January 12, 2017

Kirk Mackey
Twin and Walker Creek Watershed Association
875 Twin Lakes Road
Shohola, PA 18458

RE: Twin and Walker Creek Watershed Monitoring Program
2016 Water Quality Monitoring Final Report
FXB File No. PA1551-15

Dear Kirk:

The purpose of this letter is to present results of the 2016 Twin and Walker Creek Watershed Monitoring Program. The primary purpose of the monitoring program is to characterize the trophic state within Big Twin Lake, Little Twin Lake, and Walker Lake based on measurements of Secchi depth, total phosphorus, and chlorophyll a. The monitoring program consisted of volunteers from the Twin and Walker Creek Watershed Association collecting lake samples from the photic zone of Big Twin Lake, Little Twin Lake, and Walker Lake and measuring the Secchi depth on four occasions during the 2016 growing season. QC Laboratories performed the total phosphorus and chlorophyll a laboratory analysis, and F. X. Browne, Inc. analyzed all the 2016 lake monitoring data and prepared this report. In 2016, QC Labs went through a reorganization and merger with another laboratory. In the midst of this reorganization, QC Labs did not use the total phosphorus methodology with a very low detection limit as they had used in the past. The result is that many of the total phosphorus results were reported as less than a specific value, rather than a lower value. The total phosphorus results, therefore, are not representative of past years. These higher detection limits provide a higher Trophic State Index for each lake. It does not affect our evaluation of the trophic state of each lake since, in reality, the chlorophyll TSI is more important since it reflects the amount of algae in each lake. QC Labs has indicated that they will be using the appropriate total phosphorus methodology in their 2017 analyses.

Results

Table 1 presents the 2016 raw data, the seasonal average concentrations for each parameter for each lake, the standard deviation, and the seasonal Carlson Trophic State Indices for each parameter for each lake. The significance of these results is described in the following sections. In all cases, confidence interval (±) is expressed as twice the standard deviation, equivalent to approximately a 95% confidence interval.

Table 1. 2016 Twin and Walker Creek Watershed Monitoring Program Lake Monitoring Results					
Waterbody Name	***Date Collected***		***Total Phosphorus (mg/l)***	***Chlorophyll a (mg/l)***	***Secchi Depth (m)***
Big Twin Lake	6/18/2016		0.014	3.2	3.60
	7/16/2016	<	0.050	2.4	2.40
	8/20/2016	<	0.019	5.3	2.90
	9/17/2016	<	0.019	1.3	1.95
Average			***0.025***	***3.0***	***2.71***
Standard deviation			***0.017***	***1.7***	***0.71***
Trophic State Index			***51***	***42***	***46***
Little Twin Lake	6/18/2016		0.029	1.7	5.40
	7/16/2016	<	0.050	4.2	4.70
	8/20/2016	<	0.019	3.6	5.40
	9/17/2016	<	0.019	0.3	3.20
Average			***0.029***	***2.5***	***4.68***
Standard deviation			***0.015***	***1.8***	***1.04***
Trophic State Index			***53***	***39***	***38***
Walker Lake	6/19/2016		0.025	6.8	2.20
	7/17/2016	<	0.050	6.6	1.30
	8/20/2016	<	0.019	5.9	1.70
	9/17/2016	<	0.019	0.6	1.50
Average			***0.028***	***5.0***	***1.68***
Standard deviation			***0.015***	***2.9***	***0.39***
Trophic State Index			***52***	***46***	***53***

Phosphorus

Phosphorus is one of the three main nutrients of life, along with nitrogen and carbon. In the northeast United States, it is the nutrient that most often controls productivity of lake systems. Total phosphorus is a measure of all forms of phosphorus, both organic and inorganic. Total phosphorus concentrations are directly related to the trophic condition (water quality status) of a lake. Excessive amounts of phosphorus lead to algae blooms and loss of oxygen in lakes. Epilimnetic (surface water) total phosphorus concentrations less than 10 micrograms per liter (µg/L)/0.010 milligrams per liter (mg/L) are associated with oligotrophic (clean, clear water) conditions and concentrations greater than 25 µg/L (0.025 mg/L) are associated with eutrophic (nutrient-rich) conditions.

The average surface water total phosphorus concentrations during 2016 were similar for all three lakes. The average concentration was highest in Little Twin Lake (0.029 mg/L ± 0.015) and lowest in Big Twin Lake (0.025 mg/L ± 0.017). The average total phosphorus concentration in Walker Lake was 0.028 mg/L ± 0.015 mg/L. It is important to note that only the data from June were above the laboratory's detection limits; all others were below the limits, which had changed after the June sampling date. Therefore, there is only one data point that changed between all three lakes. Big Twin Lake exhibited the lowest concentration of total phosphorus, at 0.014 mg/L. Little Twin Lake exhibited the highest concentration, at 0.029 mg/L. Based on total phosphorus concentrations, all three lakes were classified as eutrophic in 2016 according to EPA trophic state criteria, although they were only slightly eutrophic. It is possible that the lakes could have been in the mesotrophic or even oligotrophic range; however, the detection limits were too high to accurately determine this.

Chlorophyll a

Chlorophyll a is the green pigment in plants used for photosynthesis, and measuring it provides information on the amount of algae (microscopic plants) in lakes. Chlorophyll a concentrations can also be used to classify lake trophic state. Concentrations less than 2 micrograms per liter (µg/L) are associated with oligotrophic conditions, while concentrations greater than 7-10 µg/L are associated with eutrophic conditions.

As in 2015, the average chlorophyll a concentration was highest in Walker Lake (5.0 mg/L ± 2.9) and lowest in Little Twin Lake (2.5 mg/L ± 1.8). The average chlorophyll a concentration in Big Twin Lake was 3.0 mg/L ± 1.7 mg/L. Therefore, based on chlorophyll a concentrations, Walker and Big Twin Lakes were classified as mesotrophic during 2016, and Little Twin Lake was classified as oligotrophic. Chlorophyll a concentrations were slightly lower in all three lakes in 2016 compared to 2015.

Transparency

Transparency is a measure of water clarity in lakes and ponds. It is determined by lowering a 20 cm black and white disk (Secchi disk) into a lake to the depth at which it is no longer visible from the surface. Since algae are the main determinant of water clarity in non-stained lakes that lack excessive amounts of inorganic turbidity (suspended silt), transparency is used as an indicator of lake trophic state. Transparencies greater than 4.6 meters (15.1 feet) are associated with oligotrophic conditions, while transparencies less than 2 meters (6.6 feet) are associated with eutrophic conditions.

As in 2015, the average Secchi disk transparency was highest (most favorable) in Little Twin Lake (4.68 m ± 1.04), and lowest at Walker Lake (1.68 m ± 0.39). The average Secchi disk transparency was 2.71 m ± 0.71 m in Big Twin Lake. Therefore, based on Secchi disk transparency, Little Twin Lake was classified as oligotrophic, and Big Twin Lake was classified as mesotrophic, and Walker Lake was classified as eutrophic during 2016. Transparencies increased (improved) slightly in all three lakes compared to 2015.

Trophic State

Trophic state is a term that describes the biomass of algae and macrophytes (aquatic plants) found in a lake. *Oligotrophic* lakes have few algae and macrophytes and appear clean and clear, while *eutrophic* lakes show an overabundance of plant life and often have a pronounced green color due to algae. A more holistic approach to defining trophic state looks at the nutrient concentrations, water transparency, types of algae and macrophytes present, thermal dynamics, and dissolved oxygen dynamics.

The Carlson (1977) Trophic State Index (TSI) is the main index used in evaluating the trophic state of a lake. This index is calculated on a scale from 1 to 100 using summer or warm weather average values for total phosphorus, chlorophyll a, and Secchi Disk transparency. The 2016 TSI values for each lake are shown in Table 1. Figures 1, 2, and 3 compare trophic state indices for 2016 with those calculated for previous years. The trend over the years is as follows:

1. The total phosphorus TSI was in the mesotrophic range for Big Twin and Little Twin Lakes for most of the years 2002 through 2016; it was in the eutrophic range in past years for Walker Lake, but it has been in the mesotrophic-eutrophic range for the past 7 years.
2. The chlorophyll TSI was in the mesotrophic range for Big Twin and Little Twin Lakes from 2002 through 2016; it was in the eutrophic range in past years for Walker Lake, but it has been in the mesotrophic-eutrophic range for the past 4 years
3. The Secchi Dish transparency TSI was in the mesotrophic range from 1983 through2016 for Big Twin and Little Twin Lakes; it was mostly in the eutrophic ranged for Walker Lake from 1983 through 2016.

Dissolved Oxygen and Temperature

In late spring or the beginning of summer, temperate lakes develop stratified layers of water, with warmer water near the lake's surface (epilimnion) and colder water near the lake's bottom (hypolimnion). As the temperature difference becomes greater between these two water layers, the resistance to mixing increases. Under these circumstances, the epilimnion (top water) is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion (bottom water) may become depleted of oxygen due to oxygen being consumed by organisms decomposing organic matter at the lake bottom.

Figure 1. Comparison of Phosphorus-Based Trophic State Index 2002-2016 for Big Twin Lake, Little Twin Lake, and Walker Lake

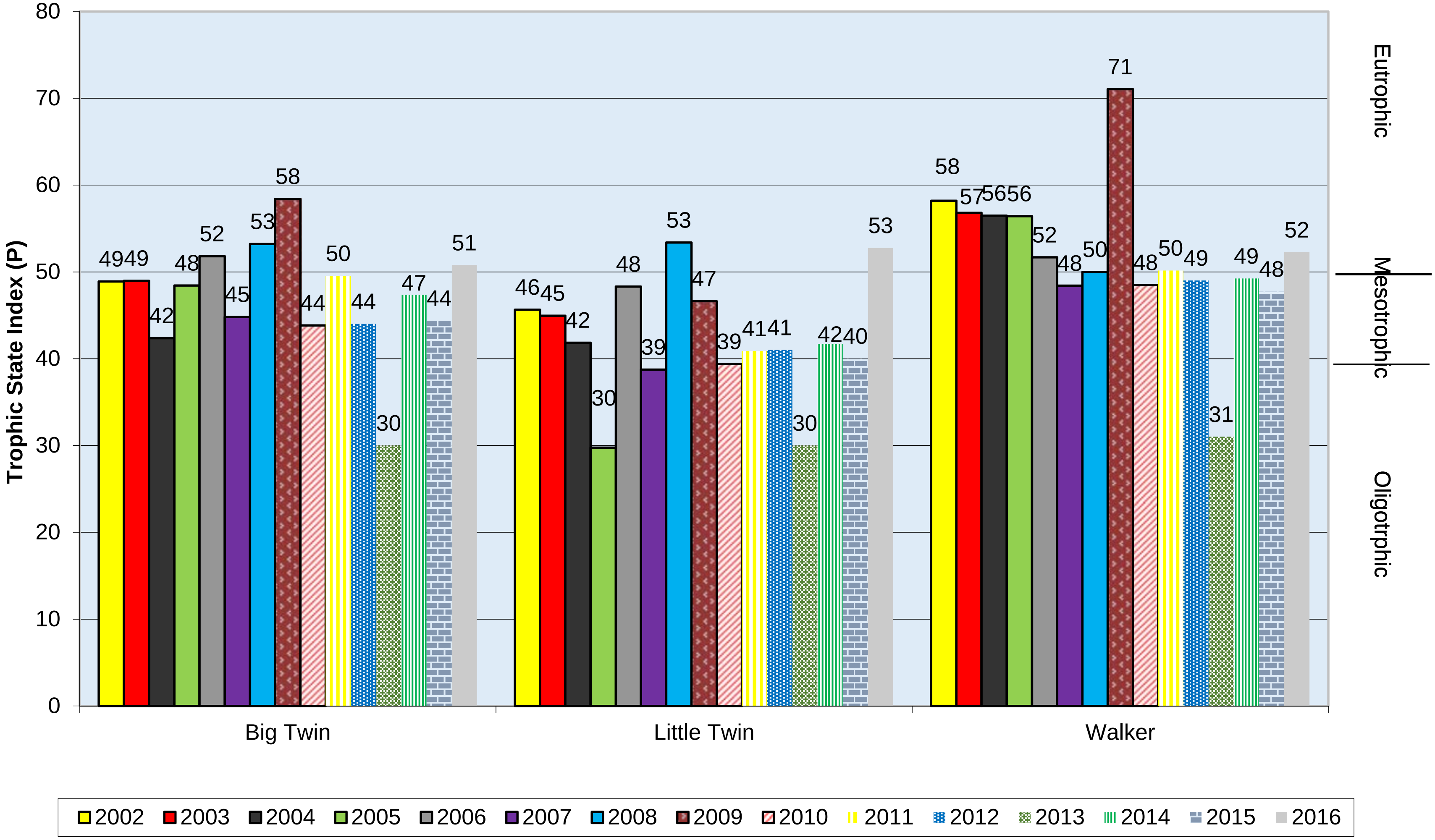


Figure 2. Comparison of Chlorophyll a - Based Trophic State Index 2002-2016 for Big Twin Lake, Little Twin Lake, and Walker Lake

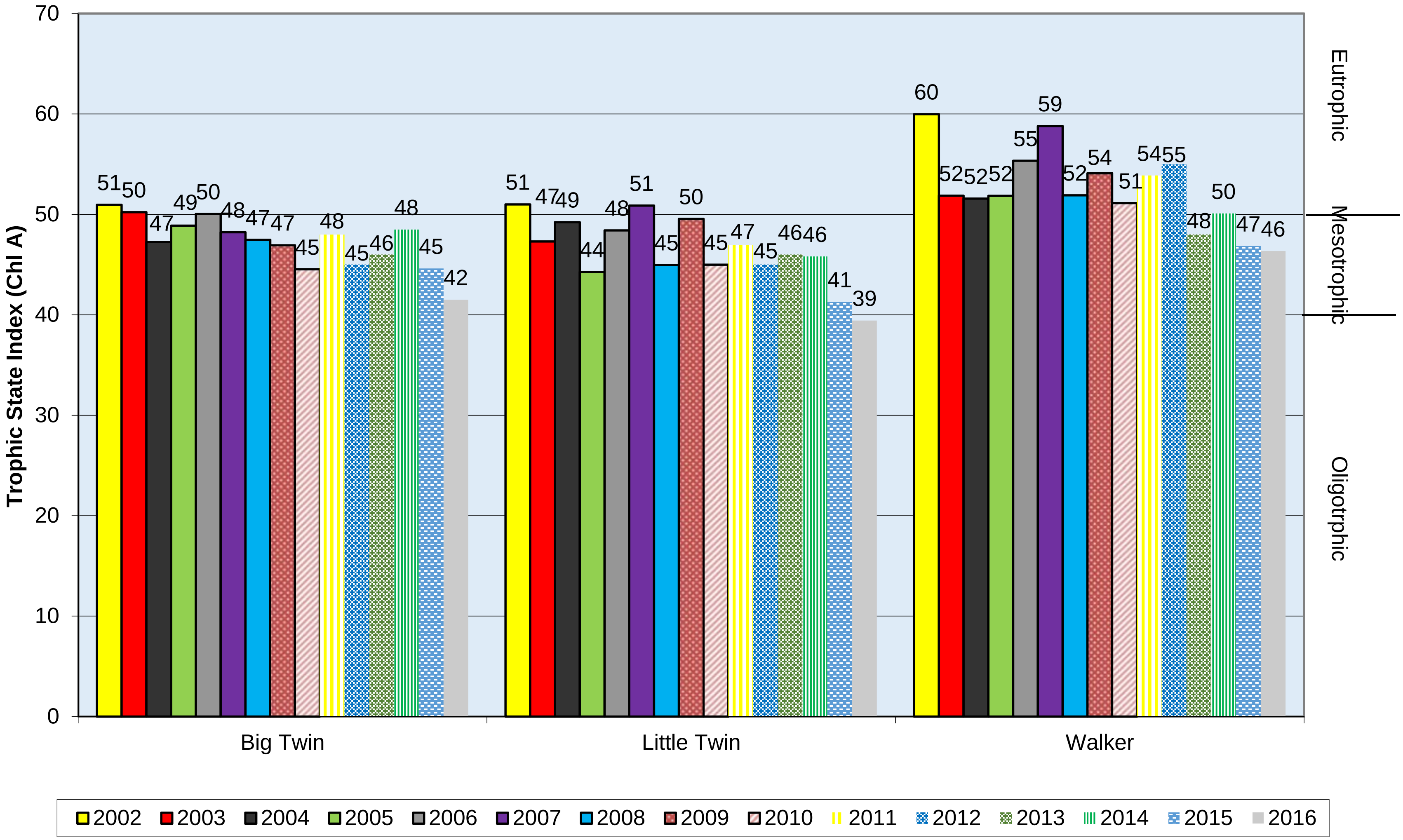
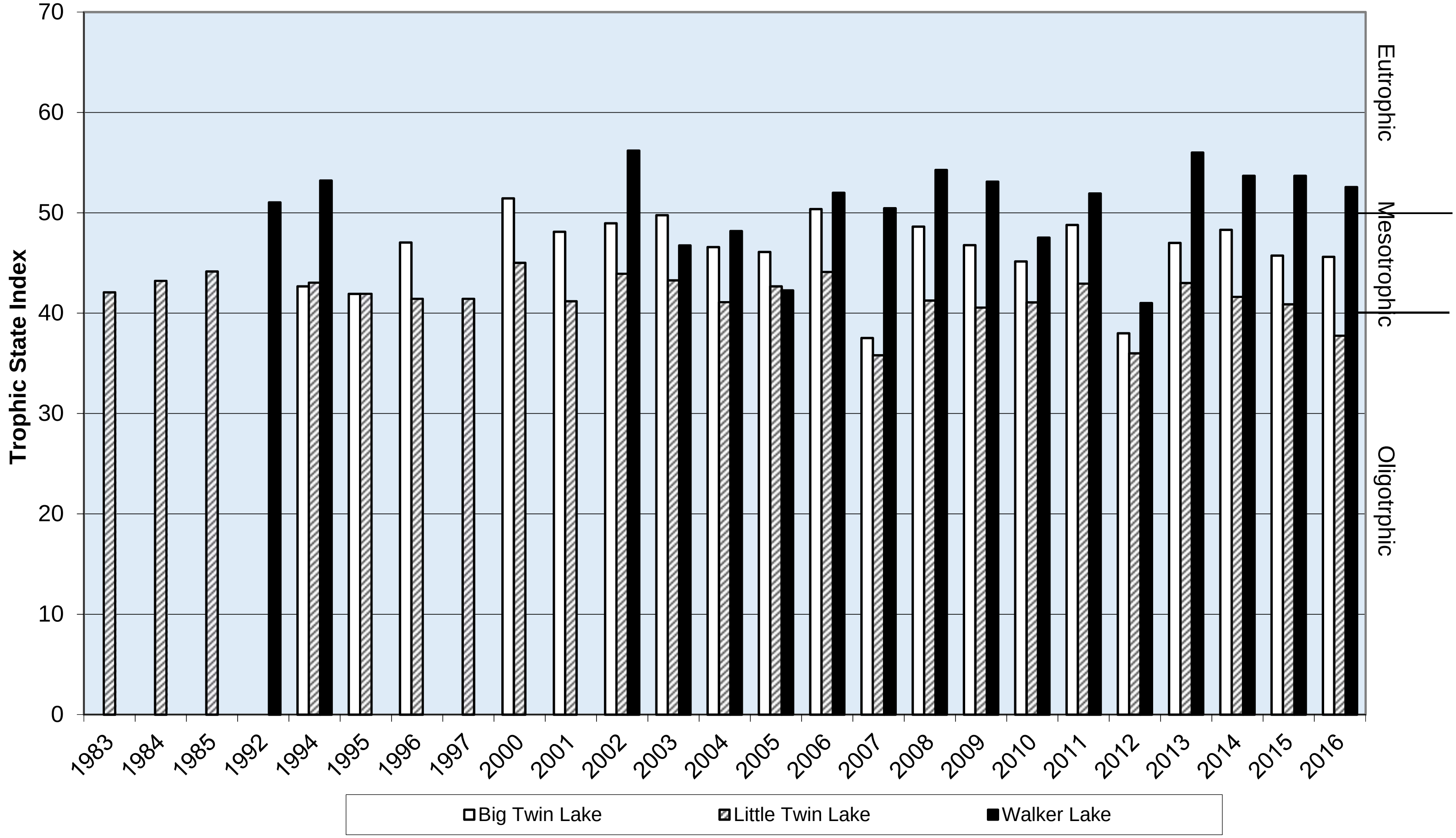


Figure 3. Comparison of Secchi Depth-Based Trophic State Index for Big Twin Lake, Little Twin Lake, and Walker Lake 1983-2016



Conversely, shallow temperate lakes may never develop stratified layers of water. For these shallow lake systems, wave action caused by the wind may be sufficient to keep the entire lake completely mixed for most of the year. In shallow lakes, low dissolved oxygen levels may occur above the lake sediments even though most of the water in the lake is completely mixed. Both shallow and deep temperate lakes can have low dissolved oxygen concentrations near the surface of the lake sediments. If low dissolved oxygen levels occur near the lake bottom, sediments may release significant amounts of nutrients (primarily orthophosphorus and ammonium) back into the lake, thereby allowing for more nutrients for algae and aquatic plant growth.

In general, the optimal water temperature for trout is 55 to 60ºF (12.8 to 15.6ºC). Trout may withstand water temperatures above 80ºF (26.7ºC) for several hours, but if water temperatures exceed 75ºF (23.9ºC) for extended periods, trout mortality is expected (Pennsylvania State University). A safe minimum dissolved oxygen concentration for trout is 5 mg/L. Warm water species (i.e. golden shiners, bass, bluegill) grow well when water temperatures exceed 80ºF (26.7ºC). For many warm water fish species, 3 mg/L is considered a safe minimum dissolved oxygen concentration.

In 2016, volunteers measured profiles of dissolved oxygen and temperature on each of the sampling dates. The dissolved oxygen and temperature profiles for all three lakes are included in Table 2 and Figures 4 and 5.

During the 2016 growing season, the following observations can be made with respect to dissolved oxygen and temperature readings:

- All three lakes were thermally stratified during the summer months of June through September.
- Big Twin Lake exhibited a temperature difference between the surface and bottom that ranged from 7.15 °C (September) to 14.1°C (August)
- Little Twin Lake exhibited a temperature difference between the surface and bottom that ranged from 8.8°C (September) to 14°C (July).
- Walker Lake exhibited a temperature difference between the surface and bottom that ranged from 11.5°C (September) to 18.6°C (August).
- Maximum temperatures were highest in August in all three lakes, at 27.2°C in Big Twin Lake, 27ºC in Little Twin Lake, and 28.4°C in Walker Lake.
- During 2016, the temperatures in all three lakes was very similar to the temperatures in 2015. Temperature was not measured in August 2015.
- Big Twin Lake and Walker Lake exhibited oxygen depletion in the bottom waters. Oxygen depletion in Walker Lake has been significant and well defined for several years. Oxygen levels quickly decrease to less than 2 mg/L at a depth of around 5.0 meters in Big Twin Lake, and at about 3.5 meters in Walker Lake. A lake aeration system for Walker Lake may be a good option to eliminate the oxygen depletion problem and improve the overall water quality of the lake. Little Twin Lake was well oxygenated throughout the water column and exhibited higher oxygen concentrations at mid-depths, which occurs in some oligotrophic and mesotrophic lakes when phytoplankton at mid-depths produce extra oxygen.

Table 2 - Chemical Profiles in Twin Lake, Little Twin Lake, and Walker Lake for 2014

Twin Lake 6/18/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	22.00	74.7	8.98	7.24	48.750
1.0	21.50	74.6	8.89	7.20	48.750
1.5	21.30	74.6	8.78	7.06	48.750
2.0	21.20	74.5	9.87	7.07	48.750
2.5	19.70	74.3	9.48	7.10	48.100
3.0	18.80	74.1	9.24	7.03	48.100
3.5	18.60	74.1	9.49	6.86	48.100
4.0	18.20	74.1	8.74	6.72	48.100
4.5	17.80	74.2	8.65	6.62	48.100
5.0	17.10	74.6	7.48	6.50	48.100
5.5	15.90	74.7	6.27	6.40	48.750
6.0	13.80	75.4	5.19	6.38	48.750
6.5	12.20	75.2	4.41	6.50	48.750
7.0	12.10	75.5	4.40	6.68	48.750
7.5					

Twin Lake 7/16/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	26.40	76.7	8.10	7.75	50.050
1.0	25.60	76.7	8.16	7.73	50.050
1.5	25.40	76.5	8.48	7.70	50.050
2.0	25.00	76.5	8.09	7.69	50.050
2.5	24.80	76.5	7.13	7.59	50.050
3.0	24.60	76.5	7.21	7.51	50.050
3.5	24.30	76.4	7.58	7.44	49.400
4.0	22.00	76.3	5.98	6.92	49.400
4.5	20.20	76.4	4.32	6.65	49.400
5.0	18.20	76.1	2.75	6.43	49.400
5.5	16.30	77.4	1.36	6.31	50.050
6.0	15.00	80	0.69	6.30	52.000
6.5	14.00	79.7	0.71	6.24	52.000
7.0	13.50	81.3	0.47	6.24	52.300
7.5	13.10	80.8	0.47	6.19	52.650

Twin Lake 8/20/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	27.20	75.8	7.82	7.95	49.400
1.0	26.80	75.5	7.40	7.59	49.400
1.5	26.40	75.4	7.60	7.57	48.750
2.0	26.20	75.4	7.60	7.54	48.750
2.5	26.00	75.4	7.30	7.42	48.750
3.0	26.00	75.3	6.50	7.23	48.750
3.5	25.70	75.4	6.00	6.87	48.750
4.0	25.10	75.5	3.70	6.43	48.750
4.5	23.00	75	0.08	6.03	48.750
5.0	20.50	85.5	0.03	6.25	55.250
5.5	18.40	86.5	0.03	6.26	55.600
6.0	16.40	87.4	0.02	6.28	57.200
6.5	14.90	89.9	0.02	6.32	58.500
7.0	14.00	91.2	0.08	6.36	59.150
7.5	13.10	93.9	0.04	6.41	61.100

Twin Lake 9/17/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	21.90	76.7	7.05	6.97	50.050
1.0	21.90	76.7	7.01	6.89	50.050
1.5	21.80	76.6	7.11	7.00	50.050
2.0	21.80	76.6	7.01	7.01	50.050
2.5	21.80	76.6	7.20	7.03	50.050
3.0	21.80	76.6	6.80	7.05	50.050
3.5	21.80	76.6	7.03	7.08	50.050
4.0	21.70	76.6	6.90	7.09	50.050
4.5	21.70	76.7	6.65	7.10	50.000
5.0	21.55	76.8	6.46	6.94	50.050
5.5	20.10	88.05	1.45	6.80	57.525
6.0	17.55	97.8	0.43	6.91	63.700
6.5	15.50	100.4	0.40	7.01	65.000
7.0	14.75	101.6	0.59	7.19	66.300
7.5					

Little Twin Lake 6/18/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	21.00	149.5	8.40	7.45	97.500
1.0	21.00	149.5	8.56	7.45	97.500
1.5	20.90	149.5	8.91	7.42	96.850
2.0	20.80	149.4	8.20	7.42	96.800
2.5	20.70	149.4	8.23	7.41	96.850
3.0	20.30	149.2	8.83	7.39	96.850
3.5	20.10	149.3	8.55	7.33	96.850
4.0	19.70	149	8.84	7.35	96.800
4.5	18.70	149	8.66	7.32	96.850
5.0	16.30	148.5	10.15	7.29	96.850
5.5	14.50	146.7	10.80	7.19	95.550
6.0	13.30	148	11.12	7.13	96.200
6.5	12.40	147.7	10.45	7.06	96.300
7.0	11.30	148.2	9.17	7.03	96.200
7.5	10.50	148.8	8.91	7.14	96.850

Little Twin Lake 7/16/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	25.70	151	6.70	7.84	98.150
1.0	25.60	151	6.80	7.78	98.150
1.5	25.60	151	6.25	7.71	98.150
2.0	25.60	151	6.50	7.66	98.150
2.5	25.50	151	6.55	7.62	98.150
3.0	25.20	150.6	7.15	7.59	98.150
3.5	24.40	150.6	6.35	7.57	98.150
4.0	24.40	150.6	6.35	7.53	98.150
4.5	22.50	150.6	8.55	7.42	98.150
5.0	20.60	150.2	9.40	7.35	98.150
5.5	18.70	149.9	9.70	7.30	97.500
6.0	16.20	150.7	10.30	7.25	97.500
6.5	14.30	149.3	10.25	7.26	96.850
7.0	12.80	149.5	8.07	7.12	96.850
7.5	11.70	149.7	8.55	6.96	97.500

Little Twin Lake 8/20/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	27.00	150.9	7.07	8.66	98.150
1.0	26.80	147.4	7.5	8.49	95.600
1.5	26.80	147.7	7.40	8.31	96.200
2.0	26.80	147.3	7.40	8.20	95.550
2.5	26.80	147.3	7.30	8.13	95.550
3.0	26.80	147.4	7.45	8.04	95.550
3.5	26.70	147.5	7.14	7.97	95.200
4.0	26.70	148.3	7.47	7.91	96.200
4.5	26.00	149.2	7.50	7.82	96.850
5.0	25.30	151.2	5.15	7.58	98.150
5.5	21.80	153	2.67	7.14	99.450
6.0	21.10	151.4	3.50	6.95	98.150
6.5	19.50	153.4	3.52	6.85	99.450
7.0	16.00	152.5	3.52	6.78	98.800
7.5	14.50	151.4	4.21	6.72	98.150

Little Twin Lake 9/17/2016

z	temp	cond	DO	pH	TDS (g/L)
0.5	22.60	149.5	7.14	6.99	96.850
1.0	22.50	149.4	7.10	6.98	96.850
1.5	22.50	149.4	7.15	6.98	96.850
2.0	22.50	149.4	7.05	6.97	96.850
2.5	22.50	149.4	6.95	6.96	96.850
3.0	22.40	149.3	6.80	6.95	96.850
3.5	22.40	149.3	7.00	6.93	96.850
4.0	22.30	149.3	6.50	6.87	96.850
4.5	20.50	148.9	5.50	6.84	96.850
5.0	18.80	150.1	0.09	6.62	97.500
5.5	16.30	154	0.10	6.71	101.100
6.0	14.80	155.4	0.10	6.83	101.400
6.5	14.80	157.9	0.11	6.93	102.700
7.0	13.80	156	0.30	7.07	101.400
7.5					

Walker Lake	6/19/2016				
z	temp	cond	DO	pH	TDS (g/L)
0.5	23.20	74	8.07	7.95	48.100
1.0	22.70	73.8	8.79	7.60	48.100
1.5	22.30	74	8.51	7.51	48.100
2.0	22.00	74.2	7.91	7.37	48.100
2.5	21.30	72.6	7.57	7.28	47.450
3.0	19.20	71.5	7.42	6.93	46.150
3.5	16.60	69.5	5.64	6.44	44.850
4.0	14.10	68.7	3.19	6.21	44.850
4.5	12.00	71.2	0.52	6.04	46.150
5.0	10.60	73.5	0.40	6.03	47.450
5.5	9.60	80.9	0.46	6.07	52.650
6.0	8.90	116.1	0.03	6.25	75.400
6.5					

Walker Lake	7/17/2016				
z	temp	cond	DO	pH	TDS (g/L)
0.5	27.00	79.9	7.48	7.88	52.000
1.0	26.70	79.7	8.06	7.81	52.000
1.5	26.20	79.3	6.83	7.68	51.350
2.0	24.80	78.9	5.48	7.26	51.350
2.5	22.70	79.2	2.61	6.54	51.350
3.0	19.90	76	0.63	6.28	49.400
3.5	16.50	74.1	0.18	6.19	48.100
4.0	14.50	71.5	0.15	6.11	46.150
4.5	12.90	73.6	0.08	6.09	48.100
5.0	10.90	81.5	0.05	6.17	53.950
5.5	9.60	114.7	0.05	6.35	74.750
6.0	9.10	159	0.03	6.53	104.000
6.5					

Walker Lake	8/20/2016				
z	temp	cond	DO	pH	TDS (g/L)
0.5	28.40	74.6	6.40	7.74	48.750
1.0	27.50	74.6	7.44	7.28	48.750
1.5	26.70	74.6	6.60	7.15	48.750
2.0	26.30	74.5	5.81	6.90	48.750
2.5	25.30	74.4	2.76	6.55	48.100
3.0	22.00	72.6	0.77	6.28	47.450
3.5	18.90	73.8	0.50	6.19	48.100
4.0	16.30	73.3	2.00	6.20	47.775
4.5	13.50	82.4	0.28	6.22	53.300
5.0	12.00	106.7	0.36	6.32	69.550
5.5	10.80	146.9	0.13	6.52	95.550
6.0	9.90	193	0.06	6.73	125.450
6.5	9.80	306.7	0.03	6.84	161.850

Walker Lake	9/17/2016				
z	temp	cond	DO	pH	TDS (g/L)
0.5	22.00	76.7	8.09	8.10	50.050
1.0	22.00	76.7	7.60	7.86	50.050
1.5	21.90	76.7	7.52	7.70	50.050
2.0	21.90	76.7	7.16	7.56	50.050
2.5	21.10	76.6	6.42	7.40	50.050
3.0	20.30	75.6	4.90	7.12	49.400
3.5	18.50	74.5	2.56	6.70	48.100
4.0	15.30	87.4	0.41	6.59	56.550
4.5	13.00	122.1	0.16	6.67	79.300
5.0	11.60	164.6	0.08	6.73	107.250
5.5	10.90	213.3	0.07	6.91	141.050
6.0	10.50	270.5	0.04	7.07	176.150
6.5	10.50	275.9	0.05	7.14	180.050

Figure 4. Temperature Profiles in 2015 for Big Twin Lake, Little Twin Lake and Walker Lake

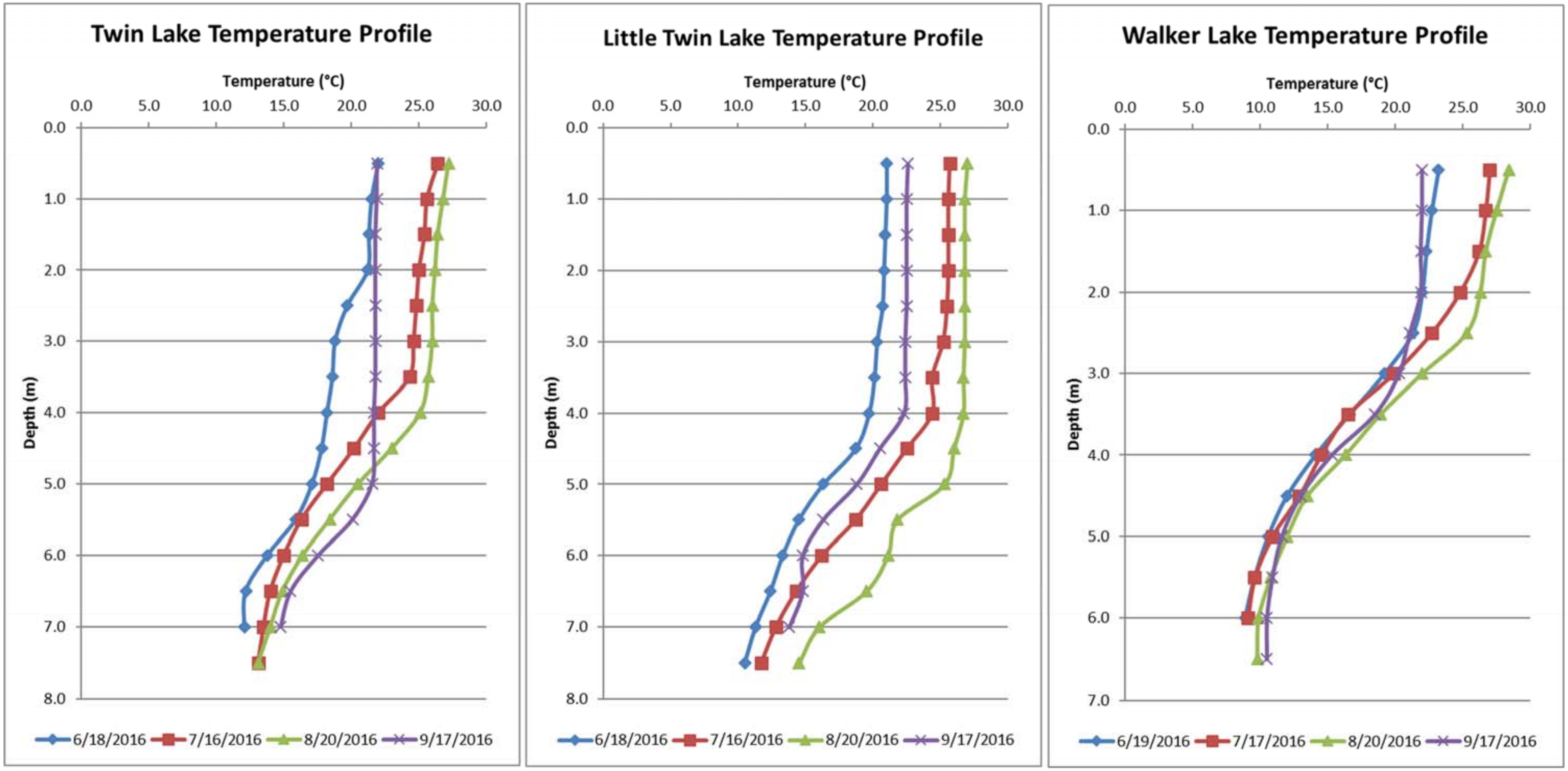
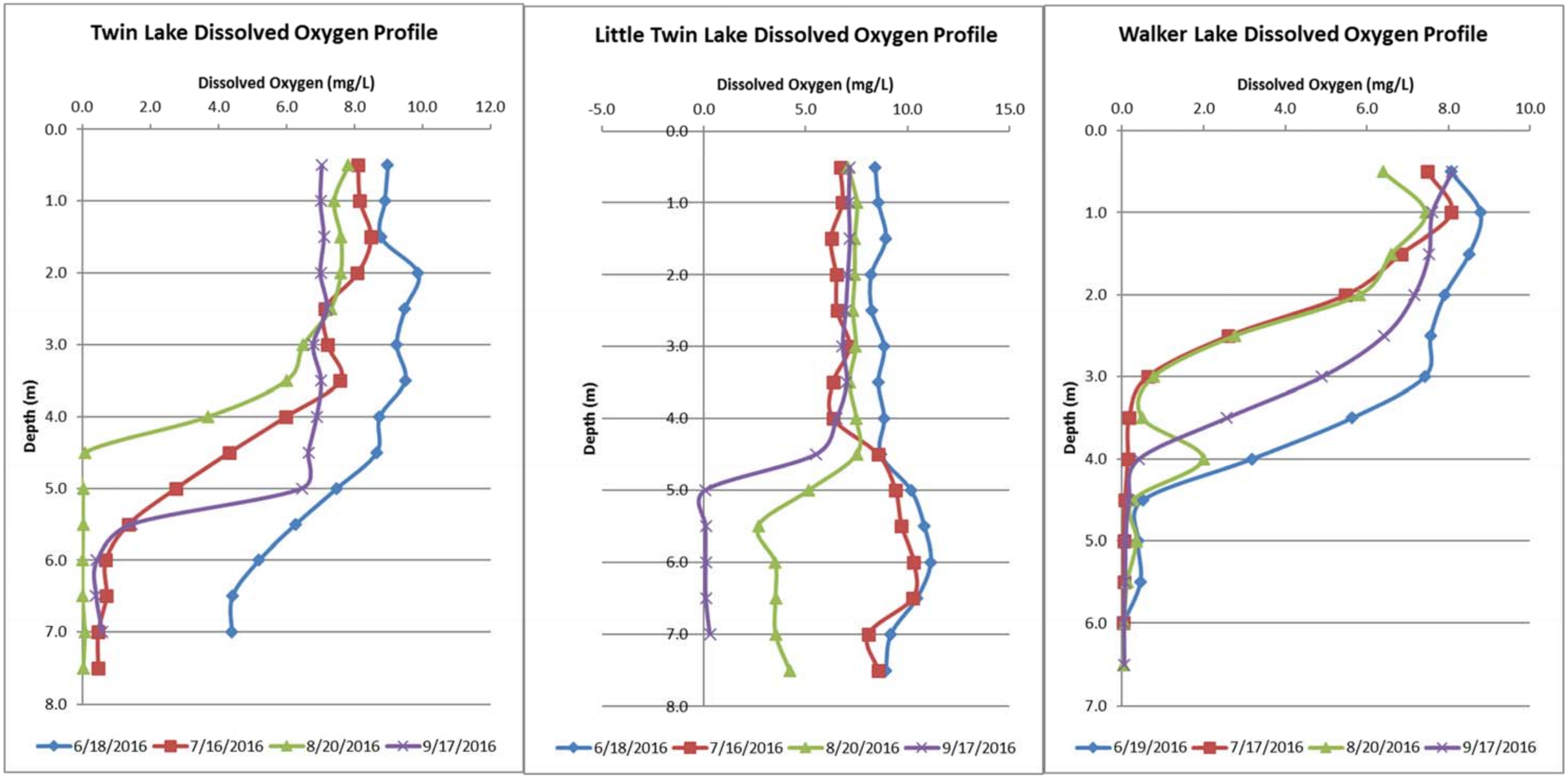


Figure 5. Dissolved Oxygen Profiles in 2015 for Big Twin Lake, Little Twin Lake and Walker Lake



pH and Conductivity

The acidity of water (concentration of hydrogen ions in water) is measured as pH and reported in standard units on a logarithmic scale that ranges from one to fourteen. Each pH unit represents a thousand-fold change in the free hydrogen ion concentration. On the pH scale, seven is neutral, lower numbers are more acidic, and higher numbers are more basic. Factors that can significantly affect the pH in a lake include the mineral composition of the surrounding watershed soils and the amount of algal growth occurring in the lake. Intense algal growth can drastically lower carbon dioxide concentrations in the water, which causes a rise in pH and alkalinity. In general, pH values between 6.0 and 8.0 are considered optimal for the maintenance of a healthy lake ecosystem. Many species of fish and amphibians have difficulty with growth and reproduction when pH levels fall below 5.5 standard units (s.u.). In almost all lakes, pH tends to be somewhat lower within the bottom waters due to carbon dioxide released by bacterial decomposition.

The pH values were similar in all lakes and ranged from 7.2 s.u. to 6.74 s.u. in Walker Lake, 7.83 s.u. to 6.9 s.u. in Little Twin Lake, and 7.0 s.u. to 6.81 s.u. in Big Twin Lake.

Conductivity (or specific conductance) is a measure of the ability of water to conduct electric current, and is related to the amount of dissolved ions within the water. Higher conductivity values are indicative of pollution by road salt or septic systems and more eutrophic conditions in a lake. Conductivities may be naturally elevated in stained water that drains from swamps and marshes. Clean, clear-water lakes typically have conductivities of around 20 to 30 micro-mhos per centimeter (µmhos/cm) while lakes in developed areas tend to have conductivities between 50 and 150 µmhos/cm.

On average, Little Twin lake had the highest surface conductivity, at 150.23 µmhos/cm, and Big Twin Lake had the lowest surface conductivity, at 75.98 µmhos/cm. Walker had a surface conductivity of 76.3 µmhos/cm. Walker had the highest bottom conductivity, at 291.3 µmhos/cm, and Big Twin had the lowest, at 87.35 µmhos/cm. Little Twin Lake had an average bottom conductivity of 149.97 µmhos/cm. All surface and bottom conductivity values are slightly higher than in previous years.

Big Twin Lake

Big Twin Lake can be classified as mesotrophic with respect to chlorophyll a and transparency during 2016, but can be classified as eutrophic with respect to total phosphorus. It is, however, likely that the total phosphorus concentrations were lower than reported due to the erroneously high laboratory minimum detection limits. Overall, conditions were similar to the past few years. Based upon oxygen and temperature profiles, Big Twin Lake would not be able to sustain a cold-water fishery for most of the summer, but warm-water fish should do well within the lake. The pH level of the lake was excellent. Conductivity levels are relatively low and are the lowest of all lakes. The water quality in Big Twin Lake was better in 2016 compared to 2015.

Little Twin Lake

Little Twin Lake was oligotrophic with respect to chlorophyll a and Secchi disk transparency during 2016, but was classified as eutrophic with respect to total phosphorus. Again, the phosphorus levels are likely erroneously high. Little Twin continued to have the best water quality of the three lakes. All three trophic state indicators (total phosphorus, chlorophyll a, and Secchi disk transparency) have remained relatively constant for the past five years indicating that the water quality in Little Twin Lake is stable. Based upon oxygen and temperature profiles, Little Twin Lake may be capable of supporting a cold-water fishery, especially using the less sensitive cold-water fish, such as brown trout and rainbow trout, but the temperature profiles were warm in shallower depths, and the dissolved oxygen profiles were low in deeper depths. Little Twin did have the lowest average temperature. The pH level of the lake was excellent. The conductivity in Little Twin Lake is almost double that of Big Twin Lake and the shallower depths of Walker Lake; however, the conductivity values are still within normal ranges for lakes located in developed watersheds. Water quality in Little Twin Lake was better in 2016 compared to 2015.

Walker Lake

Walker Lake was mesotrophic based on the chlorophyll a TSI values and eutrophic based on the Secchi depth and total phosphorus TSI values during 2016. Once more, caution should be taken in evaluating the phosphorus levels. Overall, Walker Lake would be classified as meso-eutrophic or borderline eutrophic for 2016. Based upon oxygen and temperature profiles, Walker Lake would not be capable of sustaining a cold-water fishery but warm-water fish should do well within the lake. There is a relatively large anoxic zone in the bottom waters of the lake. Walker Lake may benefit from lake aeration which would aerate the bottom waters of the lake, improve water quality, and increase fish habitat. The pH level of the lake was excellent. Conductivity levels were relatively low and similar to Big Twin Lake, with the exception of the bottom meter of water, in which the levels were almost twice what they were in Little Twin Lake. Water quality in Walker Lake did improve from 2015 to 2016.

Conclusions and Recommendations

In general, Walker Lake had the worst water quality in 2016 while Little Twin Lake had the best water quality in 2016. Water quality has remained relatively stable over the past 5 years, but continues to slightly improve. However, year to year variability indicates the lakes are sensitive to any increase in nutrient inputs. Dissolved oxygen and temperature profiles indicate that Big

Twin Lake and Walker Lake experience oxygen depletion in the bottom waters, while Little Twin Lake does not and may be capable of supporting a cold-water fishery. The oxygen depletion problem is more significant in Walker Lake. Evaluation of an aeration system from Walker Lake is recommend and would include additional dissolved oxygen and temperature monitoring.

Nutrient reduction strategies that reduce the introduction of nutrients into the lakes should be implemented to maintain or reestablish mesotrophic conditions in the Walker Lake watershed. Such strategies include septic system upgrades, diversion and/or treatment of stormwater, and the control of Canada geese populations. An educational program for lakefront property owners should be put in place in order to instruct those homeowners on proper lakefront best management practices for protecting and restoring water quality. This program can include lectures and educational materials on lakefront landscaping, proper use of fertilizer, pet waste management, runoff control, and the identification and management of invasive species.

Thank you again for choosing F. X. Browne, Inc. for your lake consulting needs. We look forward to continuing our work together in the future. If you should have any questions concerning the 2016 report, please contact me at mschoenenberger@fxbrowne.com at any time.

Sincerely,

F. X. Browne, Inc.

By:
Marie Schoenenberger
Engineering Associate

By:
Frank X. Browne, Ph.D., P.E.
President