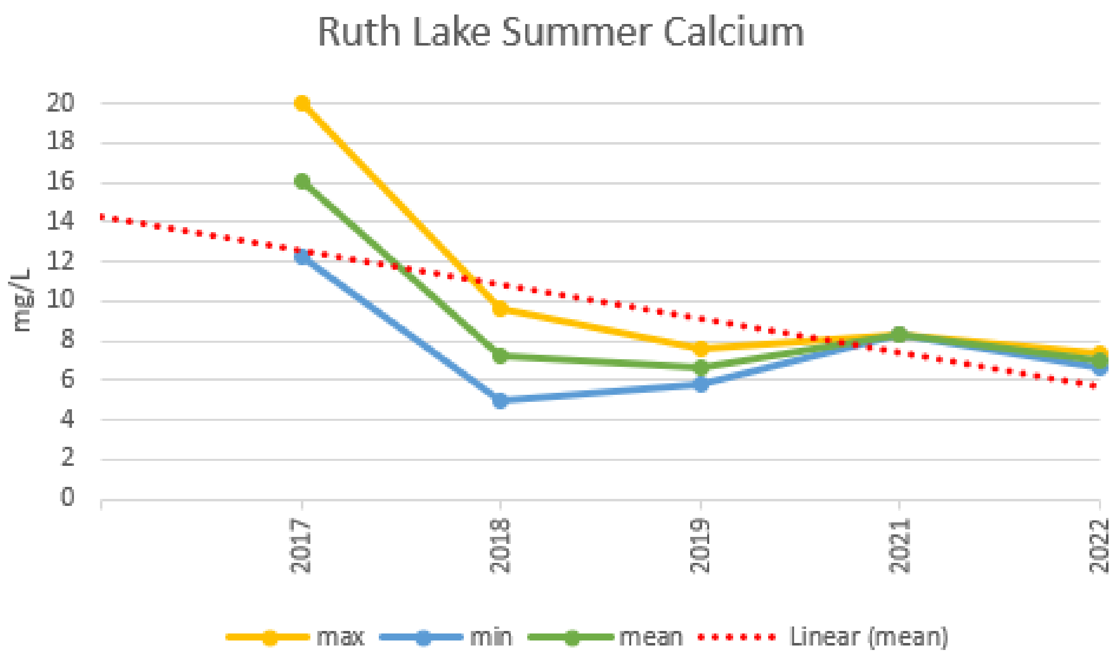
Chlorophyll a (µg/L) AUTUMN				
Year	# samples	min	max	mean
2014	2	3.7	10.7	7.2



Summary: There is only one sample year for Autumn, so no trend could be established.

Calcium (mg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2017	2	12.2	20	16.10
2018	2	5	9.6	7.30
2019	2	5.8	7.6	6.7
2020	----	---	---	---
2021	2	8.3	8.3	8.3
2022	2	6.6	7.4	7

*Calcium was not tested in 2020



Ruth Lake Summer Calcium
mg/L
20
18
16
14
12
10
8
6
4
2
0
2017
2018
2019
2021
2022
max
min
mean
Linear (mean)

Page Lake

Total Phosphorus (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2016	1	1	20.8	63.7	20.8	63.7	20.8	63.7
2017	---	---	---	---	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Sediment Phosphorus (mg/kg) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	1	700	700	700
2017	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Secchi Disk (m.) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	1	2.59	2.59	2.59
2017	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Chlorophyll a (µg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	*1	12.7	12.7	12.7
2017	---	---	---	---

*Mean of two samples

Summary: There is only one sample year, so no trend could be established.

Calcium (mg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	1	8.9	8.9	8.9

Summary: There is only one sample year, so no trend could be established.

Fern Lake

Total Phosphorus (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2016	2	2	6.5	8.8	7	13.6	6.75	11.20
2017	---	---	---	---	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Sediment Phosphorus (mg/kg) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	2	770	791	780.5
2017	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Nitrate-Nitrite Nitrogen (µg/L) SPRING/SUMMER								
Year	# samples		min		max		mean	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2016	2	2	<1.1	<1.1	<1.1	5.4	<1.1	3.25
2017	---	---	---	---	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Secchi Disk (m.) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	2	4.39	4.45	4.42
2017	---	---	---	---

Summary: There is only one sample year, so no trend could be established.

Chlorophyll a (µg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	3	5.3*	5.8	5.55
2017	---	---	---	---

*Mean of two samples

Summary: There is only one sample year, so no trend could be established.

Calcium (mg/L) SPRING/SUMMER				
Year	# samples	min	max	mean
2016	2	30.9	32.2	31.55

Summary: There is only one sample year, so no trend could be established.

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Dr. Wallace E. Fusilier, Bene Fusilier, Water Quality Investigators, Long Lake Water Quality Studies, 1993-2005 Document

GLEC/GLWSI 2021 Long Lake Water Quality Assessment, 2021 Report

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Appendix A:

Indigenous Unionid Clam Refugia from Zebra Mussels in Michigan Inland Lakes

Donna Hollandsworth[1], Rex Lowe [1,2,] and Peter Badra[3]

University of Michigan Biological Station, 9133 Biological Rd., Pellston, MI 49769

Department of Biological Sciences, Bowling Green State University, Bowling Green, OH 43403
Michigan Natural Features Inventory, 530 W. Allegan St., Lansing, MI 48933

Abstract

Zebra mussel *Dreissena polymorpha* Pallas, invasion into the Great Lakes region has resulted in high mortality or extirpation of native unionids from all or parts of Lake Erie, Lake St. Clair, and the Detroit River. Extirpation of native unionids has occurred primarily in open water, but small remnant populations occur in the Lake St. Clair delta and three areas of Lake Erie: Presque Isle Bay, Erie, PA; Metzger Marsh near Toledo, OH; and near the mouth of the Raisin River, Monroe, MI. In contrast, little is known about impacts of zebra mussels on native mussels in Michigan inland lakes although zebra mussels occur in at least 260 Michigan lakes. In laboratory studies, minimum calcium requirements for zebra mussel reproductive and establishment success has been reported as 20 mg/L, and in European lakes, minimum calcium requirements for colonization have been reported as 28.3 mg/L. Because some unionids (e.g. *Elliptio complanata* and *Pyganodon (= Anodonta) grandis)* occur at concentrations as low as 3 mg/L, it may be possible that soft water lakes, that is, lakes with calcium concentrations below 28.3 mg/L, might provide protection from zebra mussel induced mortality and/or extirpation of native unionids. This study identified Michigan inland lakes that have calcium concentrations less than 28.3 mg/L and have high potential for zebra mussel invasion (are heavily used by fishermen and have nearby lakes and/or streams where zebra mussels are established and could potentially serve as colonists). Five calcium poor lakes were identified that had 5 different unionid species present among them, where zebra mussel colonization had not occurred.

Introduction

Zebra mussel *(Dreissena polymorphas* Pallas) invasion into the Great Lakes region has resulted in high mortality or extirpation of native unionids from all or parts of Lake Erie, Lake St. Clair (Schloesser et al., 1998), and the Detroit River (Schloesser et al., 1998). Extirpation of native unionids has occurred primarily in open water, but small remnant populations occur in the Lake St. Clair delta (Zanatta et *al.*, 2002) and three areas of Lake Erie: Presque Isle Bay, Erie, PA (Schloesser and Masteller, 1999), Metzger Marsh near Toledo, OH (Nichols and Amberg, 1999) and near the mouth of the Raisin River, Monroe, MI (Schloesser *et al.*, 1997). In contrast, little is known about impacts of zebra mussels on native mussels in Michigan inland lakes although zebra mussels occur in at least 260 Michigan lakes (Michigan Sea Grant, 2008 and United States Geological Survey Nonindigenous Aquatic Species Website, 2008). Studies of zebra mussel habitat requirements have found that pH, temperature, salinity, substrate, nutrients, and calcium may limit zebra mussel colonization (Strayer, 1991; Ramcharan *et al.*, 1992; Stanczykowska and Lewandowski, 1993; Mellina and Rasmussen, 1994; and Hincks and Mackie, 1997). The establishment of zebra mussels and their impact on unionids in European lakes has been well documented. In European lakes, calcium concentrations 28.3 mg/L were found to be required for survival of zebra mussel veligers and to support zebra mussel colonization (Ramcharan et *al.*, 1992). Results of a risk assessment for zebra mussel invasion into 3000 North American streams and rivers showed the majority of zebra mussel establishments were in regions where calcium concentrations were > 28.3 mg/L or where surface water drained high calcium areas into regions where concentrations were 28.3 mg/L (Whittier et al 2008). In laboratory studies, calcium requirements for zebra mussel reproductive and colonization success has been reported as low as 20 mg/L (Cohen and Weinstein, 2001).

In contrast, calcium requirements of unionids vary among species and some inhabit soft water lakes (lakes with calcium concentrations less than 28.3 mg/L) (Boycott, 1936; Mackie and

Flippance, 1983). In a study of six low-alkalinity lakes in Ontario, *Pyganodon* (— *Anodonta) grandis* and *Elliptio complanata* were found in Blue Chalk Lake and Harp Lake with calcium concentrations of 2.99 mg/L and 3.15 mg/L respectively (Rooke and Mackie, 1984). A large population of *Pyganodon* (= *Anadonta) grandis* is found in Shell Lake, a small arctic lake, with a calcium concentration of 10 mg/L (Green, 1980). *Elliptio coniplanata* is known to occur in calcium-poor waters (Hinch et *al.*, 1988) and is found in Mirror Lake, New Hampshire with calcium concentrations of 2 -3 mg/L (Strayer *et al.*, 1981). In this study, nine Michigan soft water inland lakes were surveyed for native unionids to determine which species occur naturally in these systems and to determine if colonization of zebra mussels has occurred. There are several Michigan inland lakes that meet the criteria of 28.3 mg/L calcium concentration and hypothetically will not support zebra mussel colonization (Michigan Department of Environmental Quality's Surface Water Information Management System). Nine soft water lakes investigated in this study are: Lake Independence (Marquette Co.); Larks Lake (Emmet Co.); Douglas Lake (Cheboygan Co.); Long Lake (Grand Traverse Co.); Otsego Lake (Otsego Co.); Lake Mitchell (Wexford Co.); Houghton Lake and Lake St. Helen (Roscommon Co.); and Round Lake (Iosco Co.) (MDEQ's Mi SWIMS). These lakes have public boat access, and with the exceptions of Lake Independence and Larks Lake are judged to experience heavy use. All lakes but Lake Independence are in close proximity to lakes and streams that are colonized by zebra mussels that could serve as sources of zebra mussels colonists.

Methods

Unionid Survey

Native unionids were collected from inland lakes chosen for study for the purpose of establishing a species inventory list for each lake. Searches were performed along 3 transects perpendicular to the shore to a depth of 1 to 2 m where snorkeling and/or visibility were allowable. Unionids were photographed and their length, height, and breadth were measured using calipers. Unionids were returned into the habitat where they had been collected from and placed into the substrate in the same position in which they were found. Where unionids were biofouled, zebra mussels were collected from the unionids and placed in labeled zip lock bags for transfer to the laboratory. Unionids were identified by following Cummings and Mayer (1992), Goodrich (19o2), Heard and Burch (1966), Thorp and Covich (2001), and by comparisons with taxonomic reference collections (Detroit Edison Company, Detroit Michigan).

Zebra Mussel Survey

A sampling of substrate suitable for zebra mussel attachment, specifically, cobble and rocks, logs and sticks, living snails and mussels, shells of dead snails and mussels, boat hoists, dock filings, and vegetation in each lake were searched for zebra mussels. The survey was limited to substrate found in water depths to a maximum of 1 m. In lakes where zebra mussels were present, zebra mussels were collected through searches within 5-0.25 m^2 quadrats placed in zebra mussel habitat. All zebra mussels were removed from each quadrat and placed in labeled zip lock bags for storage and transfer back to the laboratory.

Calcium and pH Determination

Water samples were collected from each lake, and calcium concentrations were determined. Samples were collected in locations where unionids and zebra mussel surveys were performed. Two 250 mL samples were collected directly into clean acid washed polyethylene bottles that had been rinsed in lake water and then water samples were treated with concentrated HNO to a pH of less than 2. Samples were stored at 4°C and transported to the laboratory. Calcium determination was performed using atomic absorption flame spectrometry following methodology in Standard Methods for the Examination of Water and Wastewater (1985). pH was determined using a Fisher Scientific accumet portable pH/mV meter model AP10.

Data Analysis

Student t-test was used to determine if there was a difference in the mean of calcium 10c concentrations of lakes where zebra mussels were absent and the mean of calcium concentrations of lakes where zebra mussels were present using Minilab 14.

Results

Unionid Survey

A total of 143 unionid individuals and 5 species were found in 7 of the 9 lakes surveyed (Table 1). Lampsilis siliquoidea was found in 5 of the 7 lakes and P. grandis occurred in 6 of the 7 lakes surveyed. Zebra mussels and unionids were found coexisting only in Houghton Lake, and 3 of the 8 unionids collected were biofouled with zebra mussels. Of the 143 unionid individuals collected, 55.5% were from Lake Independence in Michigan's Upper Peninsula. Zebra Mussel Survey Zebra mussels were found in 3 of the 9 lakes surveyed: Houghton, St. Helen, and Douglas Lakes. Zebra mussels occurred in very low densities between the shoreline and to a depth of 1 m in all three lakes. Zebra mussels were found only on living or dead snails and/or unionids in Houghton Lake and Douglas Lake and were found on sticks, branches, and small rocks in Lake St. Helen, however this survey was limited to the shallow littoral zone.

Calcium and pH Determination

Total calcium concentrations in the 9 lakes ranged from 17 — 34 mg/L (Table 2). Lake Independence (Marquette Co.) had the lowest total calcium concentration and Houghton Lake (Roscommon Co.) had the highest total calcium concentration (Fig.1). The mean of calcium concentration of lakes with zebra mussels present differed significantly from the mean of calcium concentration of lakes where zebra mussels were absent ($p = 0.009$, $df=6$) (Fig. 2), and the mean calcium concentration of lakes with zebra mussels was 32 mg/L and of lakes without zebra mussels was 24 mg/L (Fig. 2). The 9 Michigan lakes studied all had pH values that ranged between 7.9 and 8.8 (Fig. 2).

Discussion

A significant difference in the mean of total calcium concentrations in lakes where zebra mussels were absent and in the mean of lakes where zebra mussels were present was observed. Mean calcium concentration for lakes with zebra mussels present was 32 mg/L and for lakes without zebra mussels was 24 mg/L. Calcium concentrations for lakes here were determined through a single sample, and calcium content is reported to vary minimally with depth and seasonality in soft water lakes (Wetzel, 1975). In laboratory studies, minimum calcium requirements for zebra mussel reproductive and colonization success has been reported as 20 mg/L (Cohen and Weinstein, 2001) however, in a study of European lakes, zebra mussels were not found in lakes with calcium concentrations below 28.3 mg/L (Ramcharan, et al., 1992). In this study, zebra mussels were absent in 6 lakes, and of those lakes 5 have calcium concentrations 5 26 mg/L. All lakes have one or more public boat access sites and/or campgrounds/parks and have lakes and/or streams nearby that are colonized by zebra mussels, and with the exception of Lake Independence and Larks Lake are judged to be used heavily for recreation. Lake Mitchell (calcium concentration = 20 mg/L) is frequently fished as is the Manistee River at Tipee Dam, which is heavily infested with zebra mussels, however Lake Mitchell has remained zebra mussel free (Larry Solce, Unit Supervisor, Mitchell State Park, Cadillac, MI, pers. comm.). In Long Lake (calcium concentration = 26 mg/L) Eurasian water-milfoil, another invasive that like zebra mussels is transported between water bodies on boats, has been established since 2006 (Michigan Sea Grant). It is likely that zebra mussels have been introduced into Long Lake too but were unsuccessful. Zebra mussels are absent from Larks Lake (calcium concentration = o1 mg/L), however it is not a heavily-used lake and may not have received potential colonists.

European lakes without zebra mussels all have pH values below 7.3 (Ramcharan, et al., 1992), and all 9 Michigan lakes in this study have pH values that ranged between 7.9 and 8.8. pH values fluctuate diurnally owing to photosynthesis and with depth (Wetzel, 1975). Because only single pH values were measured here, pH may not be a useful predictor of zebra mussel presence here. Zebra mussel densities were low in Houghton Lake, Lake St. Helen, and Douglas Lake and absent altogether in the remaining 6 lakes surveyed. Zebra mussel establishment has been reported for Houghton Lake, Lake St. Helen, and Douglas Lake as 1993, 1994, and 2001 respectively, (USGS Nonindigenous Aquatic Species Website, 2008 and University of Michigan Biological Station Website, 2008). Houghton Lake and Lake St. Helen had experienced population explosions in 2006 and Douglas Lake 1n 2005, and zebra mussel populations have declined since their explosion in all three lakes especially where water depths are shallower than 1 m (Pam Tyning, Progressive AE, Grand Rapids, MI, pers. comm.; Pete Rieli, Lake St. Helen Lake Association, St. Helen, MI, pers. comm.; and Rex Lowe pers. comm.). Zebra mussel density in a dozen European lakes has fluctuated over a thirty-year period, and population declines after population explosions with large zebra mussel individuals has occurred (Stanczykowska and Lewandowski, 1993). Zebra mussel density in Houghton Lake, Lake St. Helen, and Douglas Lake may experience similar fluctuations and explain present low densities; however, zebra mussels have successfully colonized these lakes.

Live A. ferussacianus, E. complanata, L. siliquoidea, L. nasuta, and P. grandis were found in 6 of the 9 lakes studied, and 5 of the 6 lakes where unionids were present have calcium concentrations below the theoretical zebra mussel colonization calcium concentration requirement (Ramcharan, et al., 1992). The results of this study suggests that lakes with calcium concentrations below 26 mg/L may serve as refugia from zebra mussel induced mortality and/or extirpation for A. ferussacianus, E. complanata, L. siliquoidea, L. nasuta, and P. grandis. However, Michigan has many hardwater lakes and few calcium poor lakes that have been identified. Lakes in Michigan’s western Upper Peninsula (UP) region are low in calcium because of underlying igneous bedrock (Dorr and Eschman, 1970; Rapp, et al., 1987), but generally calcium concentrations of lakes in the remainder of the state are high because they are situated in lacustrine deposits or limestone that contain calcium carbonate (Dorr and Eschman, 1970).

In a study of 12 lakes along Lake Superior, 3 lakes found to have lower buffering capacities are situated in sandy lacustrine deposits while 9 lakes having higher buffering capacities are situated in lacustrine deposits with a clay component (Rapp, et al., 1987). Soft Water lakes in the Lower Peninsula (LP) may be calcium poor because they are shallow and/or seepage lakes and situated in glacial sand several feet thick (Table 3) (Akers, 1938; Western Michigan University, 1981). Lake water calcium concentration in Houghton Lake may be greater than that of other lakes in this study because a lacustrine clay, one derived from limestone, underlies the lake's margins just below a layer of sand a few inches thick (Dennis Albert, pers. comm.).

More research is needed to identify lakes where unionids live and zebra mussels cannot, so these lakes can be protected. Surveys that include a dive component to detect species presence and establish abundance for the purpose of monitoring unionid status should be done. Additional work to identify calcium poor lakes could serve to provide temporary or permanent refuges for threatened mussels from the Great Lakes and other water bodies.

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Figure 1: Calcium concentrations of Michigan inland lakes surveyed.

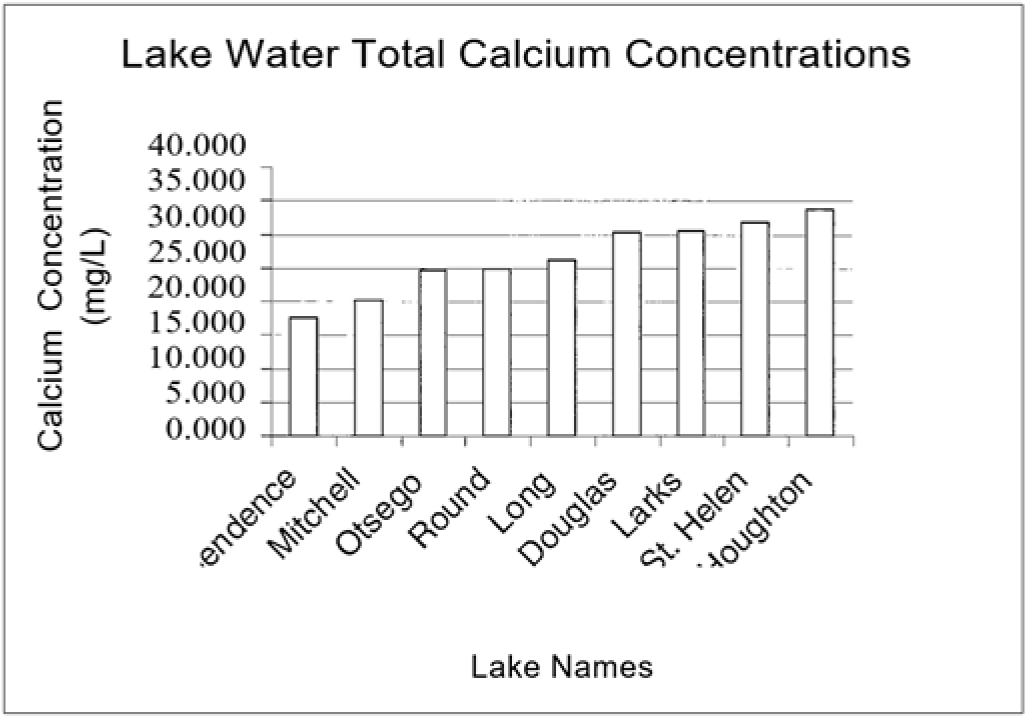

Figure 2: Mean of calcium concentrations and 95% confidence intervals for lakes where zebra mussels are absent (n=6) and lakes where zebra mussels are present (n—3).

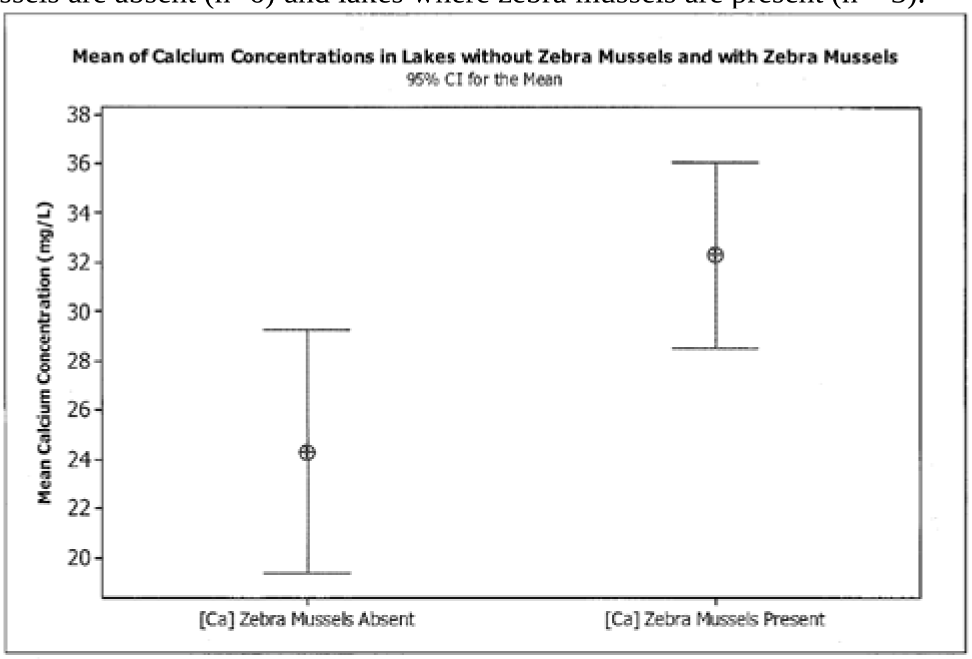

Table 1. Species lists of unionids in Michigan inland lakes surveyed.

Unionid Species and Lake Names	*Anodontoides ferussacianus*	*Elliptio complanata*	*Lampsilis siliquoidea*	*Ligumia nasuta*	*Pyganodon grandis*	
Douglas			•		•	
Houghton				•		
Independence		•	•		•	
Larks			•		•	
Long	•				•	
Mitchell			•		•	
Round			•		•	

Table 2. Total calcium concentrations and pH values for Michigan inland lakes surveyed.

Lake Name	**Total Calcium (mg/L)**	**pH**
Independence (Marquette Co.)	18	8.1
Mitchell (Wexford Co.)	20	8.0
Otsego (Otsego Co.)	25	7.9
Round (Iosco Co.)	25	8.1
Long (Grand Traverse Co.)	26	8.4
Douglas (Cheboygan Co.)	31	8.8
Larks (Emmet Co.)	31	8.8
St. Helen (Roscommon Co.)	32	8.6
Houghton (Roscommon Co.)	34	8.4

Table 3. Glacial drift thickness, maximum depth, inlets, and outlets for Lower Peninsula lakes (Western Michigan University, 1981; Michigan Recreational Boating Information System Website)

Lake Name	Glacial Drift Thickness (ft)	Maximum Depth (ft)	Inlets	Outlets
Mitchell (Wexford Co.)	801-1,000	20	•	•
Otsego (Otsego Co.)	801-1,000	23		
Round (Iosco Co.)	201-400	19		
Long (Grand Traverse Co.)	401-600	80		•
Douglas (Cheboygan Co.)	201-400	89	•	•
Larks (Emmet Co.)	201-400	9	•	•
St. Helen (Roscommon Co.)	401-600	25	•	•
Houghton (Roscommon Co.)	401-600	21	•	•

Figure Legend

Figure 1: Calcium concentrations for Michigan inland lakes surveyed.

Figure 2: Mean of calcium concentrations in lakes where zebra mussels and absent and of lakes where zebra mussels are present.

Table Legend

Table 1: Species lists of unionids mollusks in Michigan inland lakes surveyed.

Table 2: Total calcium concentrations and pH values for Michigan inland lakes surveyed.

Table 3. Glacial drift thickness, maximum depth, inlets, and outlets for Lower Peninsula lakes.