Water Quality Monitoring
Long Lake
Mickey Lake
Ruth Lake

Monitoring Year 2014

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Long Lake Association

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SECTION 1: 2014 Long Lake Water Quality Assessment

Long Lake monitoring was initiated in 2014 by Great Lakes Environmental Center (GLEC) with the intent to supply a continuing assessment of lake water quality which could be compared with legacy data (1997-2011). This continuing long-term assessment allows any important emerging trends in water quality to become evident, and provides the opportunity for appropriate action to be taken to address any concerns. Monitoring of Long Lake included the same parameters as in previous years: 1) monitoring of Long Lake water quality parameters using a Hydrolab Quanta (dissolved oxygen, temperature, conductivity, oxidation-reduction potential and pH) every three meters from surface to bottom at three established sampling sites (Figure 1); 2) measurement of water chemistry (total phosphorus levels at the surface and near bottom in the water column); 3) levels of Chlorophyll a at each sampling site (an indirect indicator of algae in the water column); and 4) measurement of secchi disk depth at each of the three sampling points. As in the 2011 assessment, measurement of nitrate-nitrite nitrogen (NO_x) was not done in 2014 as lake nitrogen levels have not been shown to be of significant concern over the years. Sampling was completed on June 10 (Summer) and October 10, 2014 (Fall).

Water Chemistry

Total Phosphorus. The results of the 2014 monitoring year demonstrated water chemistry trends that were generally comparable to results observed from 1997-2011 (Table 1). Near bottom phosphorus levels were slightly lower compared to 2011 at Site 2 and Site 3 but were marginally higher than 2008 levels (Table 1). The late fall samples exhibited higher surface phosphorus concentrations than the early summer samples, but were still at concentrations which would be considered low and indicative of excellent water quality. An examination of average yearly surface and bottom phosphorus levels from 1997 to 2014 demonstrates moderate variability over the sampling years, but concentrations consistently fall with the oligotrophic (highest quality) range. Overall, combined averages of surface and bottom phosphorus levels were consistently lower or equivalent for most sites than averages calculated for 1997-2005 and only slightly elevated from observations from 2008/2011 (Table 1). These accumulated phosphorus concentrations agree with data for Long Lake collected by Dr. Fusilier from 1993 to 2005 (Fusilier, 2005).

Chlorophyll a. Average chlorophyll a concentrations for 2014 were very similar to data from 1999 – 2005, but slightly elevated from 2008-2011 (Table 2). Chlorophyll a levels can vary widely from year to year and can be influenced by the time of year they were sampled (e.g. early spring, late fall, etc) or by the specific environmental conditions present on the lake during the year. However, long term averages can be a good indicator of water quality. Chlorophyll *a* levels were very consistent throughout the sampling period among sampling sites but did show a slight elevation in the fall sample event (Table 2) which is consistent with all previous sampling events from 1997 – 2011, and may be indicative of a normal increase in the algal community as the water warms.

Secchi Depth. The secchi depths (measure of water clarity) in Summer as measured during the 2014 sampling are higher than most sampling events from 1997 – 2005 and 2011, and equivalent to 2008 sample events (Table 2). Fall secchi depths are comparable to all sampling years (Table 2). As with chlorophyll a, the timing of the sample event can influence the water clarity. In this case, the 2014 summer sample event was somewhat earlier than 2011 and may, in part, have had an impact on the water clarity because general lake productivity may have been lower at this time in the year (less algal growth) or may have been due to environmental conditions which may have resulted in less suspended particulates, thereby increasing water clarity.

Sediment Phosphorus

Periodic monitoring of sediment phosphorus was suggested in 2011 to examine the sediment reservoir of one of the primary plant nutrients, total phosphorus. Monitoring in 2005 demonstrated the highest concentration at Site 3 (654 mg/kg), 322 mg/kg at Site 1 and the lowest observed concentration at Site 2 (33 mg/kg – see Table 4). This periodic examination of sediment phosphorus may provide insight into any dramatic changes in accumulation of this nutrient which may be subsequently released under low oxygen conditions. For 2014, the concentrations at the three sample sites were nearly identical to 2005: Site 1 (379 mg/kg), Site 2 (48 mg/kg) and Site 3 (811 mg/kg) (Table 4). Based on these values, it does not appear than there is a significant change in the reservoir of sediment phosphorus at these sites. It should be noted that these are very discrete locations, and that there may be differences in sediment phosphorus elsewhere in Long Lake that are not measured. Previous measurements of shoreline sediment phosphorus measured in 2006 demonstrated that sediment phosphorus levels were low, usually less than 30 mg/kg dry weight.

Hydrolab Data

The Hydrolab profiles for both Summer and Fall, 2014 exhibited the same characteristics of temperature and dissolved oxygen (DO) profiles which are typical of deeper lakes such as Long Lake (Figures 2a and 2b). Normally, fall DO levels decline with depth due to the inherent temperature stratification (e.g., thermocline) of the lake that occurs during summer in the deeper areas. These decreased DO levels were observed in the Summer sampling event at all sites in 2014. The Fall sampling event continued to exhibit very low DO levels at Site 1, but not at Site 2 or Site 3. This can likely be explained by the fact that the fall lake “turnover” (a mixing of the water which eliminates the temperature and DO differences) may have partially occurred and the sampling performed by GLEC was after this turnover. Predicting when turnover will occur is difficult. It is assumed that prior to turnover, DO levels were decreased at increased depth, as has been observed in almost every sampling event done since 1997. Prolonged DO deficits near bottom sediments may lead to a release of phosphorus bound in the sediments. There was slight increase in the bottom phosphorus concentrations measured at Site 2 in the Fall sampling, compared to Site 1 and 3, suggesting a sediment phosphorus release, but the levels were not excessively high. Elevated concentrations, possibly due to low DO, have been observed consistently in previous data measured since 1997 (Table 1), are consistent with data reported by Dr. Fusilier (1993-2005 data) and do not seem to be unusual or indicative of major problems.

Conclusions

The data from the year 2014 sampling season indicate that Long Lake would continue to be considered an oligotrophic, high quality lake based on total phosphorus in the water, chlorophyll a levels and secchi depth (Table 3). This status has been documented since 1997 and maintained throughout the past 17 years. Although lake phosphorus levels are slightly higher than other area lakes (Table 4), Long Lake still compares favorably with these lakes and maintains its oligotrophic status. Long Lake has historically high concentrations of bottom sediment phosphorus (Table 4). This phosphorus can be a significant source of nutrients to the Lake through an internal loading process when bottom oxygen concentrations drop to near zero. Anoxic (low oxygen) conditions are known to consistently occur (based on 1997-2011 data) and this potential flux of phosphorus from the sediments is an important component of the overall phosphorus budget for the Lake. Because of the historical nature of high sediment phosphorus, it is recommended that additional sediment samples be taken from the three sampling points and analyzed for phosphorus again within a five to six year time frame.

The development of a thermocline in deep lakes is a natural process. The combination of anoxic conditions coupled with high sediment phosphorus levels continues to provide potential of significant internal loading of phosphorus in Long Lake. This internal loading may cause late season algal blooms and potential increases in aquatic plants within the lake ecosystem. However, seasonal variability in weather (temperature, wind, rainfall) may moderate or exacerbate the potential for lake water sampling impacts. Thus, as was noted in previous years, water quality conditions in Long Lake have potential to be vulnerable to deterioration. It is recommended that Long Lake continue to have a comprehensive outreach and education component regarding nutrient use near the lakeshore, as well as continuing efforts for surface water runoff control. These will all will help limit the introduction of additional phosphorus to the lake ecosystem and help preserve the oligotrophic status.

Table 1. Concentrations of Total Phosphorus (TP) in μg/L at each of three sampling sites on Long Lake, 1997 to 2014 (**2014 highlighted**).

1997	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
min	6.3	4.7	5.9	6.0	5.8	5.9
max	7.4	10.7	11.7	24.9	10.7	13.0
avg	6.8	8.3	7.7	12.5	7.6	7.7

	Site #1		**Site #2**		**Site #3**	
1998	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
min	5.6	5.3	4.2	9.1	4.0	4.7
max	15.3	14.3	17.6	55.0	18.2	20.2
avg	8.3	10.7	8.3	31.4	8.4	12.6

	Site #1		**Site #2**		**Site #3**	
1999	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
min	4.5	6.8	2.8	20.1	5.3	7.8
max	7.7	10.2	5.8	25.4	7.9	10.5
avg	6.1	8.5	4.7	22.0	7.0	9.5

	Site #1		**Site #2**		**Site #3**	
2000	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
min	3.1	7.1	3.9	9.1	4.0	6.4
max	17.9	20.8	11.7	18.9	9.0	19.2
avg	6.8	13.3	7.4	14.8	6.1	9.4

	Site #1		**Site #2**		**Site #3**	
2005	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
Spring	10.7	5.7	12.9	11.3	3.3	82.5**
Fall	7.5	8.1	9.7	19.9	11.7	16.5
avg	9.1	6.9	11.3	15.6	7.5	***

	Site #1		**Site #2**		**Site #3**	
2008	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
Spring	1.8	11.3	1.2	1.9	3.6	4.1
Fall	5.6	7.2	8.0	5.8	4.8	5.1
avg	3.7	9.3	4.6	3.9	4.2	4.6

	Site #1		**Site #2**		**Site #3**	
2011	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
Summer	na	na	5.4	7.5	5.0	18.4
Fall	4.9	5.5	5.0	31.7	5.4	9.1
avg	4.9	5.5	5.2	19.6	5.2	13.8

2014	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
Summer	**2.4**	**8.9**	**2.2**	**4.9**	**2.3**	**9.1**
Fall	**8.4**	**6.6**	**6.2**	**14.2**	**5.5**	**6.5**
avg	**6.6**	**7.8**	**4.2**	**9.6**	**3.9**	**7.8**

Table 2. Concentrations of chlorophyll a (Chl.A) and the secchi depth (in feet) at each of three sampling sites on Long Lake, 1997 to 2014 (**2014 highlighted**).

	Chl. A (µg/L)				Secchi (ft.)		
1997	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
min	0.7	na	na		14.0	14.0	14.0
max	4.7	na	na		22.0	31.0	29.5
avg	2.3	na	na		18.0	19.8	18.4
1998	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
min	1.4	na	na		16.5	17.0	16.0
max	5.2	na	na		40.5	34.5	32.0
avg	2.4	na	na		23.9	21.6	19.9
1999	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
min	0.1	0.4	1.3		15.0	16.0	16.0
max	2.3	2.3	3.2		18.5	24.5	18.5
avg	1.3	1.5	2.1		17.0	19.5	17.7
2000	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
min	1.1	1.2	0.2		17.0	17.0	17.5
max	2.0	2.5	2.9		32.0	33.5	32.0
avg	1.4	1.8	1.7		23.7	23.4	21.8
2005	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
Spring	1.6	1.7	1.6		28.5	28.0	28.5
Fall	2.0	2.0	2.8		18.5	18.5	18.5
avg	1.8	1.8	2.2		23.7	23.3	23.5
2008	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
Spring	0.3	0.3	0.4		41.8	41.3	37.4
Fall	1.6	1.7	1.9		20.0	20.3	18.5
avg	1.0	1.0	1.1		30.9	30.8	28.0
2011	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
Summer	na	0.9	0.8		na	24.6	24.6
Fall	1.0	1.6	1.5		19.7	19.7	23.0
avg	1.0	1.0	1.1		19.7	22.2	23.8
2014	**Site #1**	**Site #2**	**Site #3**		**Site #1**	**Site #2**	**Site #3**
Summer	**1.1**	**0.8**	**2.1**		**35.3**	**41.8**	**35.3**
Fall	**1.6**	**1.8**	**1.4**		**19.7**	**19.7**	**19.7**
avg	**1.4**	**1.3**	**1.8**		**27.5**	**30.8**	**27.5**

Table 3. Trophic State Classification (Chapra, 1997)

Variable	**Oligotrophic**	**Mesothophic**	**Eutrophic**
Total Phosphorus (μg/L)	< 10	10-20	>20
Chlorophyll a (μg/L)	<4	4-10	>10
Secchi depth (ft)	>13	6.6 - 13	<6.6

Table 4. Phosphorus Data for Area Lakes and Sediments

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
Long Lake 1997 – 2000		1999-2000
Long (Site 1)	8.6*	1742
Long (Site 2)	13.6*	1051
Long (Site 3)	9.3*	684
Long Lake 2005		
Long (Site 1)	8.0	322
Long (Site 2)	13.5	33
Long (Site 3)	10.5	654
Long Lake 2008		
Long (Site 1)	6.5	n/a
Long (Site 2)	4.3	n/a
Long (Site 3)	4.4	n/a
Long Lake 2011		
Long (Site 1)	5.2	n/a
Long (Site 2)	14.4 *	n/a
Long (Site 3)	9.5 *	n/a
Long Lake 2014		
Long (Site 1)	**7.2**	**379**
Long (Site 2)	**6.9**	**48**
Long (Site 3)	**5.9**	**811**

*****Influenced by high bottom P concentrations in summer (Site 3) and fall (Site 2) samples

Figure 1. Water quality sampling sites on Long Lake, 1997-2014.

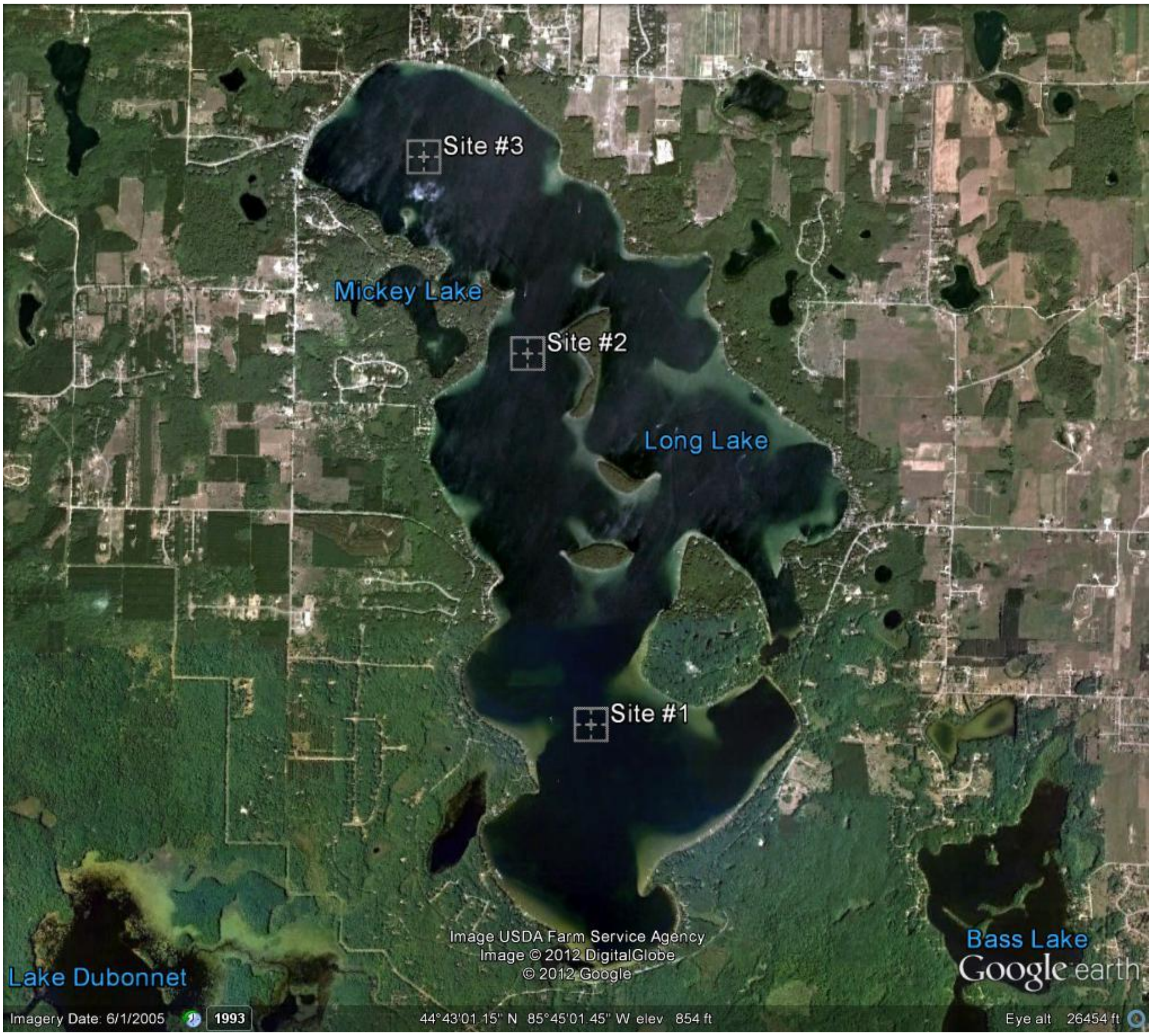


Figure 2a. Hydrolab Profiles for Long Lake Sampling Sites 1,2 and 3 on June 10, 2014.

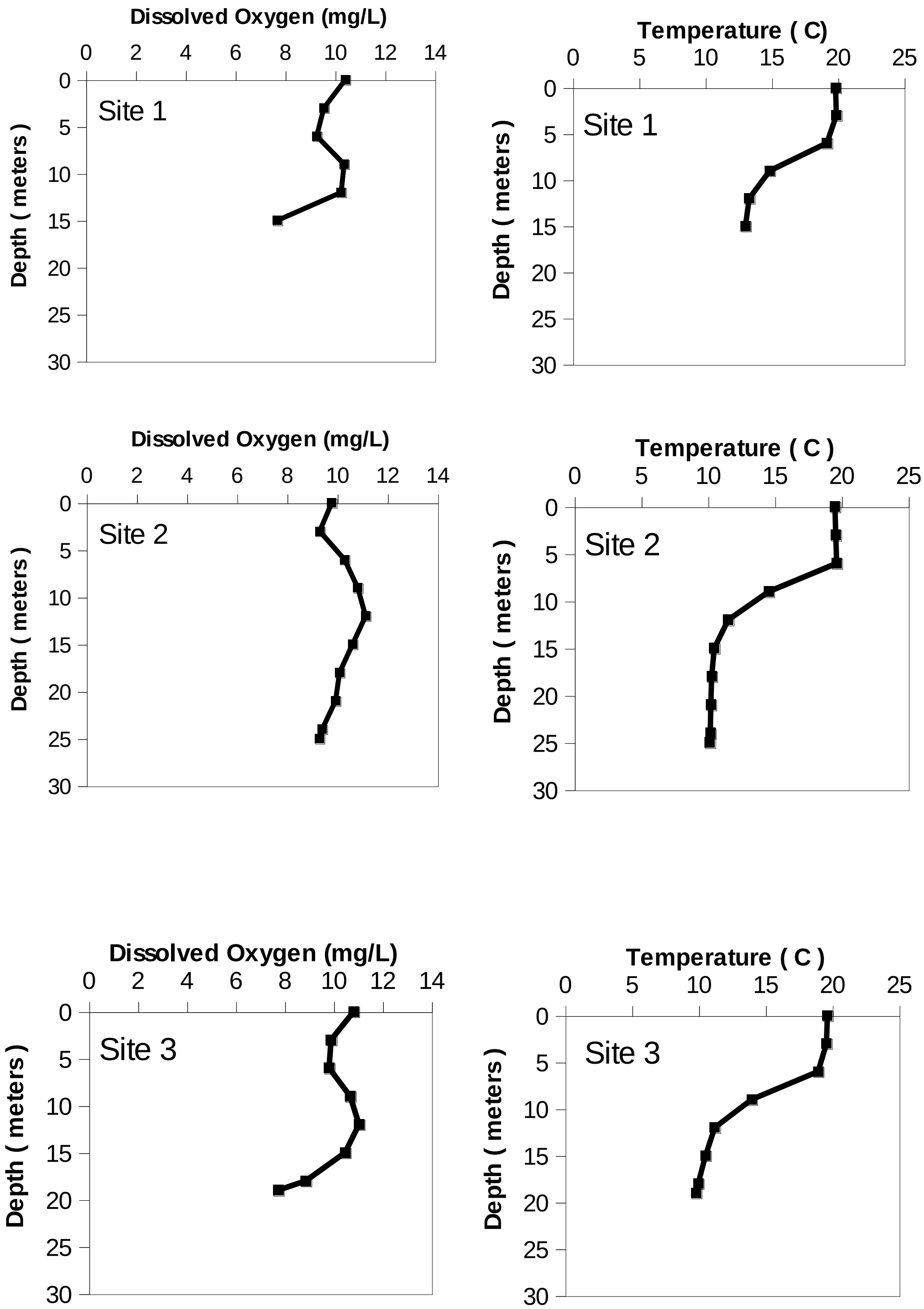
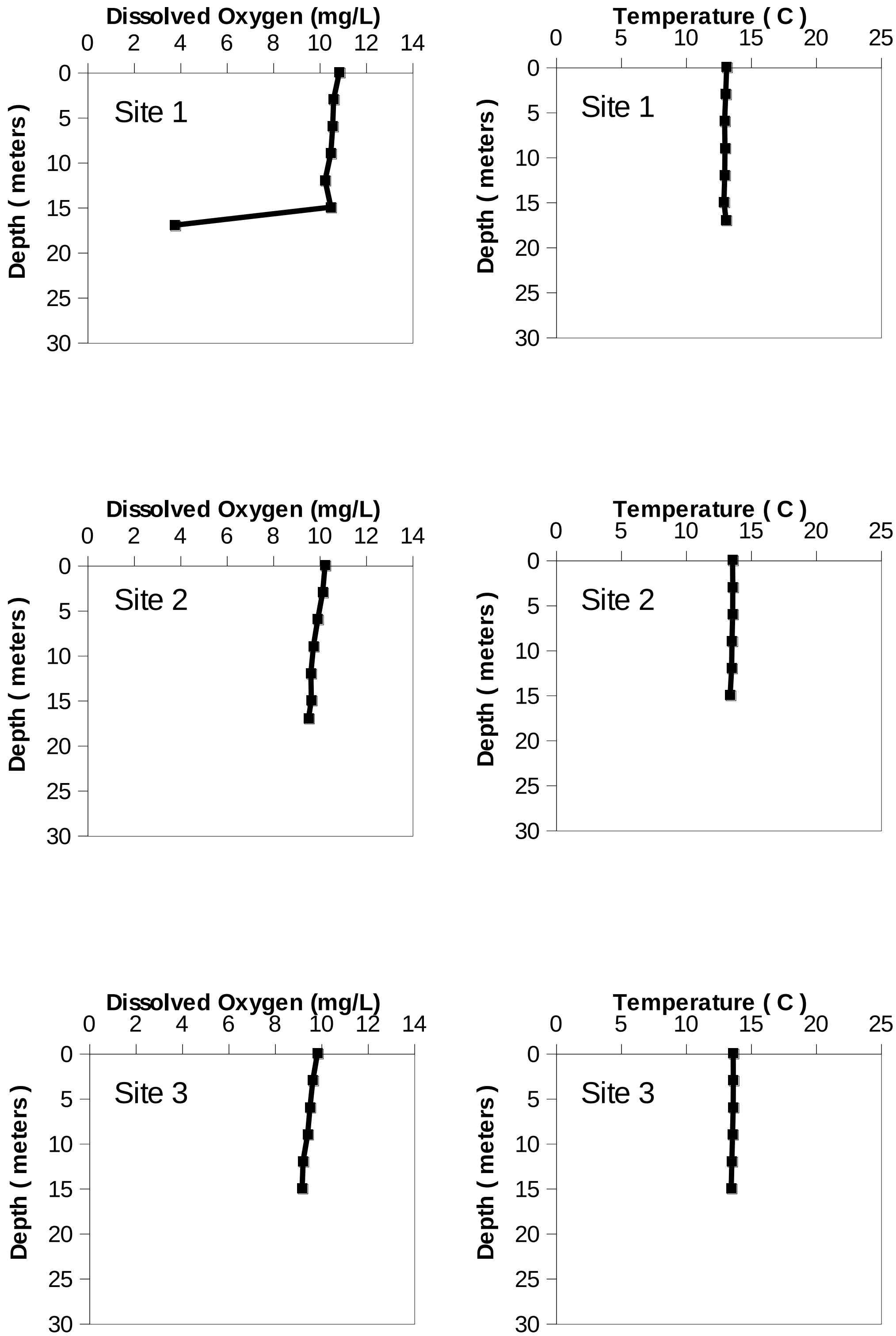


Figure 2b. Hydrolab Profiles for Long Lake Sampling Sites 1,2 and 3 on October 10, 2014.



SECTION 2: 2014 Mickey Lake Water Quality Assessment

For the 2014 sampling season, basic water quality parameters were measured at two sites in Mickey Lake in samples takin the summer (June 10, 2014) and fall (October 10, 2014) (Figure 3). Measurements were taken at two sites using a Hydrolab Quanta, which measures water temperature, dissolved oxygen, pH, specific conductance and oxidation/reduction potential. In addition, water samples were collected and analyzed for total phosphorus by the GLEC chemistry laboratory. Historically, GLEC has not been tasked with monitoring Mickey Lake for water quality parameters, other than sediment samples, bacterial contamination and a macrophyte (aquatic plant) survey (2006). Dr. Wally Fusilier has monitored Mickey Lake between 1993 and 2003 and has presented a comprehensive analysis of those data (Fusilier, 2004). For comparative purposes, it should be noted that GLEC sample site #1 roughly corresponds to Fusilier sample site #3, and GLEC sample site #2 corresponds approximately with Fusilier sample site #2. As was completed for Long Lake, measurements of total phosphorus (TP) at the surface and bottom of the two sampling points was completed, as well as chlorophyll a concentrations, secchi disk depths and sediment phosphorus.

Water Chemistry

Total Phosphorus. Total phosphorus concentrations at Site #1 were within the mesotrophic (moderate quality) range (Table 3) for both top and bottom samples (Table 5). Fall concentrations were much higher than summer measurements. Site #2 phosphorus concentrations were slightly lower at the surface compared to Site #1 and were significantly lower at the bottom (Table 5). Site 1 elevated phosphorus may be related to low dissolved oxygen content (see below) releasing phosphorus from the bottom sediments. These phosphorus values at both sampling sites are similar to historical phosphorus values reported by Dr. Fulsilier in his monitoring of Mickey Lake (Fusilier, 2004).

Chlorophyll a. Average chlorophyll a concentrations for 2014 on Mickey Lake were higher than reported for Long Lake during the same sampling period, but roughly equivalent in the fall (Table 5). Chlorophyll a levels may have been higher due to the warmer temperatures (and shallower depth) in Mickey Lake compared to Long Lake. The reported values are consistent with Dr. Fusilier's measurements from 1993-2003 (Fusilier, 2004), and the yearly average is in the oligotrophic range (Table 3).

Secchi Depth. The secchi depths (measure of water clarity) are very comparable to those values reported for Long Lake in 2014 (Table 5). Again, these values match very well with the historical values reported by Dr. Fusilier (Fusilier, 2004).

Sediment Phosphorus

Sediment phosphorus levels in Mickey Lake (Table 5) were significantly higher than those found in Long Lake (see Table 4). The concentration at Site 1 was 1625 mg/kg and Site 2 was 879 mg/kg. These higher sediment phosphorus levels may somewhat explain the higher bottom phosphorus levels measured in the summer sampling event (Table 5) under lower dissolved oxygen conditions. Because Mickey Lake is somewhat hydrologically separated from Long Lake and somewhat shallower, phosphorus accumulations in sediments may be more pronounced.

Hydrolab Data

The hydrolab data exhibit a distinct decrease in dissolved oxygen at Site 1 in both the summer (Figure 4a) and fall (Figure 4b) sample events. At Site 2, a slight increase was observed in the summer and a slight decrease at was observed in the fall (Figure 4a, 4b). The DO values are within the range exhibited by Long Lake and historical data (Fusilier, 2004). Site #1 reductions in DO near the bottom may account for the observed increase in total phosphorus in the bottom samples (Table 5). Anoxic conditions from a thermocline (see discussion for Long Lake, above) may result in a release of phosphorus from the bottom sediments.

Conclusions

Although the extent of historical water quality monitoring in Mickey Lake is limited, the data suggest that Mickey Lake would be categorized as mesotrophic (Table 3) and the water quality is generally good to excellent. Total water phosphorus levels are moderate to low, but are higher than other high quality lakes in the region (Table 4). Sediment phosphorus concentrations are noted to be somewhat higher than that measured in Long Lake.. Mickey Lake is not completely hydrological separate from Long Lake, but the connection is shallow enough that there is likely not a rapid exchange rate between the lakes. The data collected in 2014 correlate well with and are supported by historical data collected by Dr. Fusilier (Fusilier, 2004). It is recommended that approaches which limit phosphorus additions to the lake (lakeshore management) will help to reduce the phosphorus loading and subsequent accumulations in Mickey Lake.

Table 5. Total phosphorus, sediment phosphorus, chlorophyll a concentrations, and secchi depths for two sampling sites in Mickey Lake, 2014. Sampling was only conducted in the Summer (June 10, 2014) and Fall of 2014 (October 10, 2014). Sediment phosphorus collected on June 10, 2014.

Phosphorus (µg/L)

	Site #1		Site #2	
2011	**Top**	**Bottom**	**Top**	**Bottom**
Summer	na	na	na	na
Fall	7.3	8.6	8.4	12.7
avg	7.3	8.6	8.4	12.7
2014	**Top**	**Bottom**	**Top**	**Bottom**
Summer	**8.1**	**18.0**	**7.0**	**7.6**
Fall	**14.9**	**20.1**	**8.1**	**6.9**
avg	**11.5**	**19.1**	**7.6**	**7.3**

Sediment Phosphorus (mg/kg)	
Site #1	**Site #2**
1625	**879**

Chl. A (µg/L)

2011	Site #1	Site #2
Summer	na	na
Fall	2.65	2.12
avg	**2.65**	**2.12**
2014	**Site #1**	**Site #2**
Summer	**5.2**	**2.0**
Fall	**1.3**	**1.5**
avg	**3.3**	**1.8**

Secchi (ft.)

	Site #1	Site #2
2011 Summer	na	na
2011 Fall	18	18.7
2011 avg	**18**	**18.7**
	Site #1	**Site #2**
2014 Summer	**29.5**	**20.5**
2014 Fall	**19.7**	**21.3**
2014 avg	**24.6**	**20.9**

Figure 3. Water quality sampling sites for Mickey Lake, 2014.

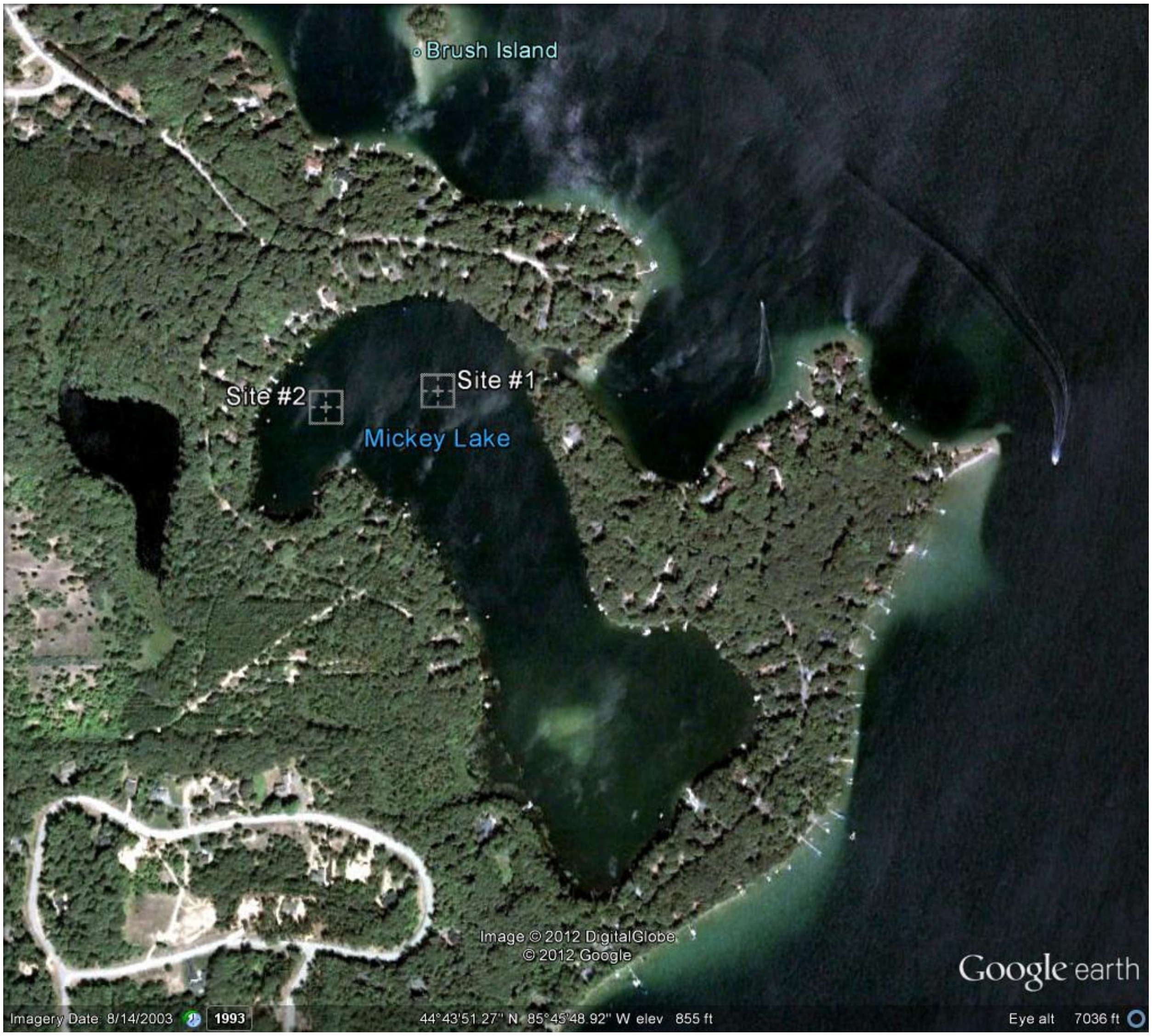


Figure 4a. Hydrolab Profiles for Mickey Lake Sampling Sites 1 and 2 on June 10, 2014.

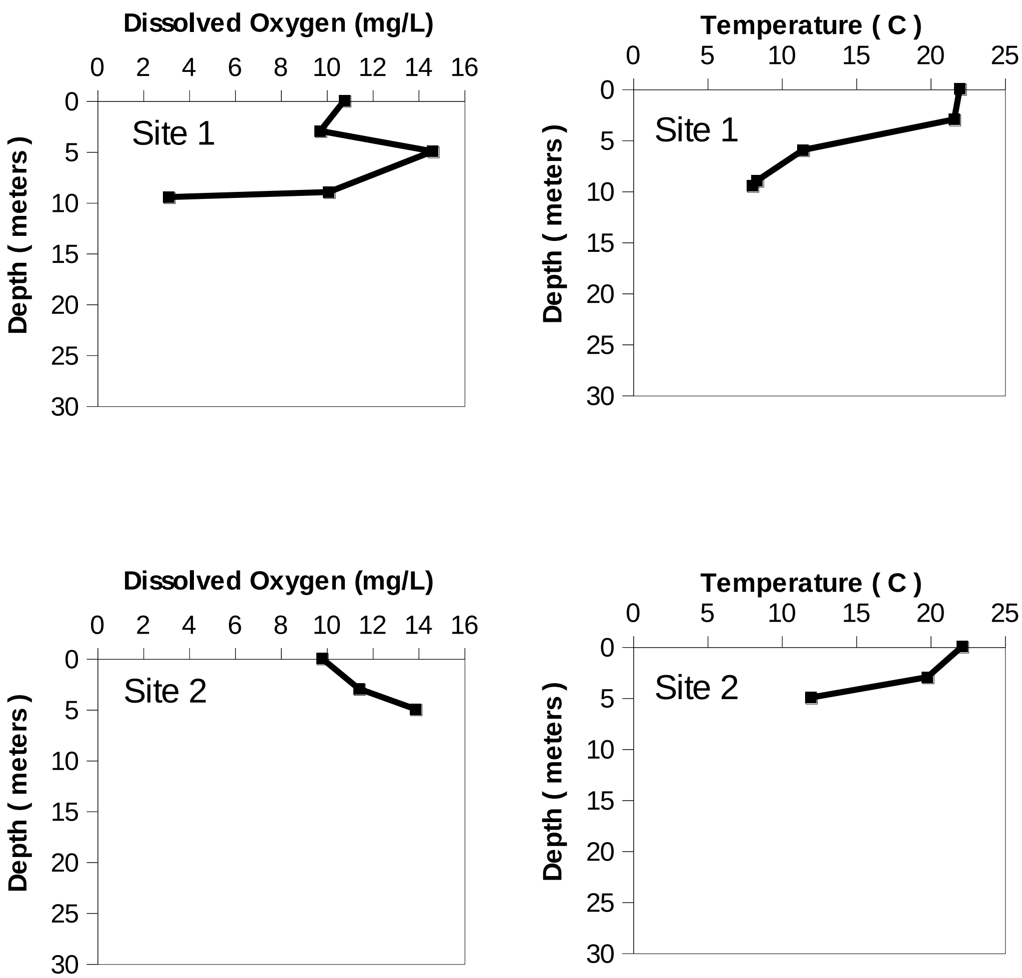
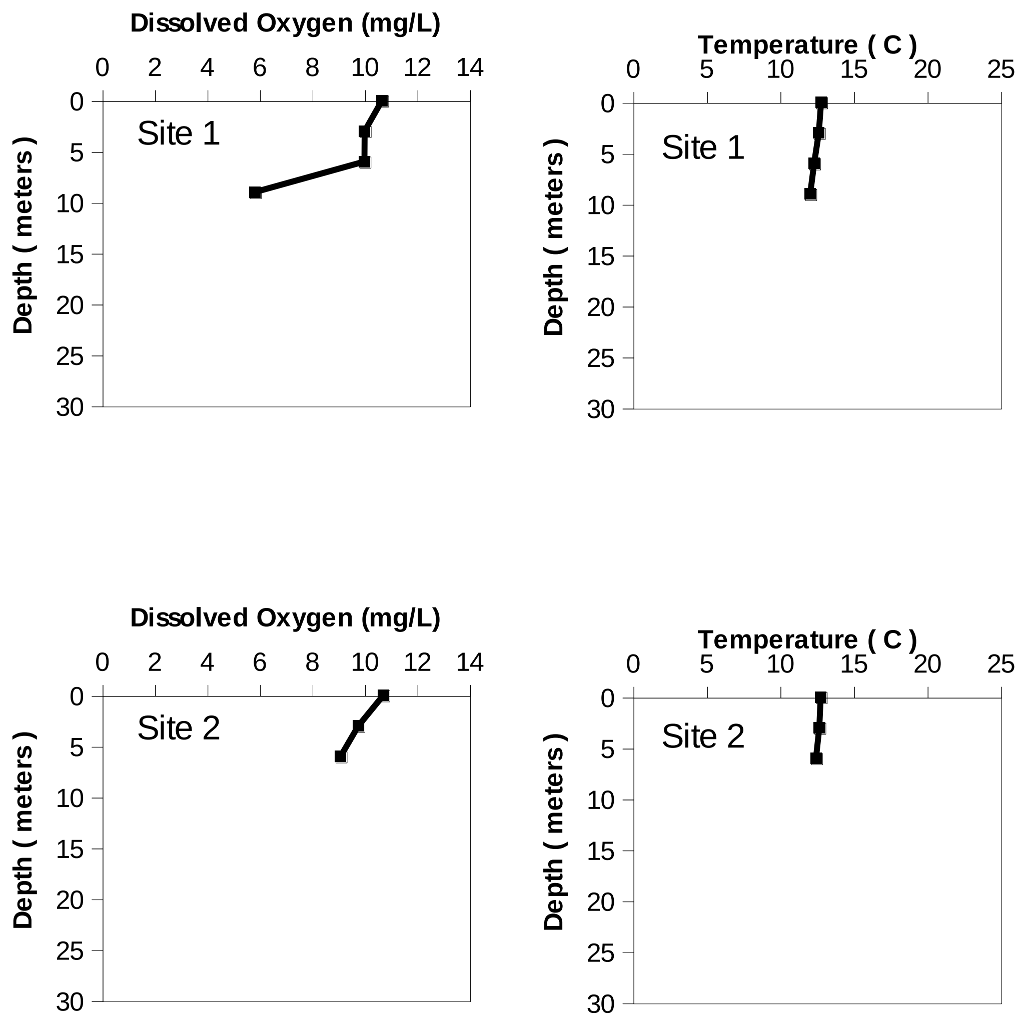


Figure 4b. Hydrolab Profiles for Mickey Lake Sampling Sites 1 and 2 on October 10, 2014.



SECTION 3: 2014 Ruth Lake Water Quality Assessment

As was done for Mickey Lake in 2014, a water quality assessment was performed on Ruth Lake for basic water quality parameters.

Water Chemistry and Hydrolab Data

In a historical perspective, in the summer of 2006, GLEC evaluated the relative water quality of Ruth Lake. Measurements were taken at four sites (2006) using a Hydrolab Quanta, which measures water temperature, dissolved oxygen, pH, specific conductance and oxidation/reduction potential. In addition, water samples were collected and analyzed for total phosphorus by the GLEC chemistry laboratory. Dissolved oxygen levels near the surface were typical for lakes in this general region. As depth increased, the oxygen content decreased to near zero, particularly at Station 1, 2 and 4. This decrease in oxygen was expected, as the bottom sediment in the relatively shallow Ruth Lake consists of significant organic matter. This organic fraction supports decomposition of organic matter, and uses oxygen to drive this process. Therefore, the oxygen is generally consumed. Water temperatures were slightly higher than Long Lake, but this is also expected due to the relatively shallow depth of Ruth Lake. Levels of total phosphorus in the water at the four sampling sites exhibited concentrations which were expected in high quality waters (Table 6), and are consistent with observations made in Long Lake. Based on the Hydrolab measurements and total phosphorus readings, no immediate problems were noted in Ruth Lake in 2006. Additional monitoring in 2011 (only at Sites 1 and 2 – see Figure 5) confirmed those observations from 2006. For 2014 sampling, total phosphorus levels were moderate and typical of lakes with moderate water quality (Table 6). Chlorophyll levels were much higher than observed for Long Lake in 2014 (no Ruth Lake Chlorophyll data taken in 2011), and were indicative of mesotrophic conditions. Secchi depths in 2014 were much shallower than in Long or Mickey Lakes. This is to be expected, however, due to the higher organic matter and general productivity of Ruth Lake. Hydrolab profiles did indicate temperature gradients (likely due to the shallow depth) and a marked reductions in dissolved oxygen at both Site 1 and Site 2 at the summer sample event (Figure 6a). Water temperatures were slightly higher than those observed in Long Lake. However, the fall sample event did not demonstrate the same temperature gradients or low DO levels as was observed in the summer (Figure 6b).

Sediment Phosphorus

Sediment phosphorus in Ruth Lake is higher than found in shoreline sediments of Long Lake (2006 Long Lake report) but is consistent with concentrations found in deeper portions of Long Lake (Table 6). Concentrations are roughly 25% of those noted in Mickey Lake: Site 1 (461 mg/kg), Site 2 (445 mg/kg).

Conclusions

The water quality in Ruth Lake would be considered of good quality based on the limited sampling performed in 2014, and consistent with observations in 2006 and 2011. However, Ruth Lake is hydrologically separate (most of the time) from Long Lake, and has a much higher aquatic plant density and inherent organic matter within the water body. These factors, along with the shallow depth, can contribute to the process of eutrophication, which is a natural process of all lakes over a long time period (often hundreds of years or more). Although Ruth Lake has a higher aquatic plant density, it is still in excellent condition and no obvious concerns are noted. Noted high concentrations of sediment phosphorus are not necessarily unexpected, but it is recommended that strategies to reduce nutrient runoff (as would be used for Mickey and Long Lakes) should be implemented or continued, as this will slow the process of eutrophication in Ruth Lake.

Table 6. Total phosphorus, sediment phosphorus, chlorophyll a concentrations, and secchi depths for two sampling sites in Ruth Lake, 2014. Sampling was only conducted in the Summer (June 10, 2014) and Fall of 2014 (October 10, 2014). Sediment phosphorus collected on June 10, 2014.

Phosphorus (µg/L)

	Site #1		Site #2	
2006	**Top**	**Bottom**	**Top**	**Bottom**
Summer	5.5	na	7.1	na
avg	**5.5**	**na**	**7.1**	**na**
2011	**Top**	**Bottom**	**Top**	**Bottom**
Summer	na	na	na	na
Fall	6.6	na	6.3	na
avg	**6.6**	**na**	**6.3**	**na**
2014	**Top**	**Bottom**	**Top**	**Bottom**
Summer	**12.4**	**na**	**14.4**	**na**
Fall	**13.7**	**na**	**11.4**	**na**
avg	**13.1**	**na**	**12.9**	**na**

Sediment Phosphorus (mg/kg)	
Site #1	**Site #2**
461	445

Chl. A (µg/L)

2011	**Site #1**	**Site #2**
Summer	na	na
Fall	na	na
avg	**na**	**na**
2014	**Site #1**	**Site #2**
Summer	**12.8**	**13.4**
Fall	**3.7**	**10.7**
avg	**8.3**	**12.1**

Secchi (ft.)

Site #1	**Site #2**
na	na
8.2	7.9
8.2	**7.9**
Site #1	**Site #2**
2.6	**2.6**
3.3	**3.3**
3.0	**3.0**

Figure 5. Water quality sampling sites on Ruth Lake, 2014.

Figure 6a. Hydrolab Profiles for Ruth Lake Sampling Sites 1 and 2 on June 10, 2014.

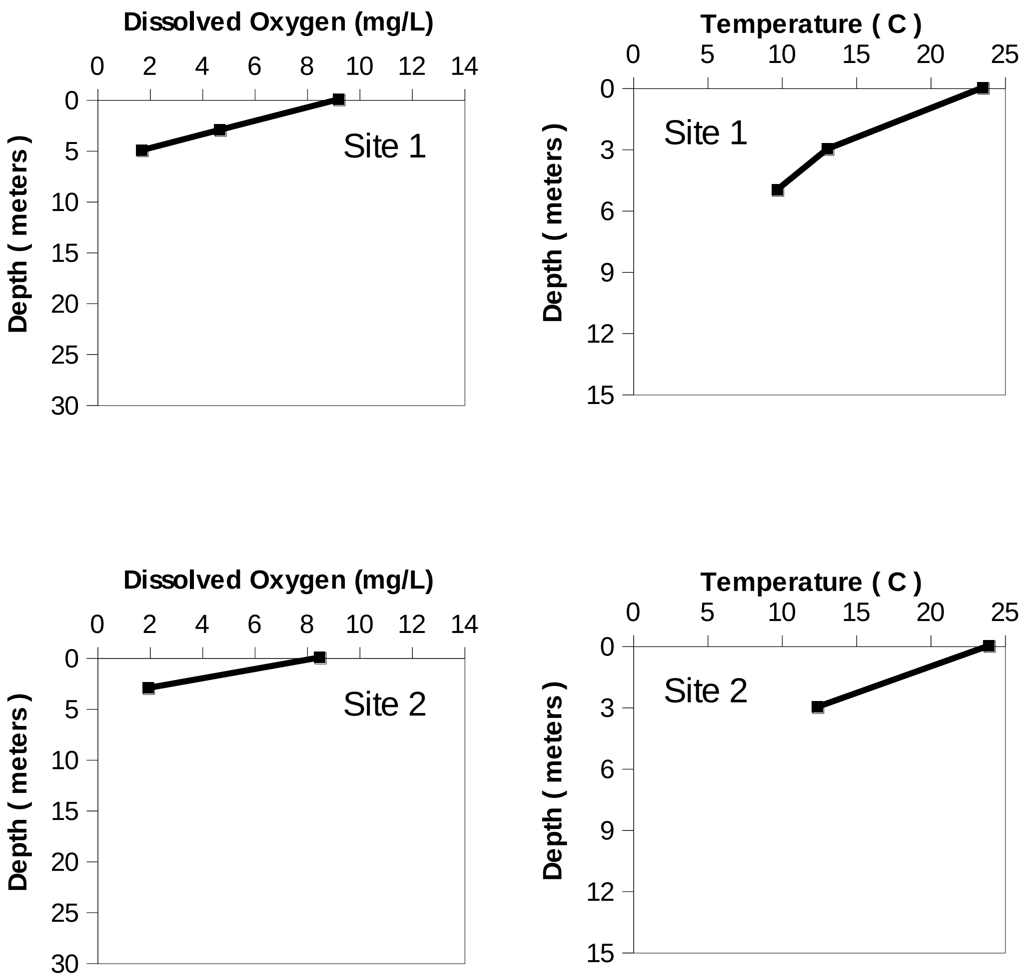
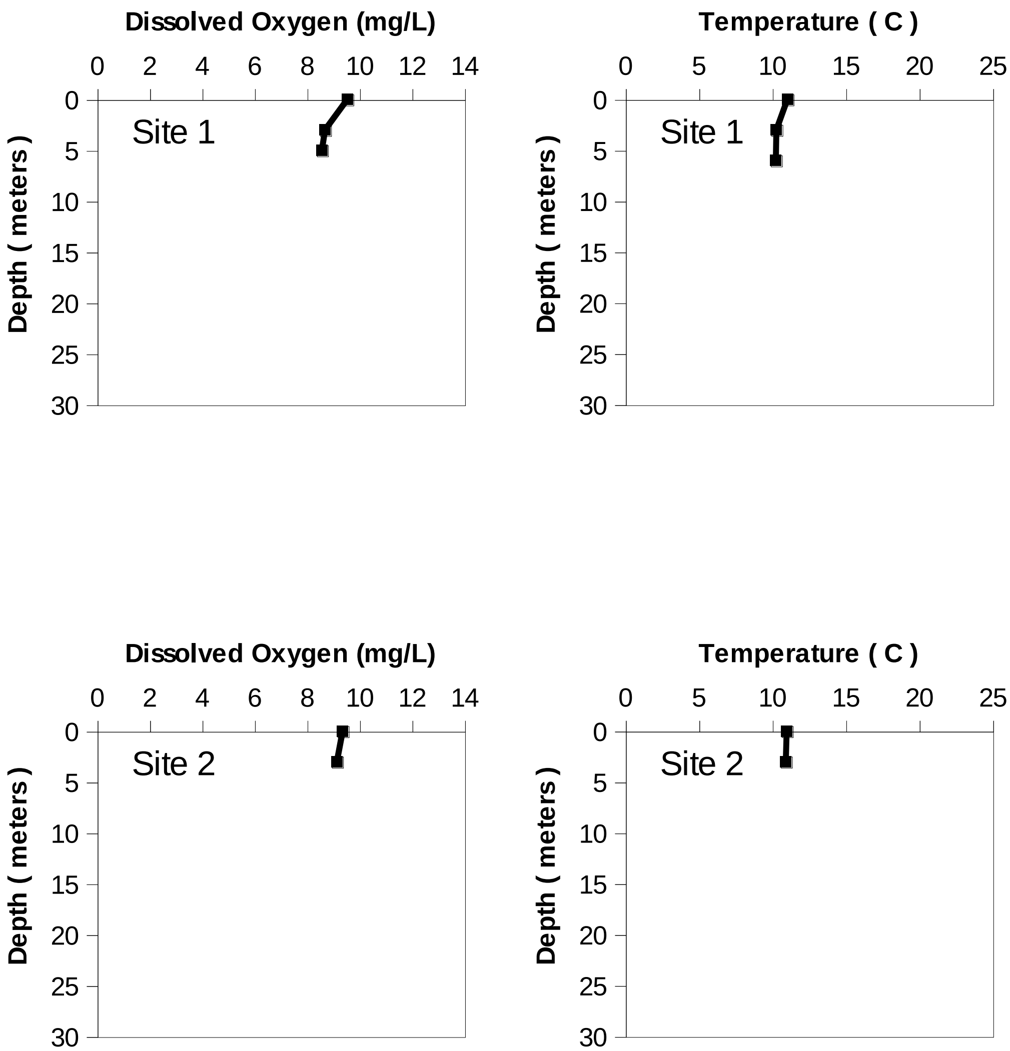


Figure 6b. Hydrolab Profiles for Ruth Lake Sampling Sites 1 and 2 on October 10, 2014.



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