2018 Lake St. Clair Water Quality Report

Prepared by Thurston County Environmental Health Division

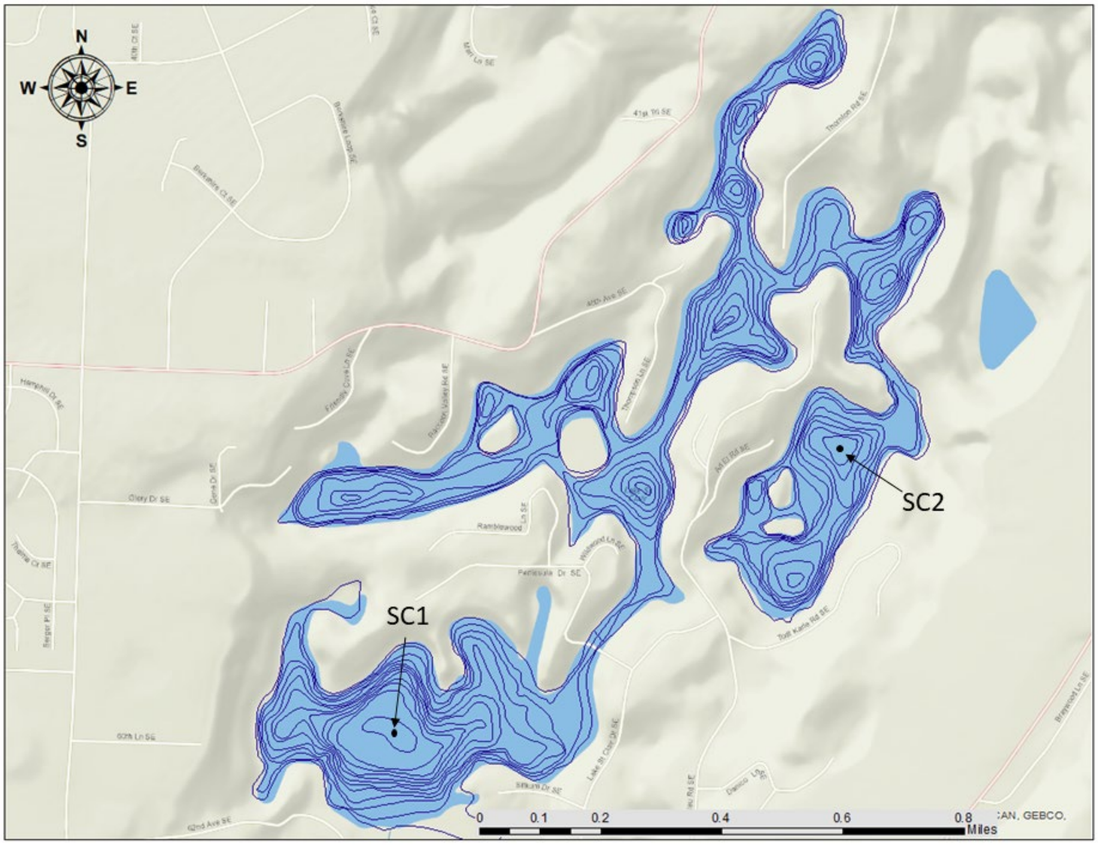


Figure 1. Lake St Clair map showing location of sample sites SC1 and SC2.

NISQUALLY REACH WATERSHED

- **SHORELINE LENGTH**: 10.4 miles
- **LAKE SIZE**: 0.42 square miles (268 acres)
- **BASIN SIZE**: 20.9 square miles
- **MEAN DEPTH**: 10.4 meters (34 feet)
- **MAXIMUM DEPTH**: 33.5 meters (110 feet)
- **VOLUME**: 8,700 acre-feet

PRIMARY LAND USES:
Forestry and agriculture upland, with dense residential development along the shoreline. Some homeowners use the lake as their domestic water source.

PRIMARY LAKE USES:
Lake St. Clair is used for domestic water supply and fishing, boating, swimming and other water sports.

PUBLIC ACCESS:
Washington Department of Fish and Wildlife operates two public boat launches.

GENERAL TOPOGRAPHY:
Lake St Clair is a kettle lake, irregularly shaped lake formed by ice blocks left during the glacial age. It has steep sides, numerous narrow arms, and four islands. Lake St Clair is fed by both surface and groundwater. Eaton Creek discharges into the lake from the south. Lake St. Claire is hydrologically connected to the groundwater system. The recharge area covers approximately 40-square miles. Groundwater enters the lake from the south and west. and exits the lake from the north, contributing to flow to McAllister Springs.

GENERAL WATER QUALITY:
Good – St. Clair is mesotrophic. Trend analysis indicates improved transparency and reduced productivity, especially at SC1. In addition, enrichment to surface waters with phosphorus and nitrogen has been reduced over the last decade at both sites.

DESCRIPTION

Due to the irregular shape of the lake with somewhat isolated basins, steep shorelines, and water depths of over 30 meters, water quality conditions between basins vary. Eaton Creek is the only surface water input, which discharges into the lake in the southwest basin. The lake bottom is in continuous contact with the aquifer. Seepage from Lake St. Clair contributes to the aquifer and flow at McAllister Springs and the McAllister well field, which is used as a water source for the City of Olympia. The lake is a natural dark brown/stained (tea-color) which restricts light penetration, limiting aquatic plant and algae growth. Many of the land owners along this lake have maintained the shoreline in its natural condition, providing valuable wildlife and fish habitat. However, increased shoreline development could threaten to alter that condition.

METHODS

In 2018, Thurston County Environmental Health (TCEH) conducted monthly monitoring at two sites from May to October. Site SC1, the deepest site at over 30 meters, is in the southwestern basin (Figure 1). The second site, SC2, is in deepest part (over 20 meters) of the southeastern basin. Table 1 lists the types of data collected (Thurston County, 2009) and Appendix A provides the raw data. The Custer Color Strip (Figure 2) has been used as a reference for water color since the 1990s.

Table 1. List of parameters, units, method, and sampling locations.

Parameter	Units	Method	Sampling Location
Transparency	meters	Secchi Disk	Depth where disk is no longer visible
Color	#1 to #11	Custer Color Strip	Color of water on white portion of Secchi Disk
Vertical Water Quality Profile	• Water Temperature (°C) • Dissolved Oxygen (mg/L) • pH (standard units) • Specific Conductivity (µS/cm)	YSI EXO1 Multi-parameter Sonde	~ 0.5 meter below the water surface to ~ 0.5 meter above the bottom sediments
Total Phosphorus	mg/L	Grab Samples with Kemmerer	Surface Sample: ~ 0.5 meter below the surface Bottom Sample: ~ 0.5 meter above the benthos
Total Nitrogen	mg/L	Grab Samples with Kemmerer	Surface Sample: ~ 0.5 meter below the surface Bottom Sample: ~ 0.5 meter above the benthos
Chlorophyll-a	µg/L	Composite of Multiple Grab Samples	Photic Zone
Phaeophytin-a	µg/L	Composite of Multiple Grab Samples	Photic Zone

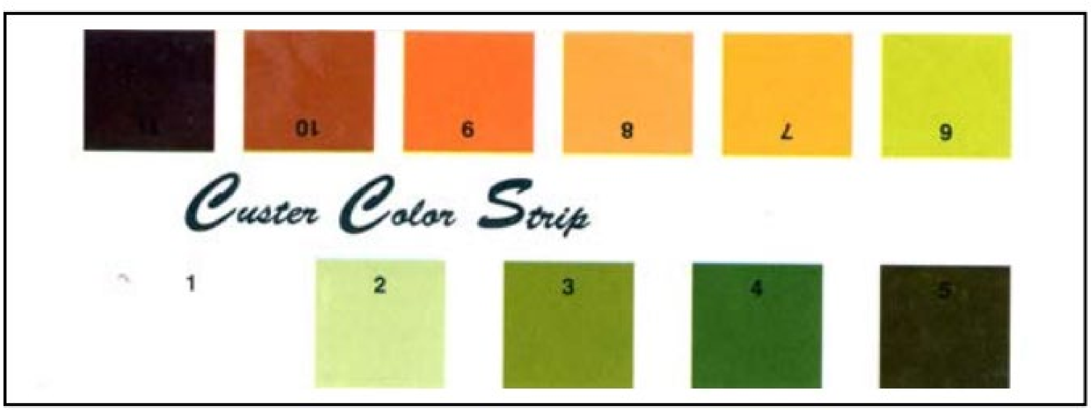


Figure 2. TCEH compared water color to the Custer Color Strip.

Quality Assurance and Quality Control (QA/QC)

TCEH collected 10% field replicates and daily trip blanks to assess total variation (three to four lakes sampled each day). The calibration of the Yellow Springs Instrument (YSI) EXO1 was verified before and after each sampling day. See Appendix B for QA/QC data.

The Seasonal Kendall Test

TCEH used the Seasonal Kendall test, a highly robust, non-parametric test, to identify trends from 2008 to 2018 (Appendix C). This test compares the relationship between data points at separate time periods and determines if there is a trend (positive or negative). The Seasonal Kendall test statistic was computed by performing a Mann-Kendall calculation for each sample month (May to October) from 2008 to 2018. TCEH calculated the Z statistic to determine if the trend was statistically significant and Theil-Sen estimator, also called Sen Slope, to estimate the magnitude of the trend over time.

RESULTS

Weather Conditions

Weather conditions during the 2018 sample season are provided in Table 2.

Table 2. Weather from the Olympia Regional Weather Station and field notes on sample days and the average, minimum, and maximum air temperatures for each month.

Month	Weather on Sample Day	Monthly Weather Temperature (°C) Mean (Low/High)
May	Sunny (9°C); 0-5 mph So wind (Gusts 10 mph)	13 (2/31)
June	Cloudy (13°C); 0-8 mph SW wind (Gusts 12 mph)	14 (5/32)
July	Cloudy early turning to Fair and Clear (33°C); 0-6 mph Var wind (Gusts 10 mph)	18 (6/34)
August	Sunny (26°C); 9-10 mph NE wind (Gusts 8 mph); smoke from wildfires east of Cascades and in Canada	18 (7/35)
September	Cloudy (14°C); 0-3 mph NNE wind	13 (2/29)
October	Fog (9°C); 0-3 mph NE, ENE wind	9 (0/22)

Vertical Water Quality Profiles

During the summer, lakes often stratify into layers based on temperature and density differences.

- Epilimnion: upper warm, circulating strata in contact with the atmosphere
- Metalimnion: middle layer with steep thermal gradient (thermocline)
- Hypolimnion: deepest layer of colder, relatively stagnant water

The vertical water quality profiles illustrate how the water column at Lake St. Clair was thermally stratified for the entire sample season (Figures 3 to 5). Thermal stratification, along with transparency, nutrient levels, and productivity affect the dissolved oxygen (DO) profile. In May and October at SC1, the DO profile resembled a clinograde curve. The hypolimnion, cut-off from the atmosphere after stratification, lost oxygen to redox processes like decomposition. The epilimnion had much higher DO because this layer gained oxygen from the atmosphere and photosynthesis.

When the water column was sufficiently transparent to permit photosynthesis by algae adapted to cooler, deeper water, oxygen to accumulated in the metalimnion. This type of DO curve is called positive heterograde, which occurred at:

- SC1 in June
- SC2 in May, July, August

Excess DO consumption in the metalimnion created a zone of oxygen depletion. This condition can be created by insufficient mixing during thermal stratification. This type of curve, called negative heterograde, was evident at:

- SC1 in July to September
- SC2 in June to October

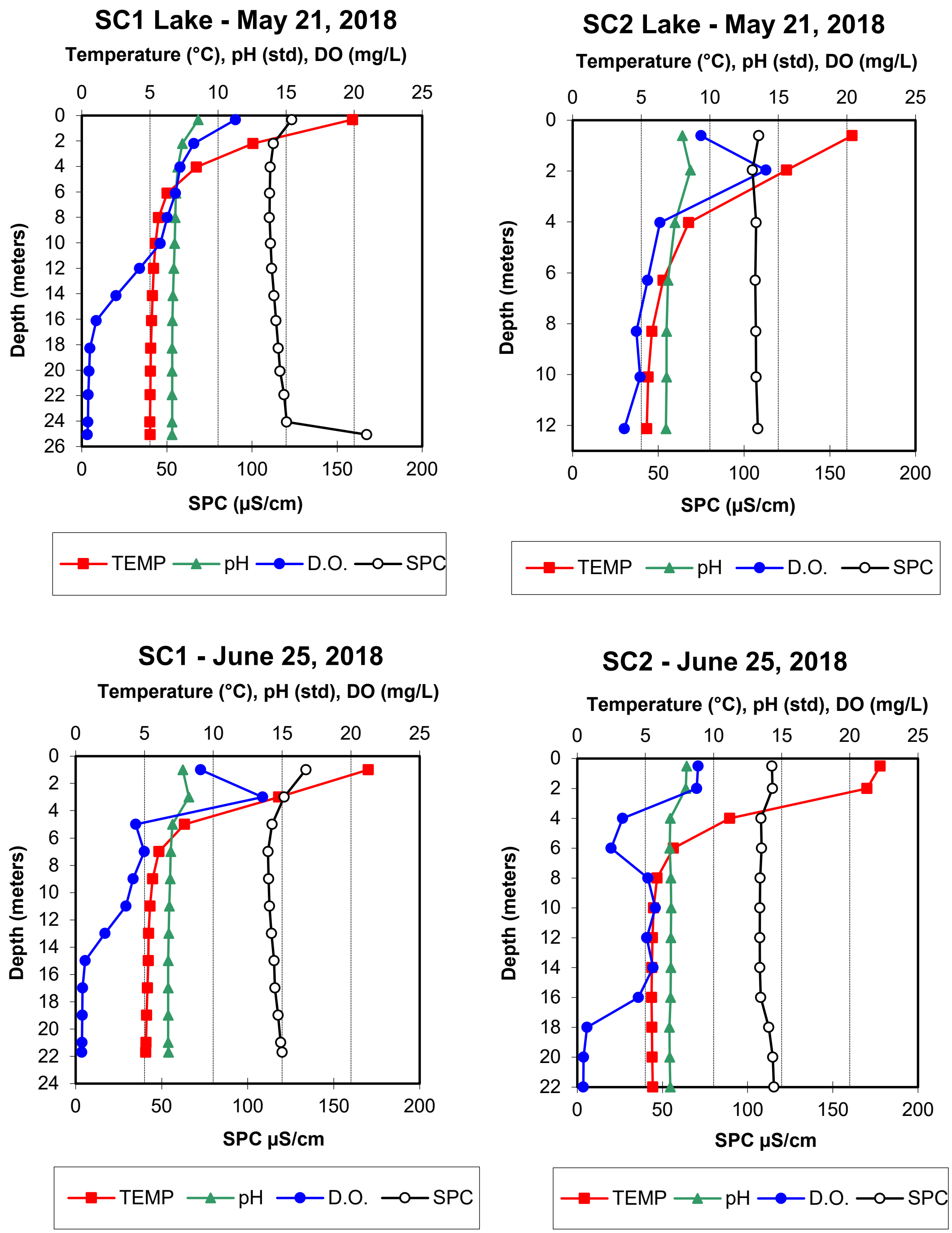


Figure 3. Vertical water quality profiles for SC1 and SC2 collected during May and June 2018.

In May, the summer sun warmed the surface water. At SC1, the epilimnion was very shallow. Below the upper two meters, temperature declined exponentially to the boundary with the hypolimnion at fifteen meters. At SC2, the upper two meters were warmest, then temperature rapidly cooled until eight meters depth. The temperature difference between the epilimnion and hypolimnion was similar at the two sites:

- SC1 Surface Temp 19.9°C; DO 11.3 mg/L
- SC1 Hypolimnion Temp 5.1°C; DO 0.6 mg/L
- SC2 Epilimnion Temp 20.4 °C; DO 9.4 mg/L
- SC2 Hypolimnion Temp 5.5°C; DO 4.3 mg/L

In June, surface temperatures increased. The thermocline extended from three to fifteen meters at SC1 and four to eight meters at SC2. The temperature difference between the epilimnion and hypolimnion was higher at SC2 compared to SC1.

- SC1 Epilimnion Temp 21.3°C; DO 9.1 mg/L
- SC1 Hypolimnion Temp 5.2°C; DO 0.5 mg/L
- SC2 Epilimnion Temp 22.2°C; DO 8.7 mg/L
- SC2 Hypolimnion Temp 5.5°C; DO 0.5 mg/L

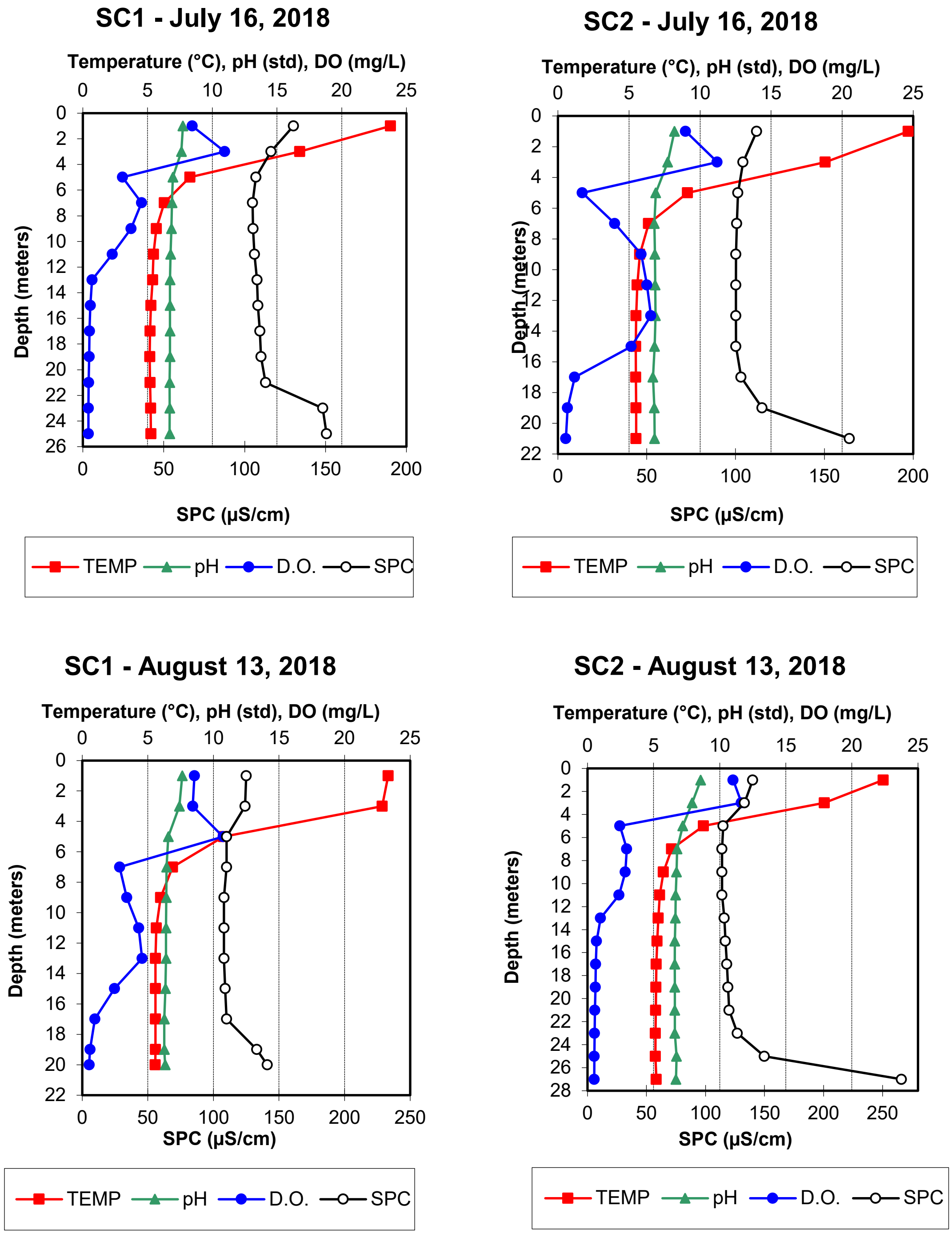


Figure 4. Vertical water quality profiles for SC1 and SC2 collected during July and August 2018.

In July, the thermocline was apparent from three to thirteen meters at both sites. The difference between temperature and DO in the epilimnion and hypolimnion was greater at SC2:

- SC1 Epilimnion Temp 23.8°C; DO 8.4 mg/L
- SC1 Hypolimnion Temp 5.2°C; DO 0.5 mg/L
- SC2 Epilimnion Temp 24.7°C; DO 9.0 mg/L
- SC2 Hypolimnion Temp 5.5°C; DO 0.8 mg/L

In August, the metalimnion was fifteen to seventeen meters deep. The difference between the oxygen supply in the epilimnion and the hypolimnion was larger at SC2 compared to SC1, but the temperature difference was greater at SC1.

- SC1 Epilimnion Temp 23.1°C; DO 8.5 mg/L
- SC1 Hypolimnion Temp 5.6°C; DO 0.7 mg/L
- SC2 Epilimnion Temp 22.4°C; DO 11.0 mg/L
- SC2 Hypolimnion Temp 5.2°C; DO 0.6 mg/L

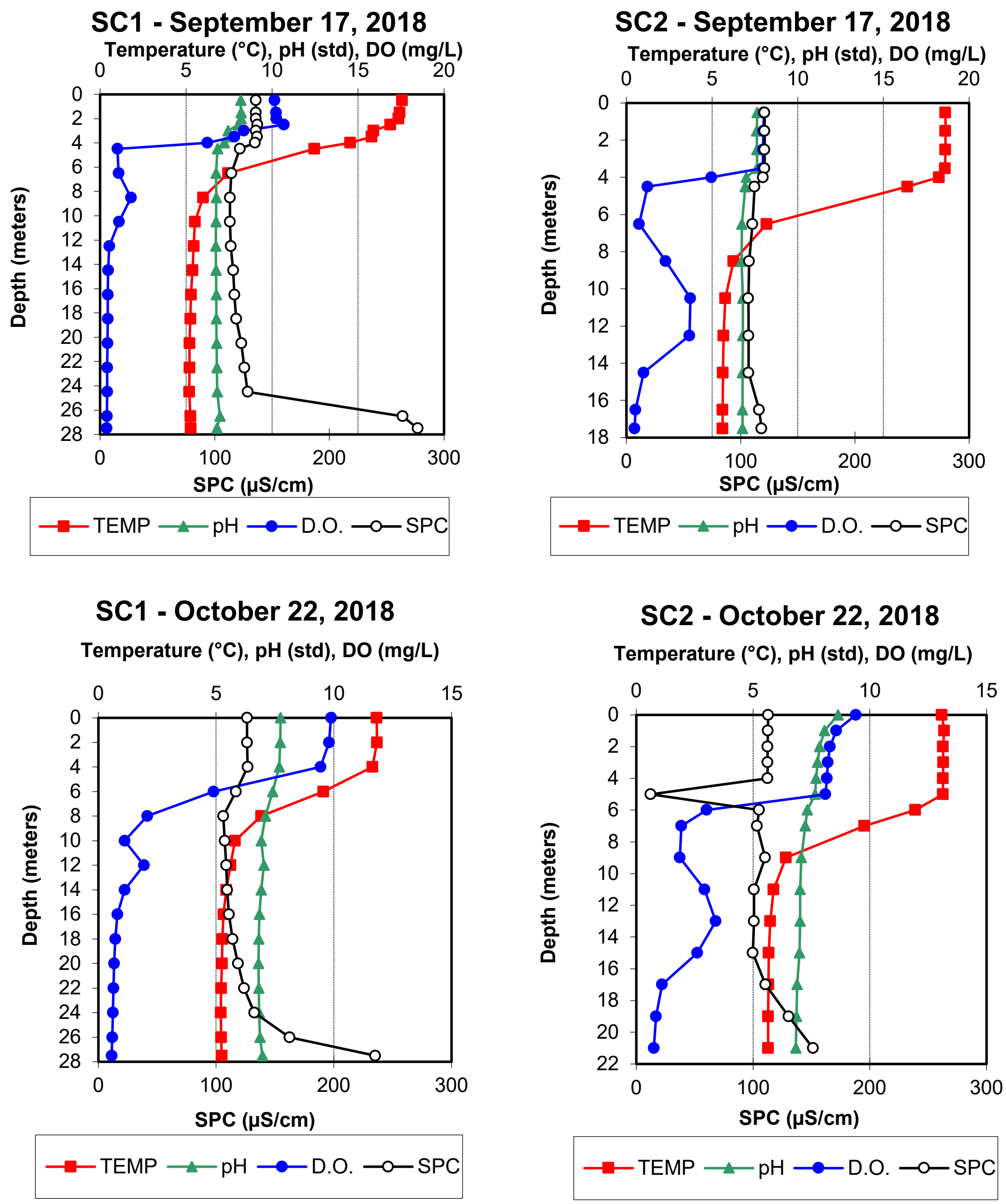


Figure 5. Vertical water quality profiles from SC1 and SC2 collected during September and October 2018.

In September, air temperatures dropped, particularly after sunset. As the epilimnion cooled, the temperature differences at the surface and the bottom declined at both sites compared to August. The thermocline extended from two to twelve meters deep at SC1 and four to seventeen meters deep at SC2.

- SC1 Surface Temp 17.4°C; DO 8.5 mg/L
- SC1 Hypolimnion Temp 5.3°C; DO 0.7 mg/L
- SC2 Epilimnion Temp 18.6 °C; DO 8.0 mg/L
- SC2 Hypolimnion Temp 5.6°C; DO 0.5 mg/L

In October, average air temperatures continued to decline (Table 2) with the arrival of fall. Lake St. Clair lost more heat than it gained, especially at night. Surface water cooled, increased in density and sank. The epilimnion at both sites grew deeper as convection currents and wind induced circulation. The temperature differences between the epilimnion and hypolimnion was reduced at both sites.

- SC1 Epilimnion Temp 11.8°C; DO 9.7 mg/L
- SC1 Hypolimnion Temp 5.2°C; DO 0.7 mg/L
- SC2 Epilimnion Temp 13.1°C; DO 8.5 mg/L
- SC2 Hypolimnion Temp 5.7°C; DO 0.9 mg/L

Surface Water Temperature Trends

The Seasonal Kendall analysis for trends for 2008 to 2018 shows that surface temperature has significantly increased in May at SC1 and at both locations from June until August (Figure 6). The largest increase in temperature occurred in June: 2.0°C at SC1 and 2.4°C at SC2. The magnitude of the trend toward warmer surface temperatures incrementally decreased until August. In September, the trend was downward, toward cooler temperatures at the surface. No trends were detected in October.

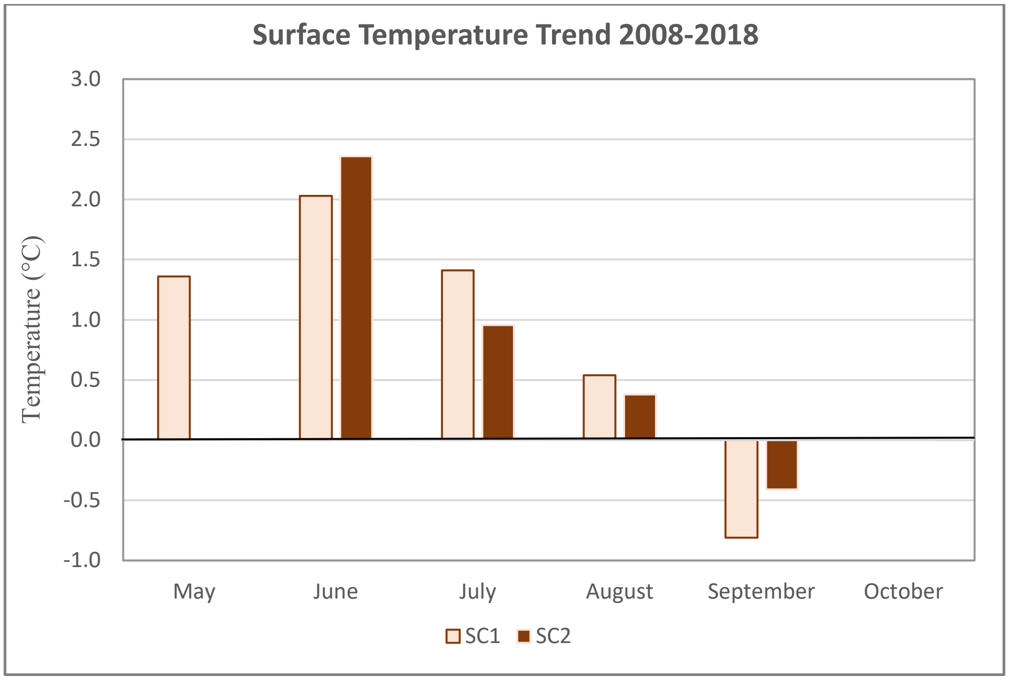


Figure 6. Surface temperature trend (+ or -) and magnitude of change (Theil-Sen estimator) for SC1 and SC2 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p<0.05$) for that time period.

Increased temperatures have many effects on freshwater environments. Warmer temperatures prolong thermal stratification and prevent mixing, enabling algal blooms to grow thicker and faster (Wells et al., 2015). Higher temperatures and nutrient pollution may increase the frequency and intensity of harmful algal blooms. Cyanobacteria (commonly known as blue-green algae) have a higher temperature optimum than eukaryotic phytoplankton, giving them a competitive advantage in warmer water. For example, Microcystis have temperature-dependent gas vacuoles that increase buoyancy, allowing this type of cyanobacteria to rise to more favorable light and temperature conditions under quiescent conditions (Michalek et al, 2013).

Water Color and Transparency

Color can reveal information about a lake's nutrient load, algal growth, water quality and surrounding landscape. High concentrations of algae cause the water color to appear green, golden, or red. Weather, rocks and soil, land use practices, and types of trees and plants influence dissolved and suspended materials in the lake. Tannins and lignins, naturally occurring organic compounds from decomposition, can color the water yellow to brown.

Transparency of water to light has been used to approximate turbidity and phytoplankton populations. Secchi depth is closely correlated with the percentage of light transmission through water. The depth at which the Secchi disk is no longer visible approximates 10% of surface light, however suspended particles in the water affect accuracy. The health department recommends visibility of at least 1.2 meters, or four feet, at public swimming beaches.

Figure 7 shows the Secchi depth (bar length) color (bar color), and chlorophyll-a concentration (purple line) for SC1 and SC2 for 2018.

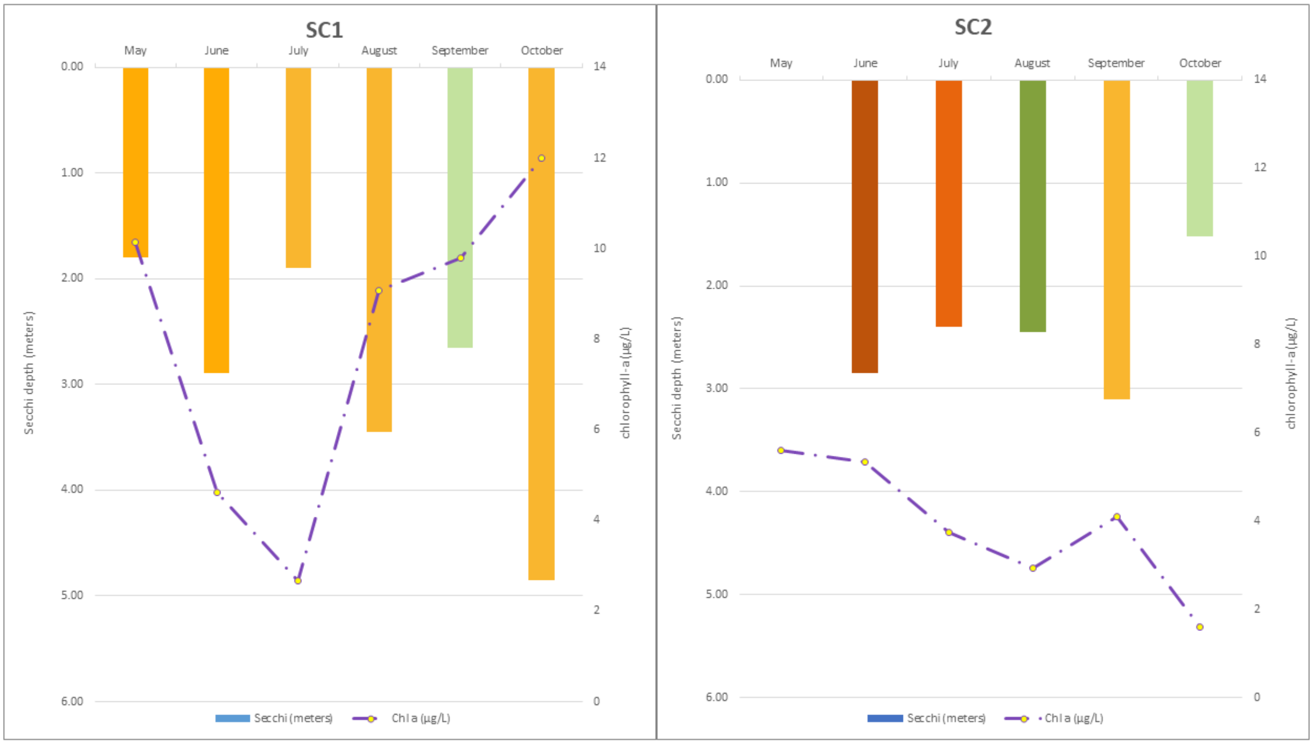


Figure 7. Water color, Secchi depths, and chlorophyll-a concentrations for 2018.

In 2018, the average transparency was 2.9 meters at SC1. In May, Secchi depth was negatively correlated to productivity. In contrast, for the rest of the sample season, transparency was greater when productivity was higher.

- SC1 from June and July - mean Secchi depth 2.4 meters, mean chlorophyll-a 3.7 µg/L
- SC1 August to October - mean Secchi depth 3.7 meters, mean chlorophyll-a 5.8 µg/L

At SC2, the average transparency was lower (2.5 meters) compared to SC1. Transparency at SC2 was better in September (3.1 meters) and June (2.9 meters) and worse in October (1.5 meters). Productivity was positively correlated to Secchi depth.

Figure 8 shows the annual average transparency (Secchi depth) compared to the long-term average. Positive values reflect transparency better than the long-term average. Compared to the long-term average, transparency was greater (+0.7 meters) at SC1 and less (-0.2 meters) at SC2 in 2018.

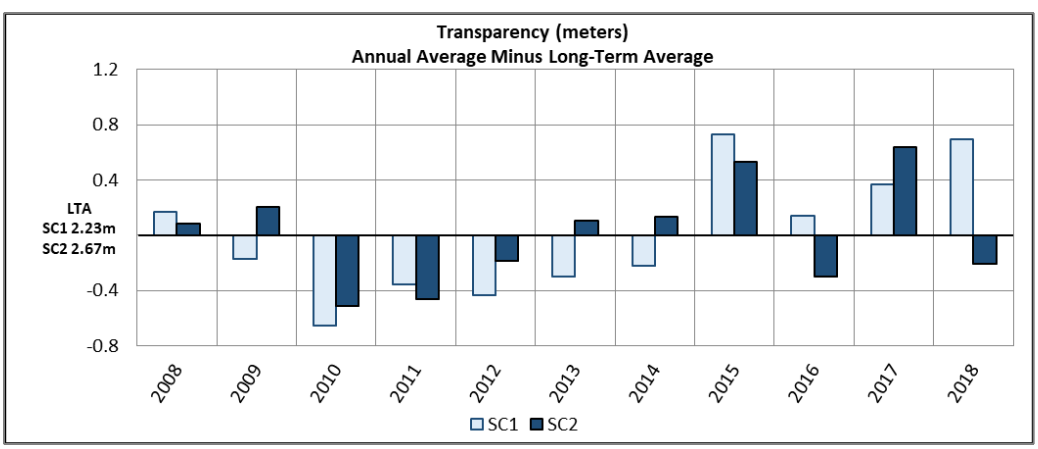


Figure 8. Transparency at SC1 and SC2 compared to the long-term average (LTA).

The Seasonal Kendall test revealed a trend of improved transparency (Figure 9) at SC1 for every month, except in September when no trend was identified. The smallest increase at SC1 was in May and the largest in October. At SC2, transparency improved in June (0.2 meters). No trends existed for the rest of the sample season at SC2.

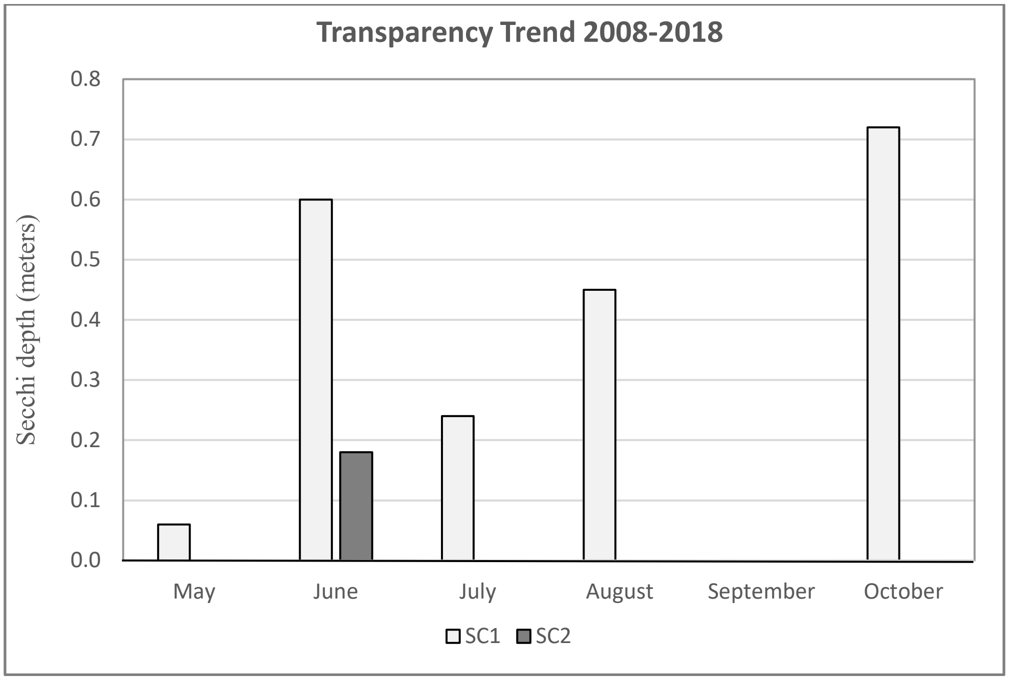


Figure 9. Transparency trend (+ or -) and magnitude of change (Theil-Sen estimator) for SC1 and SC2 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p<0.05$) for that time period.

Productivity

Pigments

Chlorophyll-a pigment is present in algae and cyanobacteria and is widely used to assess the abundance of phytoplankton in suspension. Phaeophytin is also a pigment, but it is not active in photosynthesis. It is a breakdown product of chlorophyll and is present in dead suspended material (Moss, 1967). The ratio of chlorophyll-a to phaeophytin-a has been used as an indicator of the physiological condition of phytoplankton in the sample.

Phaeophytin absorbs light in the same region of the spectrum as chlorophyll-a, and, if present can interfere with acquiring an accurate chlorophyll-a value. Phaeopigments have been reported to contribute 16 to 60% of the measured chlorophyll-a content (Marker et al., 1980).

Figure 10 shows that the highest concentration of chlorophyll-a was in May and from August to October at SC1. Productivity was lowest in June and July. The supply of oxygen in the epilimnion ranged from a low of 8.4 mg/L in July to a high of 11.3 mg/L in May (standard deviation 1.0). The ratio of chlorophyll-a to phaeophytin-a peaked in September.

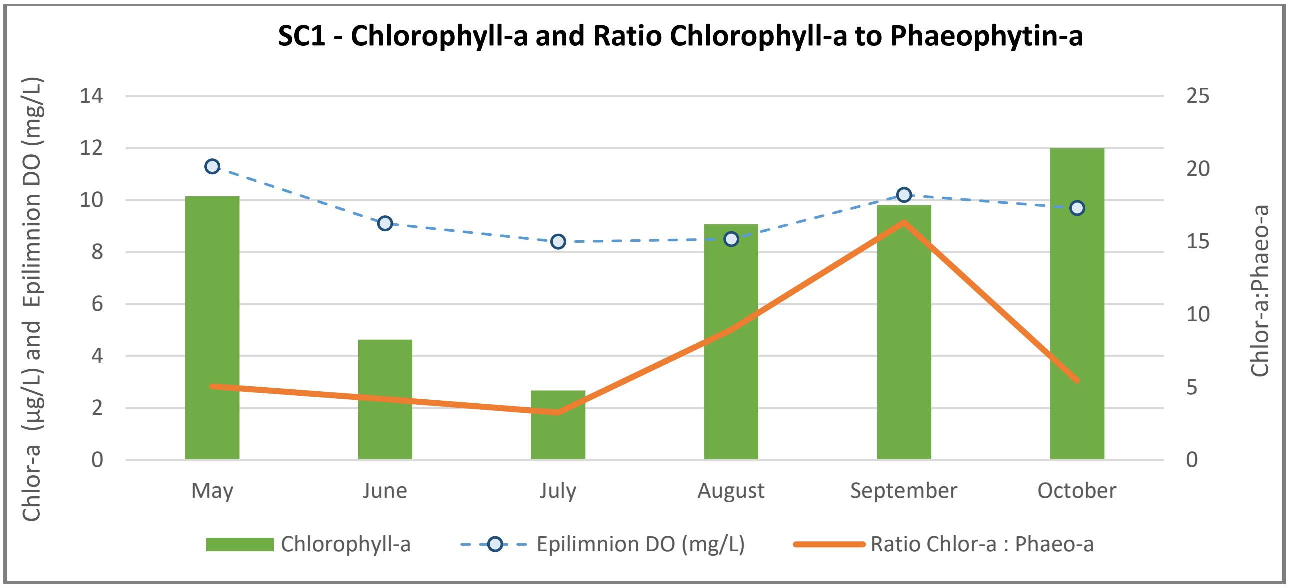


Figure 10. Chlorophyll-a concentration and ratio of chlorophyll-a to phaeophytin-a pigments in samples collected at SC1.

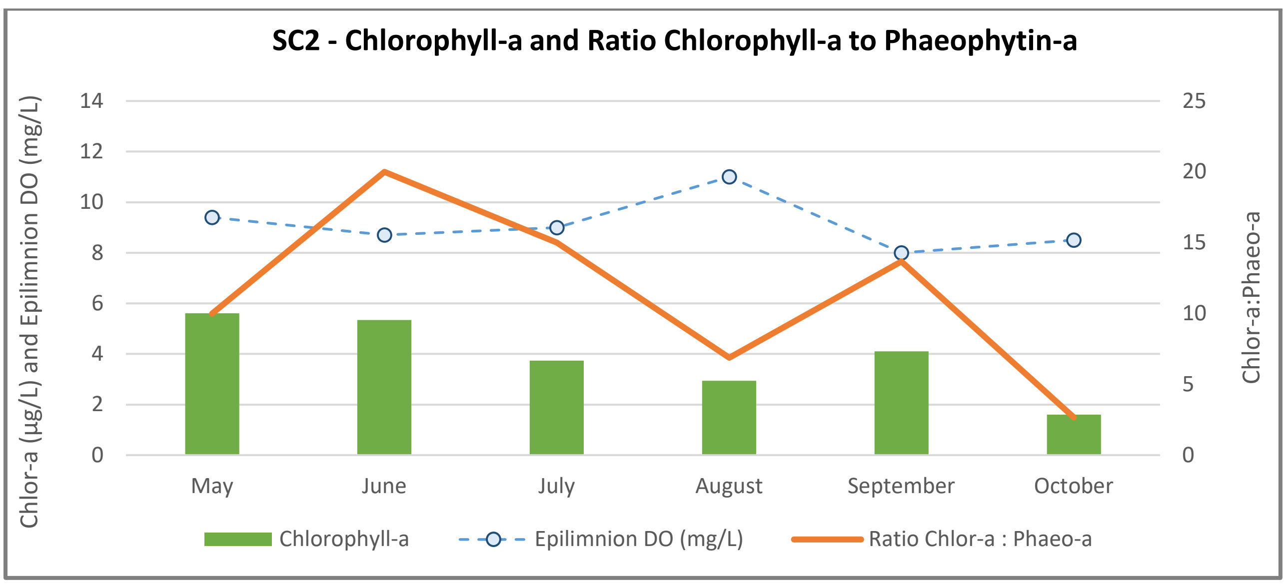


Figure 11. Chlorophyll-a concentration and ratio of chlorophyll-a to phaeophytin-a pigments in samples collected at SC2.

At SC2, the greatest productivity was in May and June and the lowest was in August and October. The ratio of chlorophyll-a to phaeophytin-a peaked in June, and again to a lesser degree, in July and September. The mean DO concentration in the epilimnion ranged from 8.0 mg/L in September to 11.0 mg/L in August (standard deviation 1.0).

An algal bloom with surface scum was reported in October 2018. TCEH collected one sample on October 22, 2018, which was tested for anatoxin-a, microcystin, cylindrospermopsin, and saxitoxin. The results were below the method detection limit (MDL) for all four algal toxins. Identification of phytoplankton would provide more information about productivity and phytoplankton assemblages.

The test for chlorophyll-a concentration trends for 2008 to 2018 indicates a significant ($p<0.05$) downward trends in chlorophyll-a:

- The greatest negative trend (5.7 µg/L) occurred at SC1 in June
- Smaller declines occurred from July to September (1.0 to 2.0 µg/L) at SC1 and in August at SC2 (0.8 µg/L) and October (2.0 µg/L)

At SC2, significant upward trend existed in September (1.1 µg/L). No trends were identified in May and October at SC1 and from May to July at SC2. Figure 12 shows the magnitude of change for all significant trends.

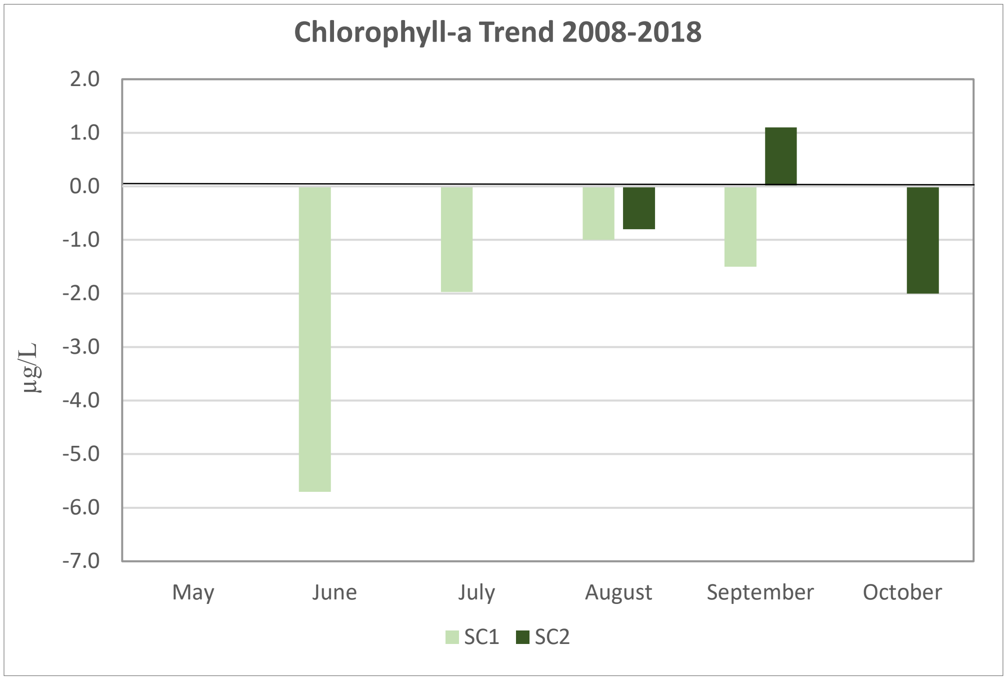


Figure 12. Chlorophyll-a trend (+ or -) and magnitude of change (Theil-Sen estimator) for SC1 and SC2 from 2008 to 2018. The lack of a bar means the site did not have a significant trend (p<0.05) for that time period.

Nutrients

Surface Nutrients

Inorganic nutrients, particularly the elements phosphorus and nitrogen, are vital for algal nutrition and cellular constituents. Over enrichment of surface waters leads to excessive production of autotrophs, especially algae and cyanobacteria (Correll, 1998) Figure 13 shows the total phosphorus (TP) and total nitrogen (TN) present in the surface waters at the two Lake St. Clair sites.

Figure 13. 2018 surface concentration of TP and TN at SC1 and SC2 sites at St. Clair.

At SC1, the concentration of both nutrients was highest in May and July. The concentration of TN at the surface was lower than the TP concentration, but changes in concentrations corresponded each month except in October. In October, the surface TP concentration grew 29% and TN diminished 5%.

Like SC1, the concentration of both nutrients was highest in May and July at SC2. Unlike SCI, TP fell in 12% October and TN climbed 14%.

Thermal stratification reduced internal loading to surface waters from May to October. Changes in the phytoplankton community and external sources likely affect nutrient levels at the surface during stratification.

Total Phosphorus

Compared to the rich supply of other elements required for nutrition or structure, phosphorus is the least abundant and most commonly limits biological productivity. Lakes in this region experience undesirable algae growth when the annual average surface phosphorus level reaches 0.030 mg/L (Gilliom, 1983). Washington adopted numeric action values in the state water quality standards to protect lakes. The action level for the Puget Lowlands ecoregion is 0.020 mg/L (WAC, 2019).

The surface TP concentration was below the action level for the duration of the 2018 sample season, except for in July at SC1 (0.024 mg/L).

- SC1 Surface Mean 0.018
- SC1 Surface Median 0.018
- SC1 Surface Std Dev 0.004
- SC2 Surface Mean 0.012
- SC2 Surface Median 0.011
- SC2 Surface Std Dev 0.003

Figure 14 displays the TP concentration, both at the surface and bottom, at the at the two Lake St. Clair sites.

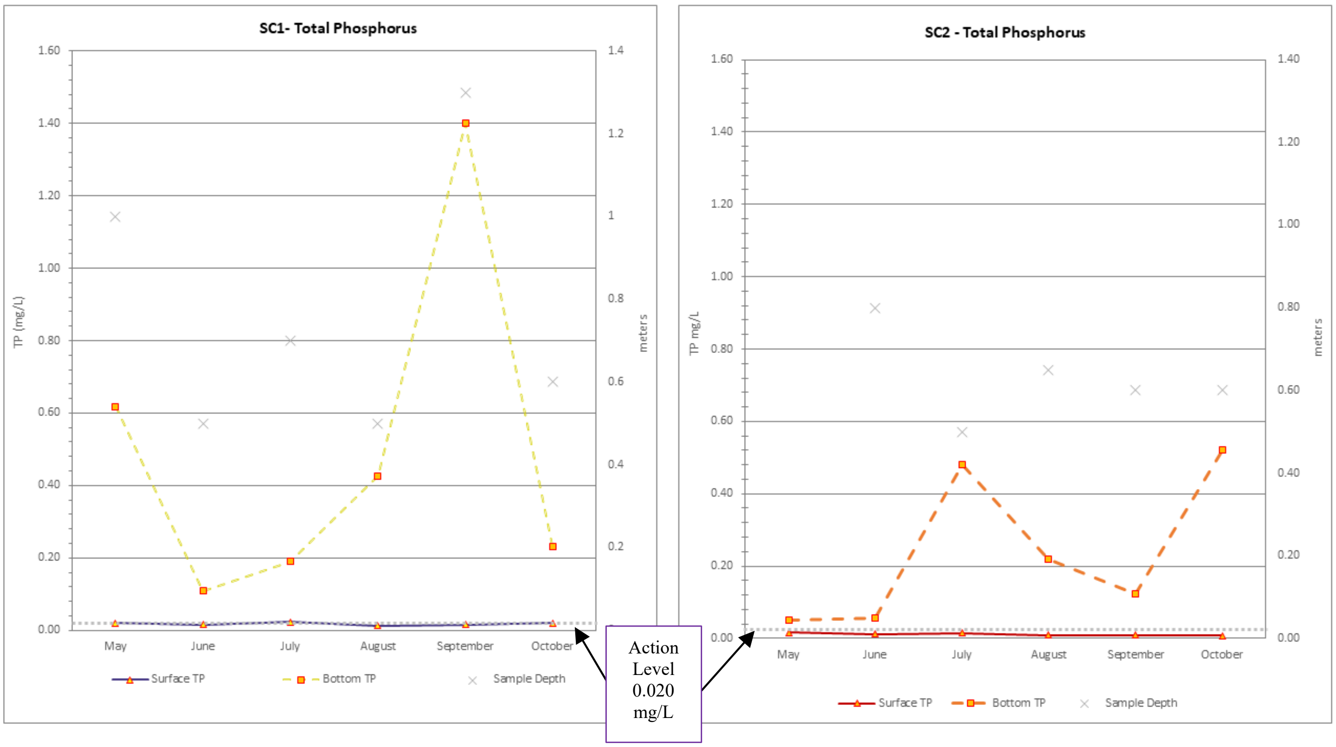


Figure 14. Concentration of Total Phosphorus at the surface and bottom of Lake St. Clair sites in 2018.

In 2018, the concentration of TP (mg/L) near the bottom was:

- SC1 Mean 0.496
- SC1 Median 0.330
- SC1 Std Dev 0.438
- SC2 Mean 0.243
- SC2 Median 0.172
- SC2 Std Dev 0.192

The vertical profile graphs show that both sites were thermally stratified from May to October. Water density disparities prevented the hypolimnion from mixing with upper strata. In the stagnant hypolimnion, decomposition and other redox processes consumed the oxygen supply. Phosphorus stored in the sediments was released into the water column and accumulated in the hypolimnion.

Figure 15 displays the average annual concentration of TP at SC1 and SC2 from 2008 to 2018. For the period of record, surface samples for TP have been above the state action level (dotted line at 0.020 mg/L):

- 73% at SC1
- 9% at SC2

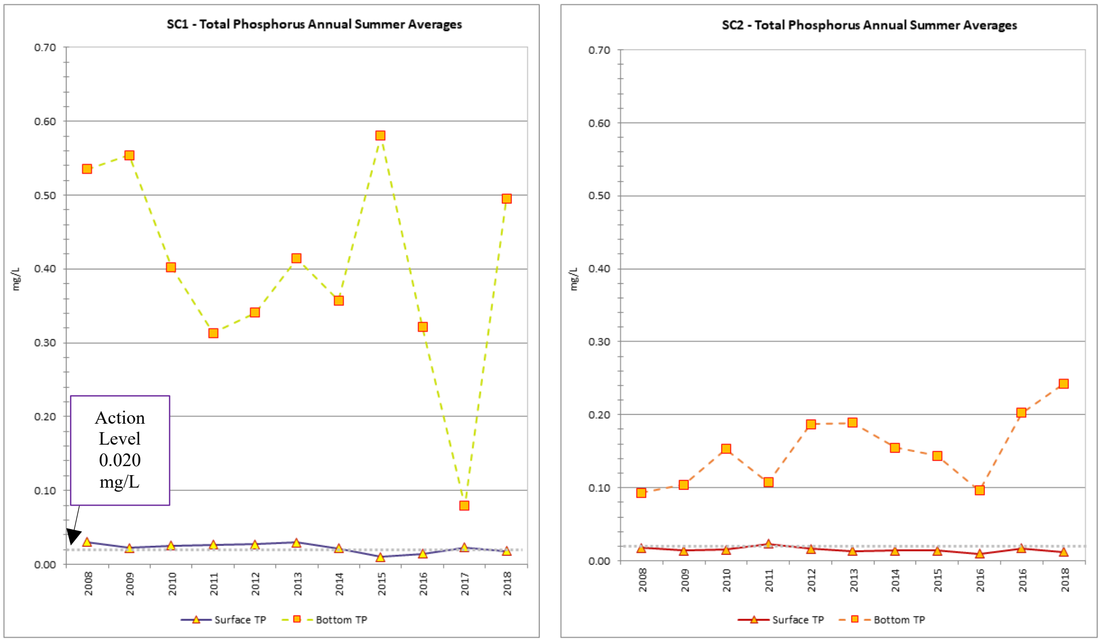


Figure 15. Average Annual Total Phosphorus at SC1 and SC2 from 2008 to 2018.

For the period of record (2008 to 2018), the TP concentration (mg/L) at SC1 was:

- Surface Mean 0.023
- Surface Median 0.023
- Surface Std Dev 0.006
- Bottom Mean 0.0399
- Bottom Median 0.403
- Bottom Std Dev 0.137

At SC2, the mean surface TP concentration was below the state action level every sample season except 2011 (Figure 15). For the period of record (2008 to 2018), the TP concentration (mg/L) at SC2 was:

- Surface Mean 0.015
- Surface Median 0.014
- Surface Std Dev 0.003
- Bottom Mean 0.152
- Bottom Median 0.153
- Bottom Std Dev 0.047

The Seasonal Kendall test (2009 to 2018) revealed significant trends of decreasing TP concentrations (Figure 16) in surface water for 67% of the sample season (four out of six months) at both sites.

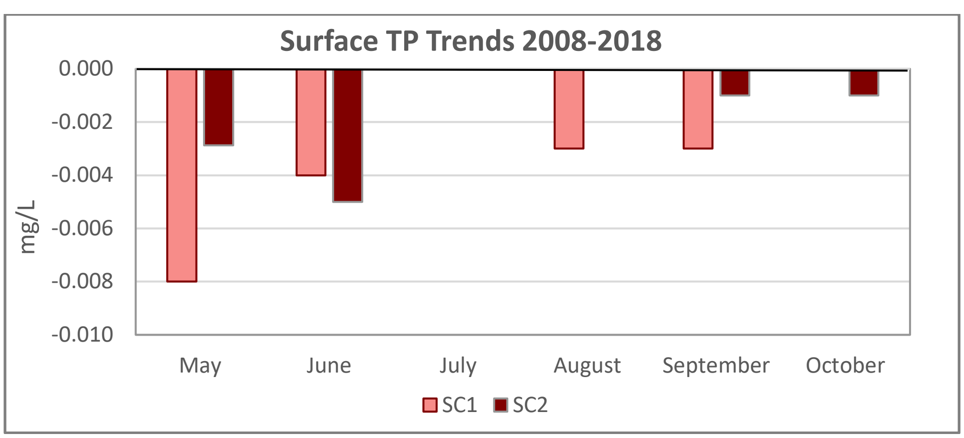


Figure 16. Surface TP trend (+ or -) and magnitude of change (Theil-Sen estimator) for SC1 and SC2 from 2008 to 2018. The lack of a bar means the site did not have a significant trend (p<0.05) for that time period.

Nitrogen

Nitrogen is also limiting to lake productivity, but supplies are more readily augmented by inputs from external sources. The State of Washington does not have established action or cleanup levels for surface total nitrogen. The average surface total nitrogen concentration was 0.382 mg/L at SC1 and 0.383 mg/L at SC2. Figure 17 shows the 2018 TN concentrations for the two sites. During stratification, the hypolimnion was anoxic; ammonia-nitrogen was released from the bottom sediments and accumulated in the hypolimnion.

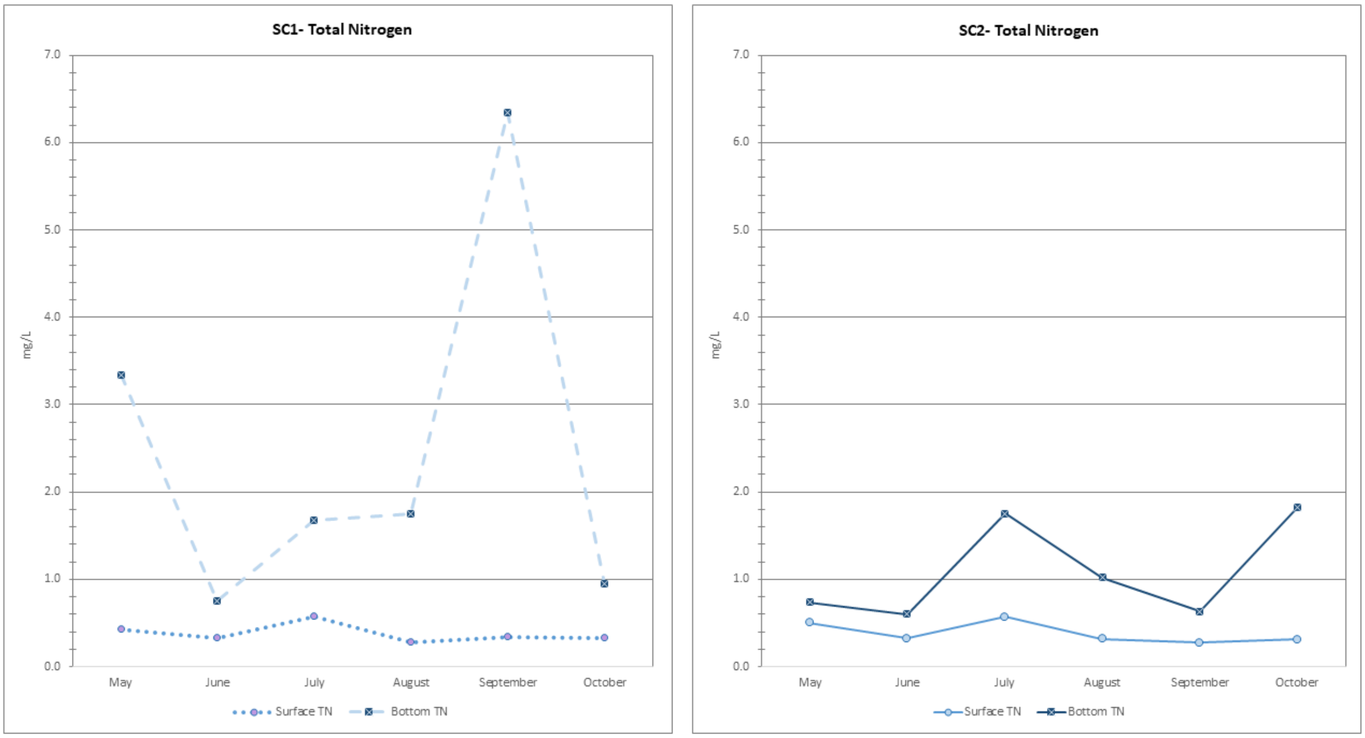


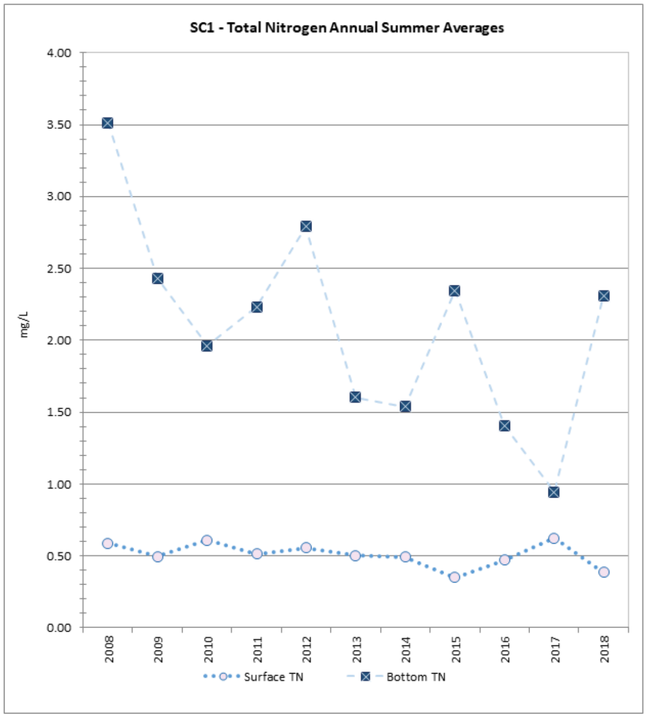
Figure 17. Concentration of Total Nitrogen at the surface and bottom at SC1 and SC2 in 2018.

In 2018, the surface TN concentration (mg/L) was:

- SC1 Surface Mean 0.382
- SC1 Surface Median 0.337
- SC1 Surface Std Dev 0.097

- SC2 Surface Mean 0.383
- SC2 Surface Median 0.319
- SC2 Surface Std Dev 0.112

Figure 18 displays the average annual concentrations for total nitrogen for 2008 to 2018.



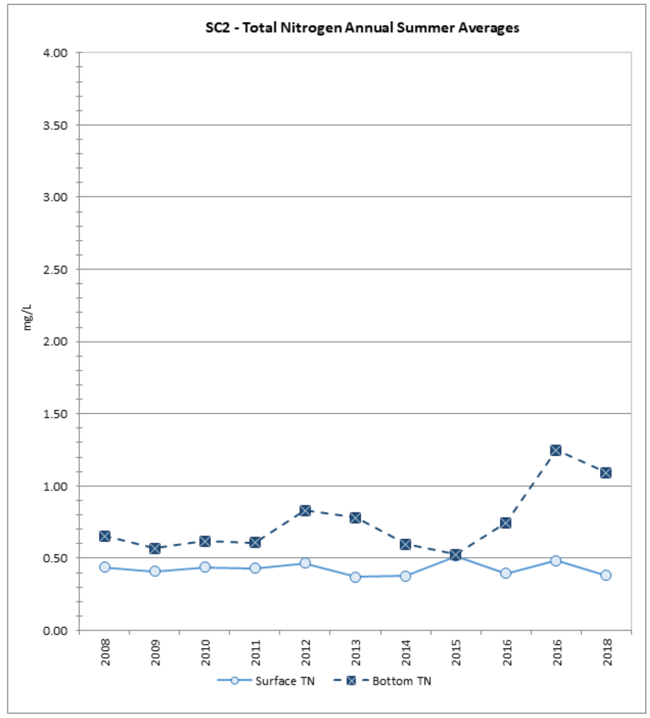


Figure 18. Average Annual Total Nitrogen at SC1 and SC2 from 2008 to 2018.

For the period of record (2008 to 2018), the TN concentration (mg/L) at SC1 was:

- Surface Mean 0.508
- Surface Median 0.504
- Surface Std Dev 0.083
- Bottom Mean 2.097
- Bottom Median 2.231
- Bottom Std Dev 0.68

At SC2, the TN concentration (mg/L) for the period of record (2008 to 2018) was:

- Surface Mean 0.428
- Surface Median 0.430
- Surface Std Dev 0.044
- Bottom Mean 0.752
- Bottom Median 0.624
- Bottom Std Dev 0.219

The Seasonal Kendall test shows a significant ($p<0.05$) downward trends (Figure 19) of surface TN concentrations at both sites. Surface TN has been reduced over the last decade:

- 67% at SC1
- 83% at SC2

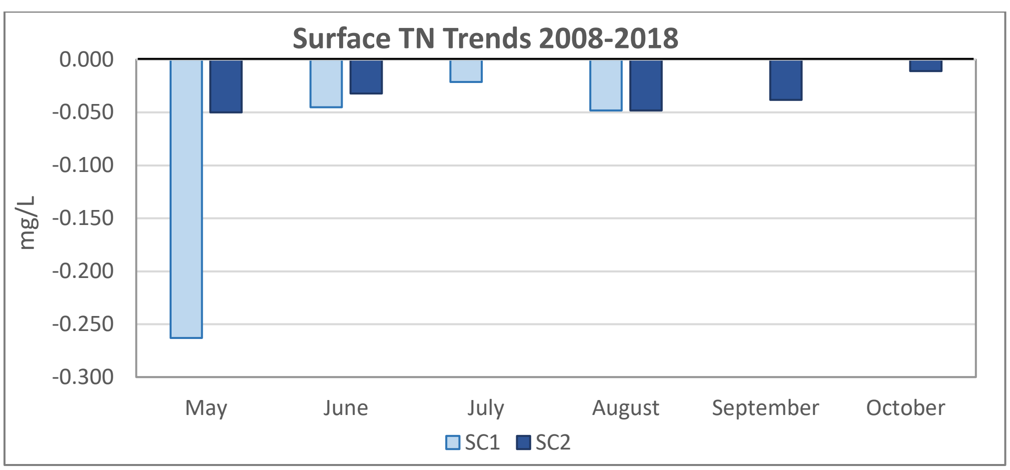


Figure 19. Surface TN trend (+ or -) and magnitude of change (Theil-Sen estimator) for SC1 and SC2 from 2008 to 2018. The lack of a bar means the site did not have a significant trend ($p<0.05$) for that time period.

Nitrogen to Phosphorus Ratios

To prevent dominance by cyanobacteria the TN to TP ratio (TN:TP) should be above 10:1 (Moore and Hicks, 2004). Figure 20 shows the TN to TP ratio of surface waters at the two Lake St. Clair sites. Both sites have been phosphorus-limited every sample season since 2008.

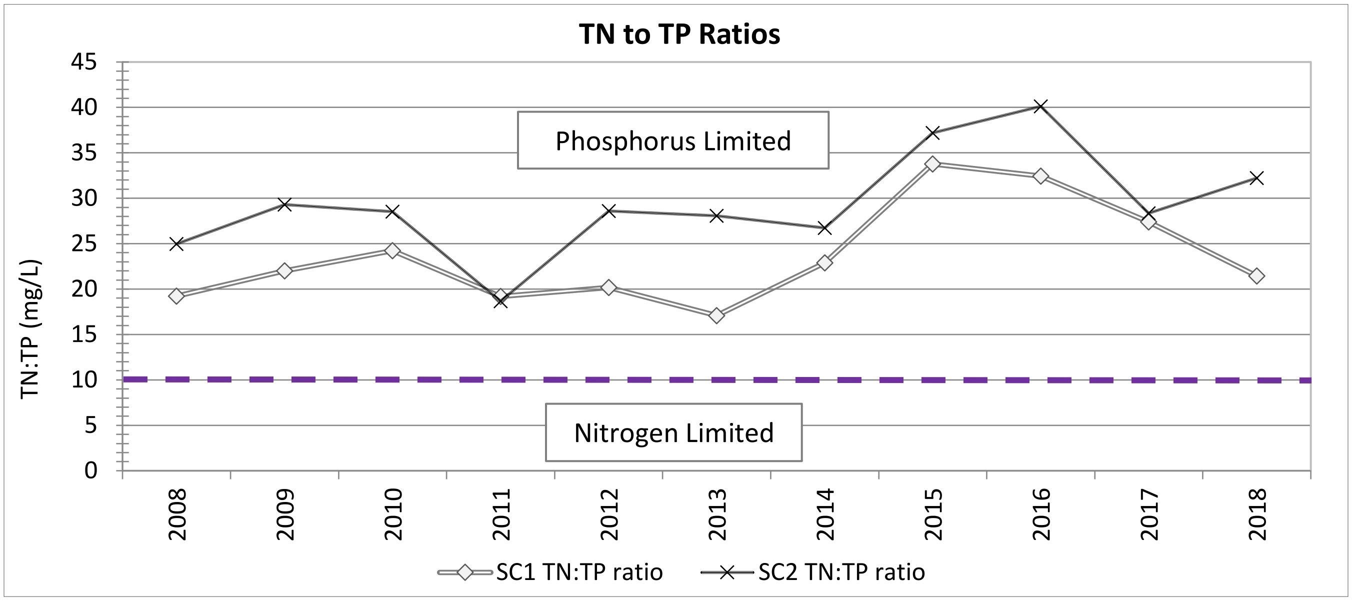


Figure 20. TN:TP at SC1 and SC2 from 2008 to 2018.

Trophic State Indices (TSI)

The most commonly used method to classify lakes is called the Carlson's Trophic State Index (Carlson, 1977). Based on the productivity, this method uses three index variables: transparency (secchi disk depth), chlorophyll-a, and phosphorus concentrations. Table 3 provides the index values for each trophic classification.

Table 3. Trophic State Index variables.

TSI Value	Trophic State	Productivity
0 to 40	oligotrophic	Low
41 to 50	mesotrophic	Medium
> 50	eutrophic	High

For SC1, the 2018 TSI results were:

- Chlorophyll-a: 51 eutrophic
- Total Phosphorus: 46 mesotrophic
- Secchi Disk: 45 mesotrophic

The average of the three TSI variables is 47, which categorizes SC1 as mesotrophic in 2018. Based on the concentration of chlorophyll-a, SC1 was classified as eutrophic 64% of the sample seasons since 2008 (Figure 21). For the period of record, TP and Secchi measurements resulted in a eutrophic classification less often:

- 36% of summers eutrophic due to high TP concentrations
- 18% of summers eutrophic due to low transparency

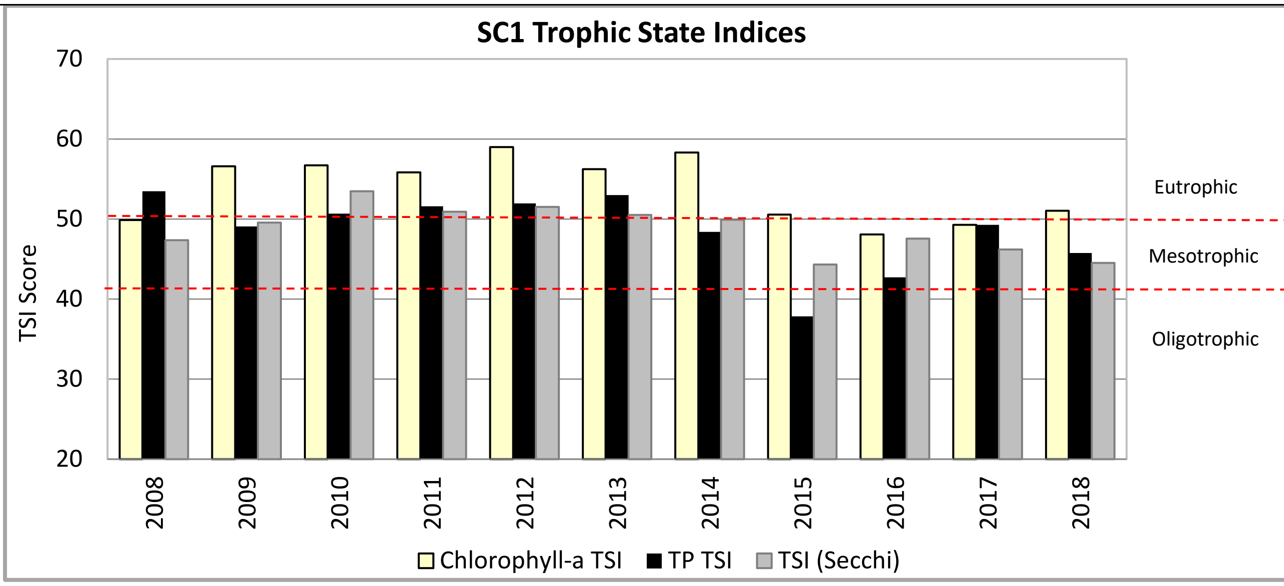


Figure 21. SC1 Trophic State Index from 2008 to 2018.

The Mann Kendall test reveals a significant trend ($p<0.05$) of decreasing TSI values for all three parameters at SC1; the trend from 2008 to 2018 was toward lower productivity and TP concentrations, and increased transparency (Appendix C).

The TSI results (Figure 22) for the west basin site SC2 were:

- Chlorophyll-a: 44 mesotrophic
- Total Phosphorus: 40 oligotrophic
- Secchi Disk: 47 mesotrophic

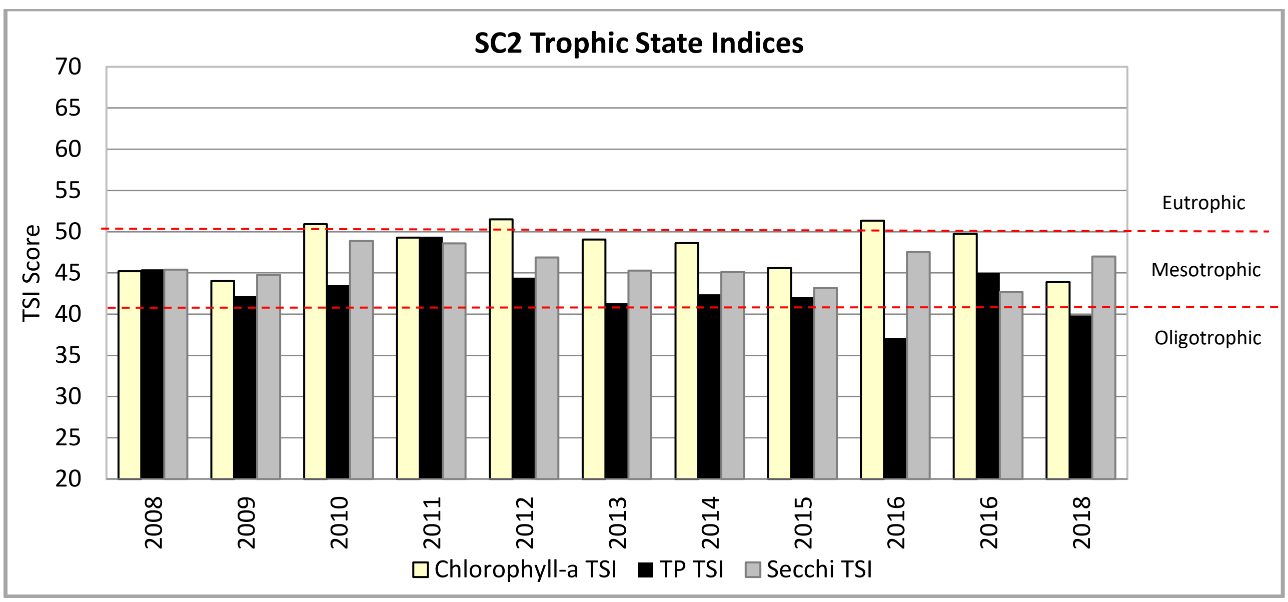


Figure 22. SC2 Trophic State Index from 2008 to 2018.

The average TSI score for SC2 was 44, which categorizes SC2 as mesotrophic. Every sample season since 2008, SC2 has been mesotrophic based on Secchi depth. Since 2008, SC2 has been classified as:

- 73% mesotrophic and 27% eutrophic based on the chlorophyll-a concentration
- 18% oligotrophic and 82% mesotrophic based on the concentration of surface TP

The trend over the last decade at SC2 was lower Secchi disk and TP TSI values, indicating a trend of increased transparency and reduced TP loading. No significant trend was observed for the chlorophyll-a TSI values.

SUMMARY

Thermal Stratification and Warmer Temperature Trends

In 2018, the water column at Lake St. Clair was thermally stratified from May to October. The trend from 2009 to 2018 was increased temperature in surface water at SC1 in May and at both locations from June to August. The trend was toward cooler temperatures at the surface in September at both sites. No significant trends existed in October.

Transparency and Improving Trends at SC1

In 2018, the mean transparency was slightly higher at SC1 compared to SC2. At SC1, transparency has improved over the last decade every month except September. At SC2, transparency has not changed significantly over the last decade, except for a moderate increase in June.

Chlorophyll-a and Lower Productivity Trends at SC1

In 2018, the concentration of chlorophyll-a was highest in May and from August to October at SC1. The Seasonal Kendall test for chlorophyll-a concentration trends (2008 to 2018) indicates lower productivity at SC1 from June to September, as shown by significant downward trends for the chlorophyll-a concentrations and the TSI chlorophyll-a value. In 2018 at SC2, productivity was highest in May and June. The trends were mixed at SC2: down in August and October, up in September, and no trends from May to July and for the TSI chlorophyll-a value.

Nutrients and Trending Toward Lower Enrichment

The mean surface TP concentration was below the action level (0.020 mg/L) at both sites. The Seasonal Kendall test (2008 to 2018) revealed significant downward trends for TP in surface water for 67%of the sample season at both sites.

The mean/median surface TN concentration was 0.382/0.337 mg/L at SC1 and 0.383/0.319 mg/L at SC2. The Seasonal Kendall test shows a significant ($p<0.05$) downward trend of surface TN concentrations in the last decade.

- 67% of the sample season at SC1
- 83% of the sample season at SC2

Classified as Mesotrophic

In 2018, both basins of Lake St. Clair were classified as mesotrophic based on an average of the three TSI variables. At SC1, the trend for TSI values from 2008 to 2018 was toward lower productivity and TP concentrations, and increased transparency. At SC2, trend analysis of TSI scores indicates a trend of increased transparency and reduced TP loading. No significant trend was observed for the chlorophyll-a TSI values.

DATA SOURCES:

Thurston County Community Planning and Economic Development
(360) 786-5549 or
https://www.thurstoncountywa.gov/planning/Pages/water-gateway.aspx

Thurston County Environmental Health
(360) 867-2626 or
https://www.co.thurston.wa.us/health/ehrp/annualreport.html
For digital data contact the main telephone number or sarah.ashworth@co.thurston.wa.us

For corrections, questions, and/or suggestions, contact the author of the 2018 report:
renee.fields@co.thurston.wa.us

FUNDING SOURCE:

Thurston County funded monitoring in 2018.

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Appendices

Appendix A. Raw data

Table A-1 Raw data collected at site SC1 located in the southwestern basin.

SC1 Date	Time	Bottom Depth (meters)	Secchi (meters)	Water Color	Bottom Sample Depth (meters)	Surface TP (mg/L)	Bottom TP (mg/L)	Surface TN (mg/L)	Bottom TN (mg/L)	Chl a (µg/L)	Phae a (µg/L)	Lake Notes
5/21/2018	15:51	28.00	1.80	8	27.0	0.020	0.617	0.430	3.341	10.1	2.0	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 0, 2, 4, 6
6/25/2018	11:55	22.00	2.89	8	21.5	0.016	0.109	0.329	0.754	4.6	1.1	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 3
7/16/2018	11:47	25.70	1.90	7	25.0	0.023	0.187	0.584	1.683	2.7	0.9	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 3; gage at bridge = 70.20
7/16/2018	**11:47**	**-**	**-**	**-**	**-**	**0.024**	**0.191**	**0.565**	**1.660**	**2.7**	**0.7**	QA
8/13/2018	10:14	20.00	3.45	7	19.5	0.013	0.427	0.284	1.750	9.1	1.0	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 3
9/17/2018	11:15	28.80	2.65	6	27.5	0.015	1.400	0.345	6.340	9.8	0.6	gage=69.44; partly cloudy; 0-3 mph NW wind; depth calibrated
10/22/2018	10:00	20.10	4.85	7	19.5	0.020	0.232	0.329	0.953	12.0	2.2	

Table A-2 Raw data collected at site SC2 located in the southeastern basin.

SC2 Date	Time	Bottom Depth (meters)	Secchi (meters)	Water Color	Bottom Sample Depth (meters)	Surface TP (mg/L)	Bottom TP (mg/L)	Surface TN (mg/L)	Bottom TN (mg/L)	Chl a (µg/L)	Phae a (µg/L)	Lake Notes
5/21/2018	17:24		-	-		0.016	0.052	0.503	0.737	5.6	0.6	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 0, 2, 3, 4; Secchi depth and color not recorded
6/25/2018	10:03	22.30	2.85	10	21.5	0.012	0.057	0.322	0.602	5.3	0.3	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 3
7/16/2018	10:47	22.00	2.40	9	21.5	0.016	0.481	0.570	1.755	3.7	0.2	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 3; gage at bridge = 70.20
8/13/2018	11:08	27.15	2.45	3	26.5	0.01	0.220	0.316	1.020	2.9	0.4	Chlorophyll a and Phaeopigments Composite Sample collected at the following depths (meters): 1, 2, 3
9/17/2018	10:11	17.60	3.10	7	17.0	0.009	0.124	0.272	0.633	4.1	0.3	partly cloudy; 0-3 mph NW wind; depth calibrated
10/22/2018	10:59	28.73	1.52	6	22.5	0.008	0.522	0.313	1.820	1.6	0.6	

Appendix B. Quality Assurance

Table B-1 provides the amount of instrument drift for specific conductivity, dissolved oxygen (collected with optical sensor), and pH. The temperature thermistor was checked against a NIST thermometer on May 31, 2018 and difference was 0.04° C.

Table B-1. Instrument drift for Lake St. Clair sample days in 2018.

Date	SPC (µS/cm)	ODO (% sat)	pH (std units)
5/23/2018	0	-0.13	0.02
6/27/2018	-3.3	-0.85	0.07
7/18/2018	2.2	-0.82	0.11
8/15/2018	1.5	-0.01	0.17
9/19/2018	0.1	-0.29	-0.05
10/24/2018	-0.1	-0.03	0.01
% difference	0.01	-0.36	0.78

TCEH collected 10% field replicates and one blank lab sample each day. For the dates that Lake Lawrence was sampled, field replicates were collected for chlorophyll-a, phaeophytin-a and both nutrients (Table B-2).

Table B-2. Precision of field replicates collected at Lake St. Clair in 2018.

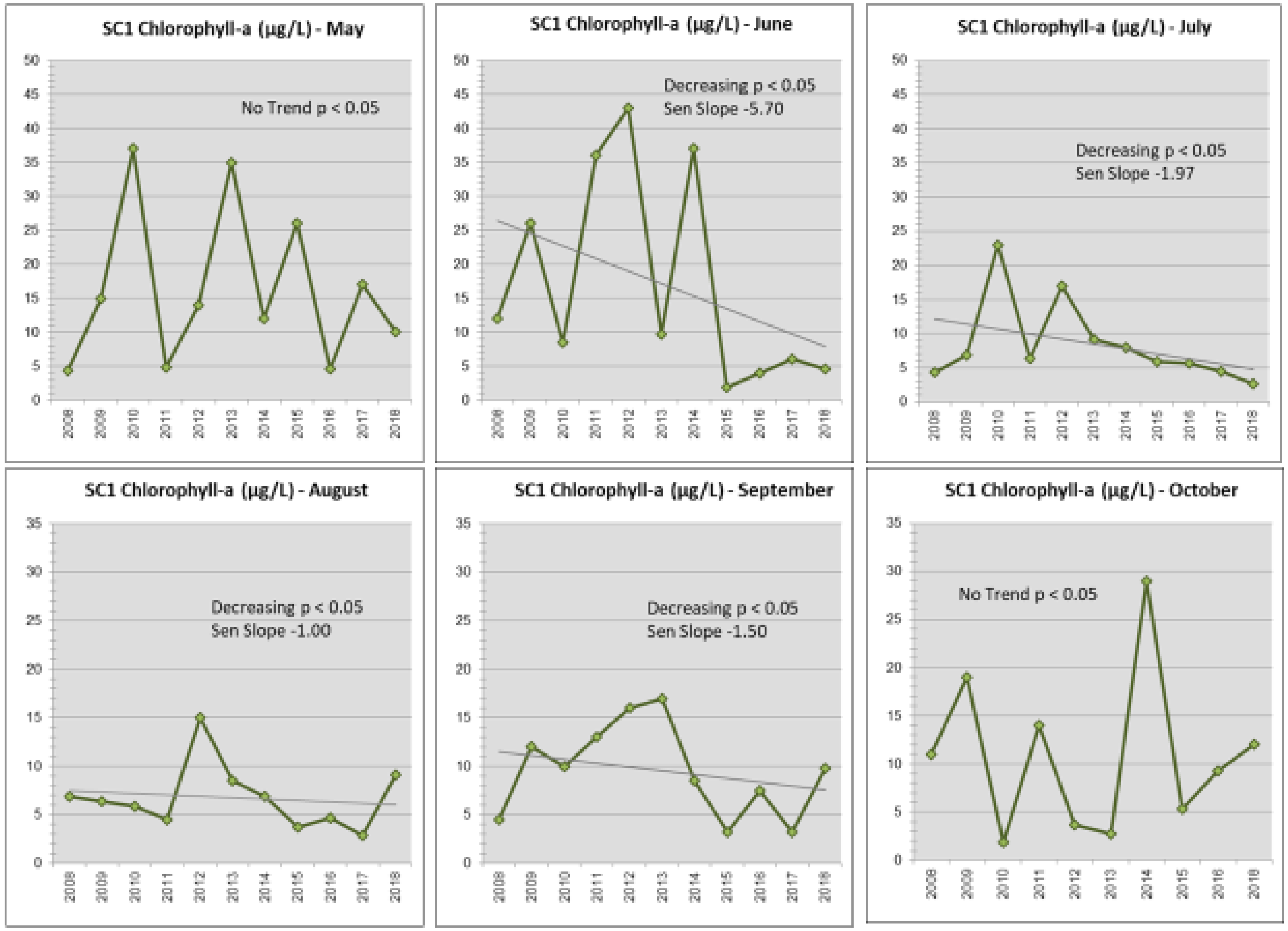
Site	Datetime	sample	field replicate	Relative Percent Difference
SC1 Surface TP	7/16/2018 11:47	0.023	0.024	4.26
SC1 Bottom TP	7/16/2018 11:47	0.187	0.191	2.12
			Relative Standard Deviation TP samples:	***1.18***
SC1 Surface TN	7/16/2018 11:47	0.584	0.565	3.31
SC1 Bottom TN	7/16/2018 11:47	1.683	1.660	1.38
			Relative Standard Deviation TN samples:	***0.93***
SC1 Chlor-a	7/16/2018 11:47	2.70	2.70	0.00
			Relative Standard Deviation Chlor-a samples:	**0.00**
SC1 Phaeo-a	7/16/2018 11:47	0.90	0.70	25.00
			Relative Standard Deviation Phae-a samples:	**12.50**

Appendix C. Trends

Trends
2008 to 2018

Lake St. Clair
Site SC1

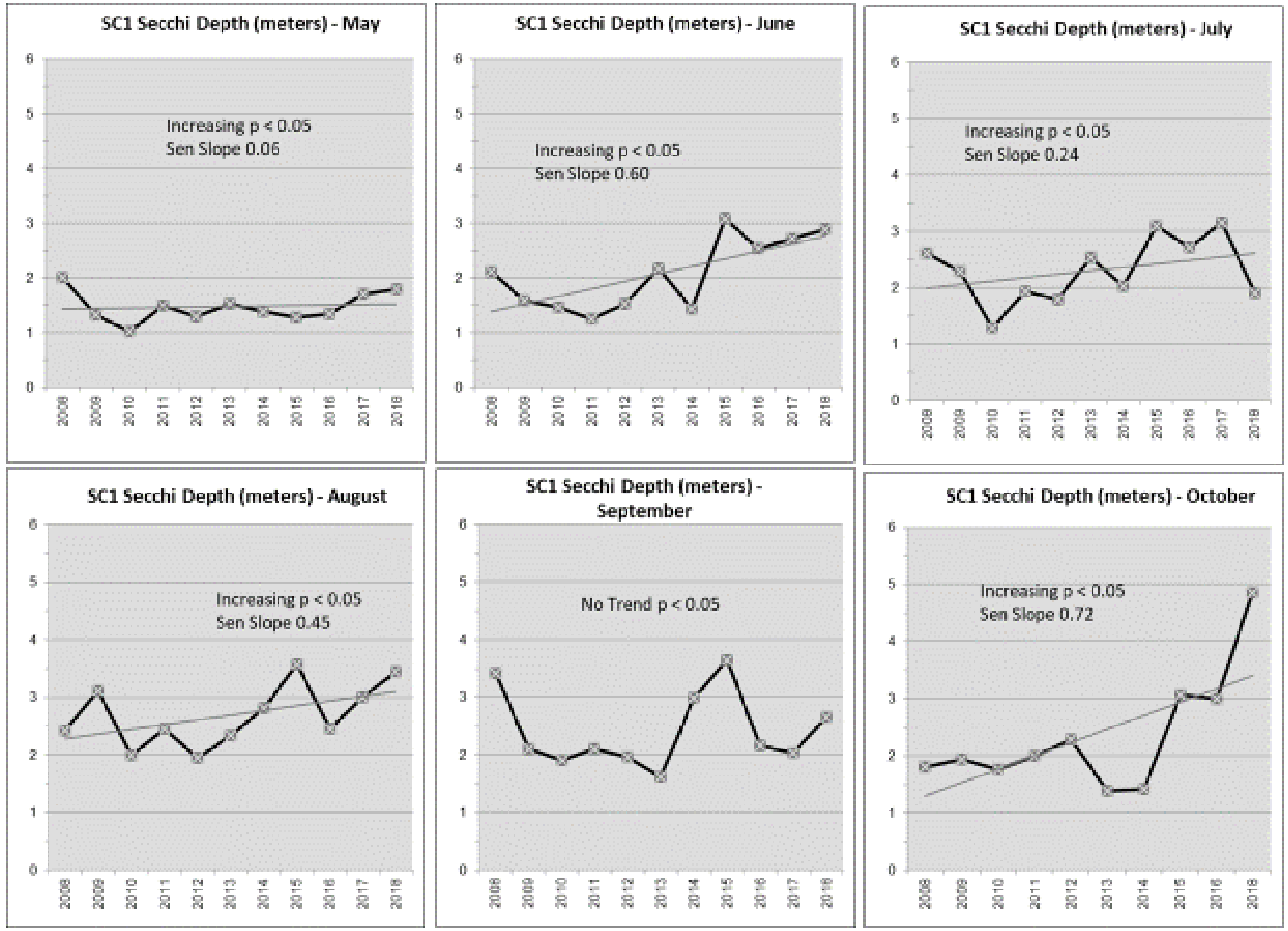
Chlorophyll-a concentration (µg/L)



Trends
2008 to 2018

Lake St. Clair
Site SC1

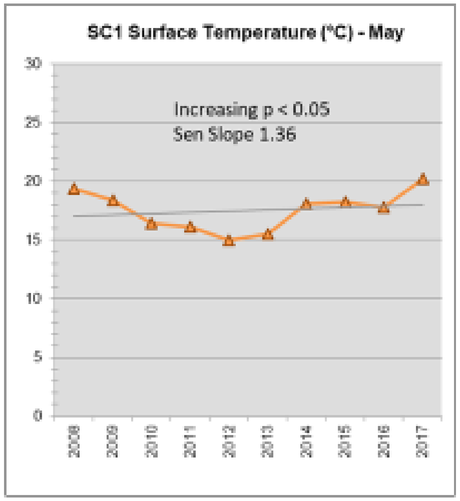
Secchi Depth
(meters)

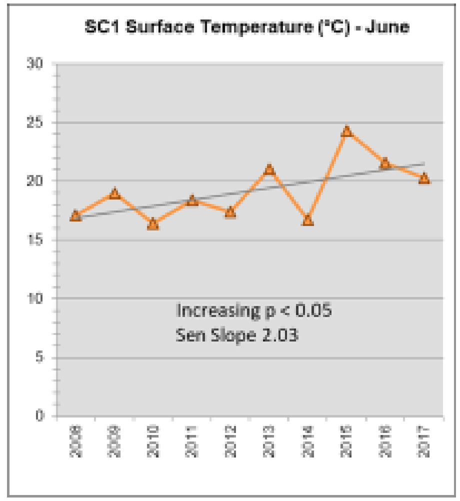


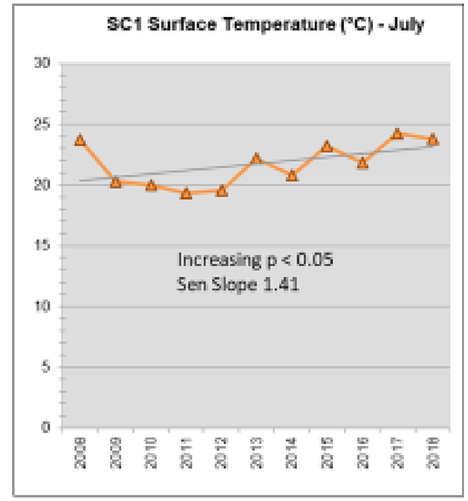
Trends
2008 to 2018

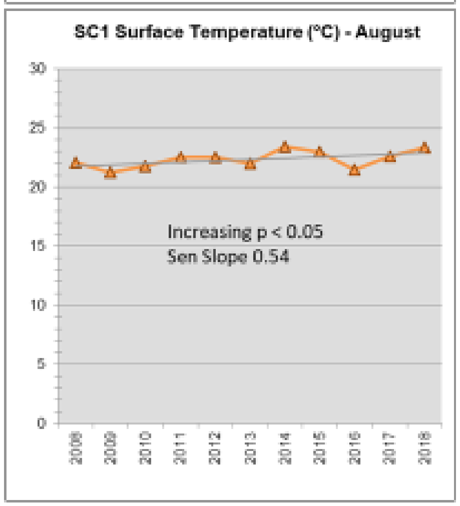
Lake St. Clair
Site SC1

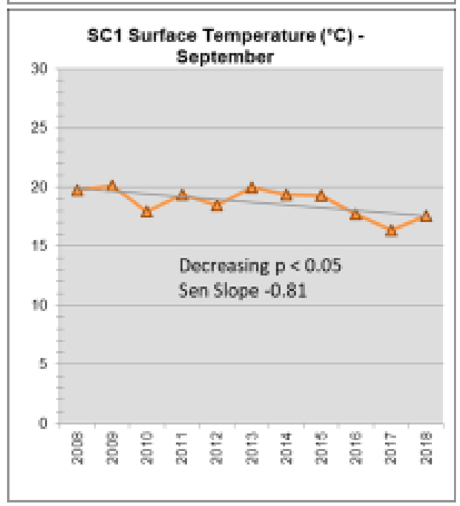
Surface
Temperature
(°C)

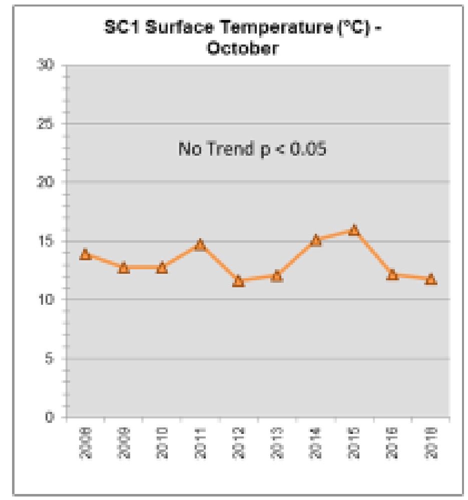








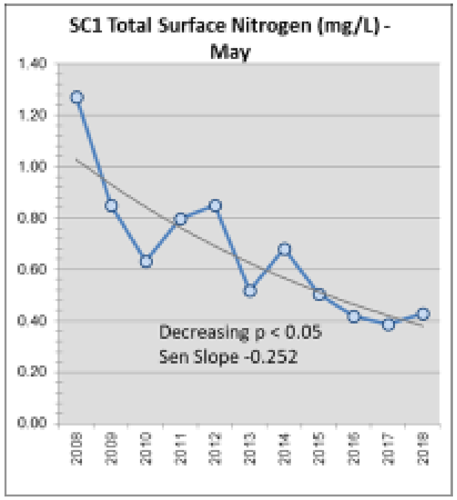


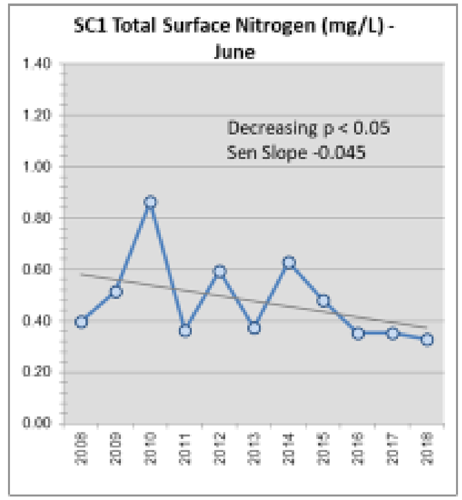


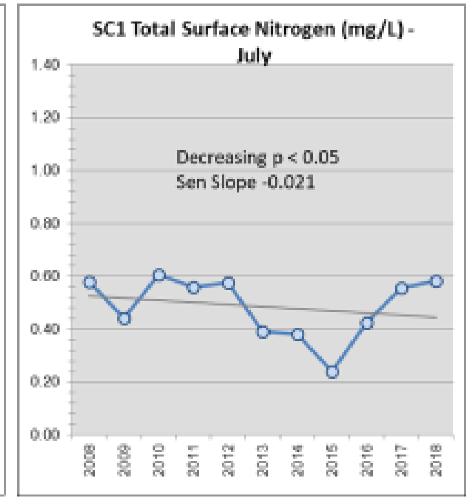
Trends
2008 to 2018

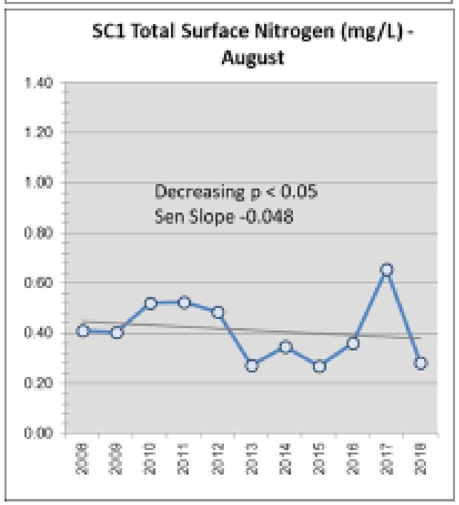
Lake St. Clair
Site SC1

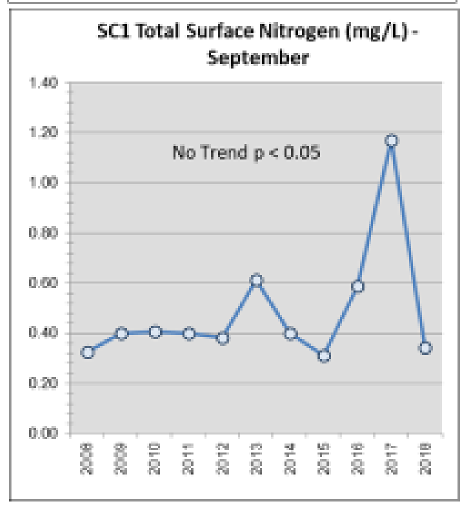
Total Nitrogen (TN) concentration (mg/L)

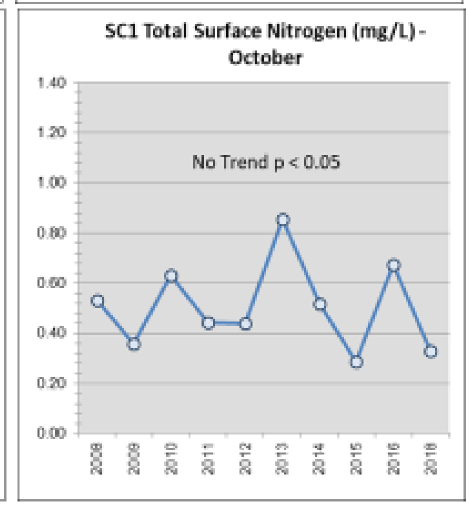








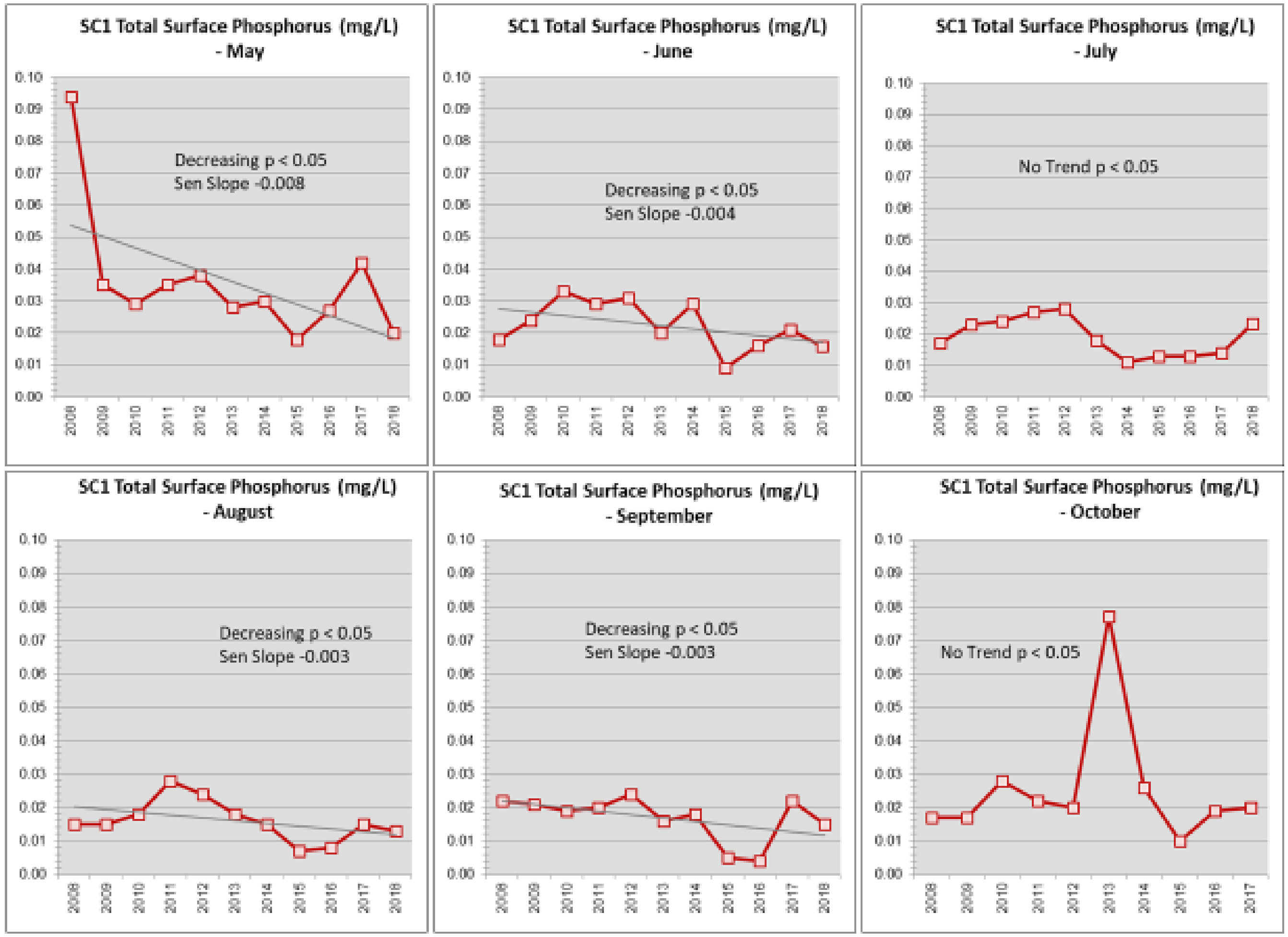




Trends
2008 to 2018

Lake St. Clair
Site SC1

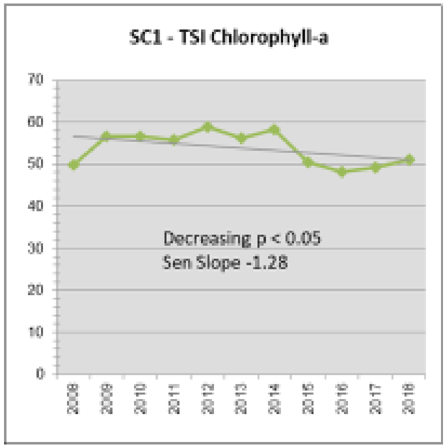
Total Phosphorus
(TP)
concentration
(mg/L)

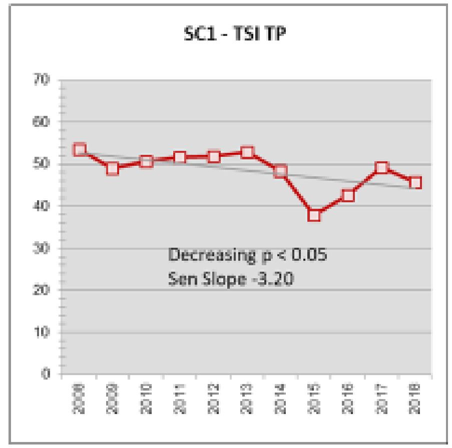


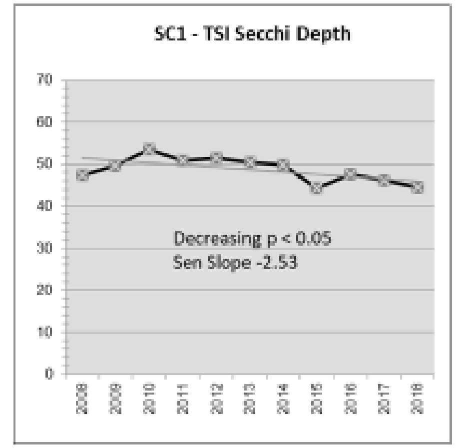
Trends
2008 to 2018

Lake St. Clair
Site SP1

TSI Values



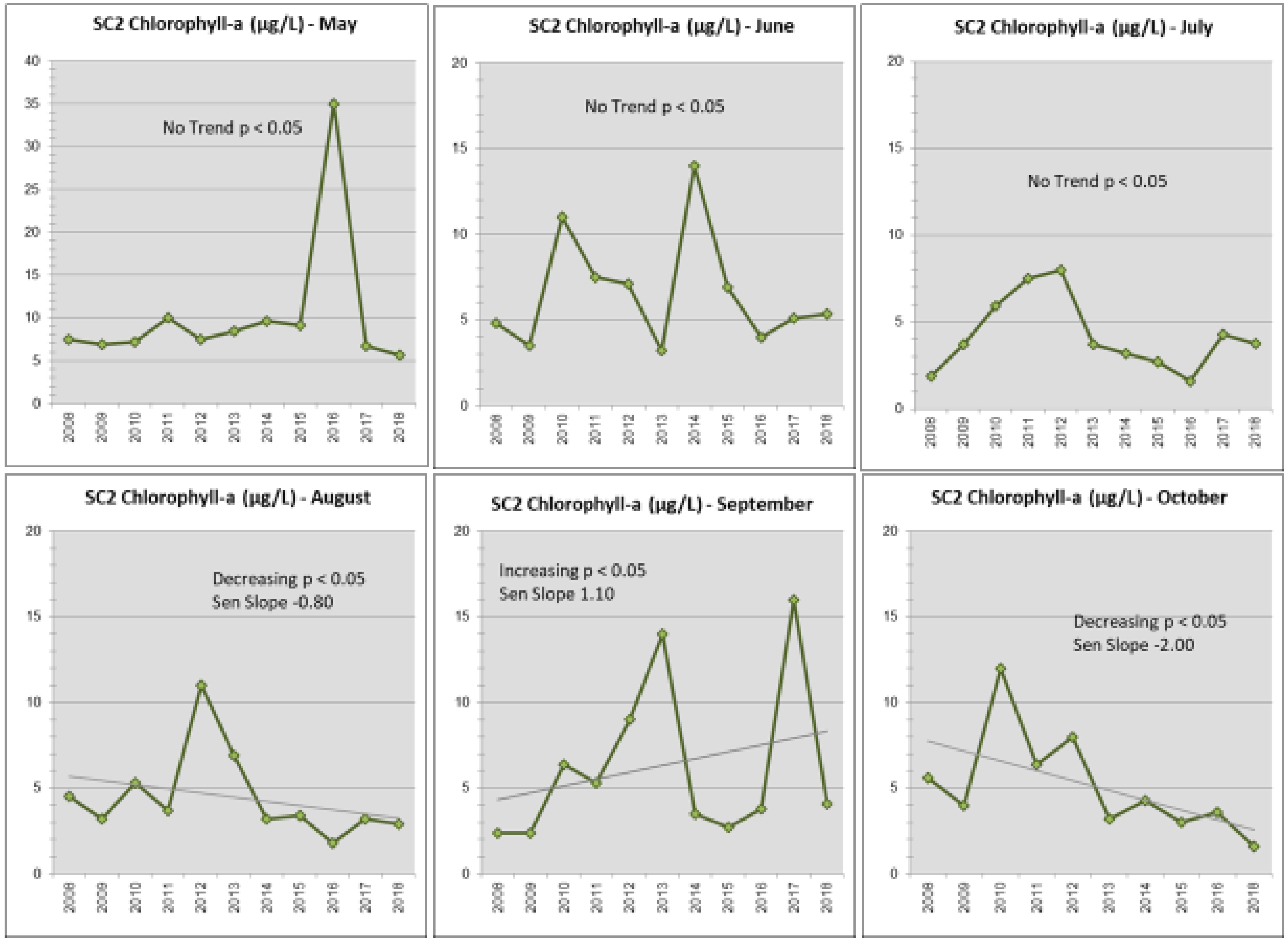




Trends
2008 to 2018

Lake St. Clair
Site SC2

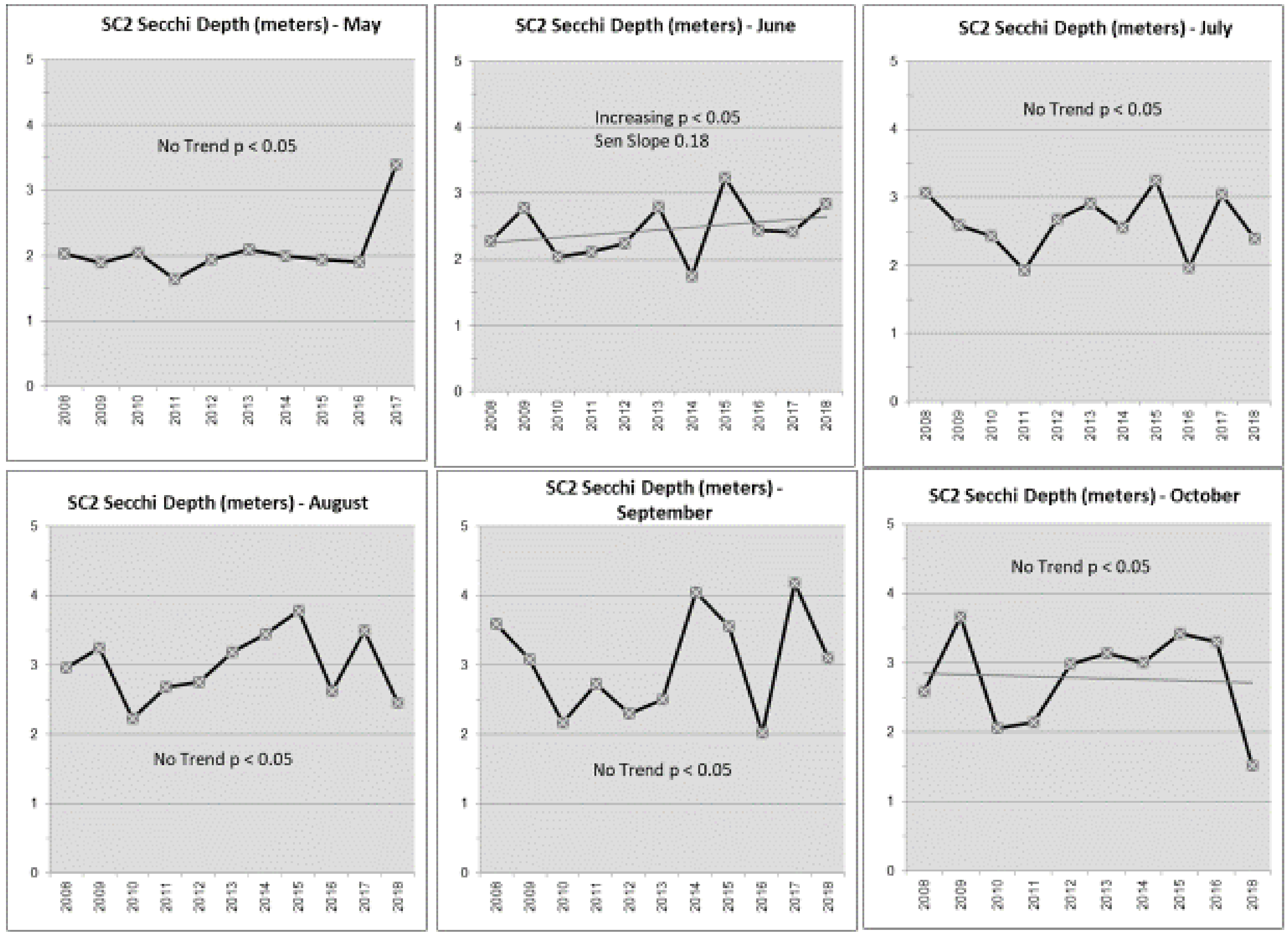
Chlorophyll-a
concentration
(µg/L)



Trends
2008 to 2018

Lake St. Clair
Site SC2

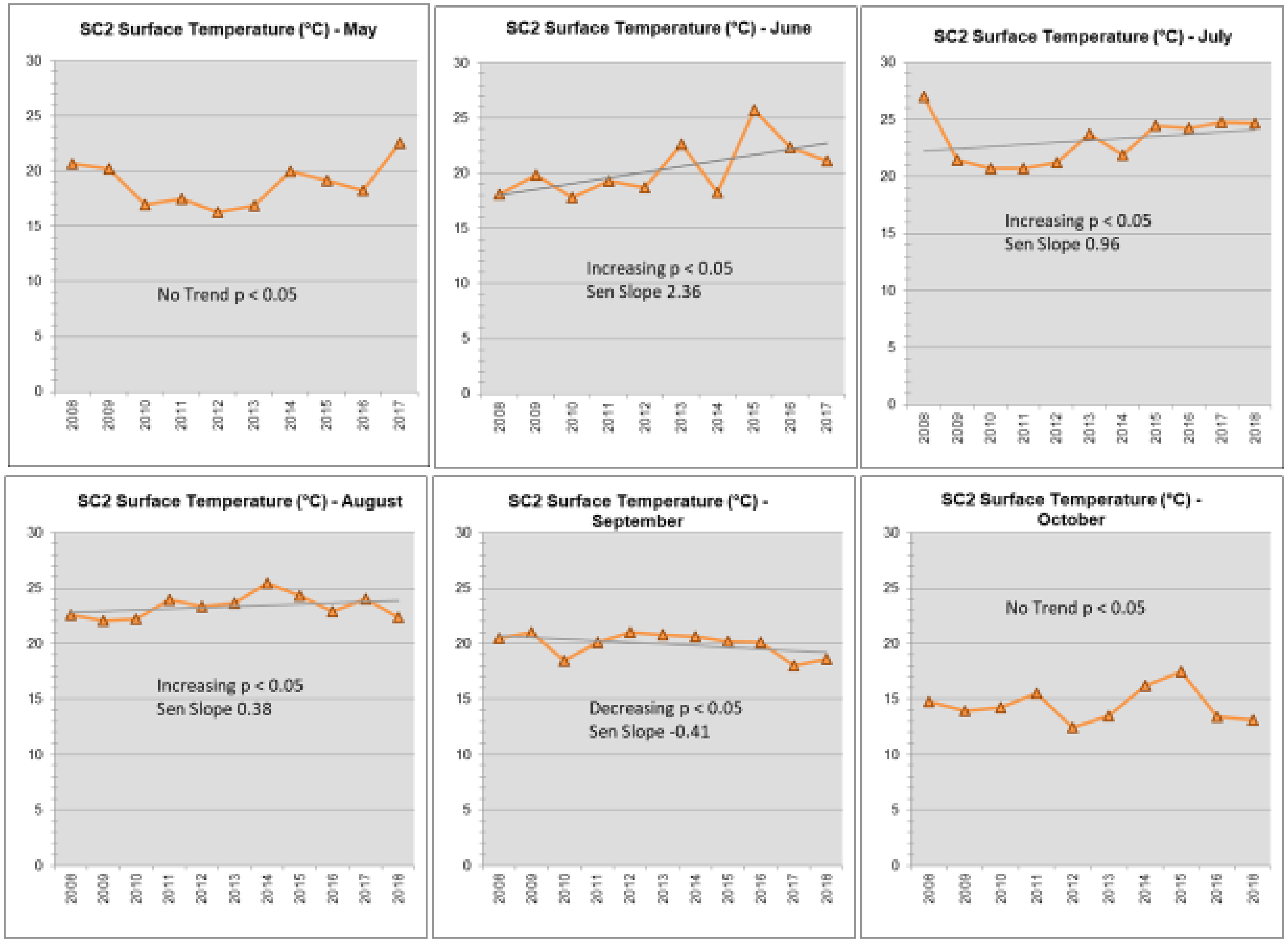
Secchi Depth
(meters)



Trends
2008 to 2018

Lake St. Clair
Site SC2

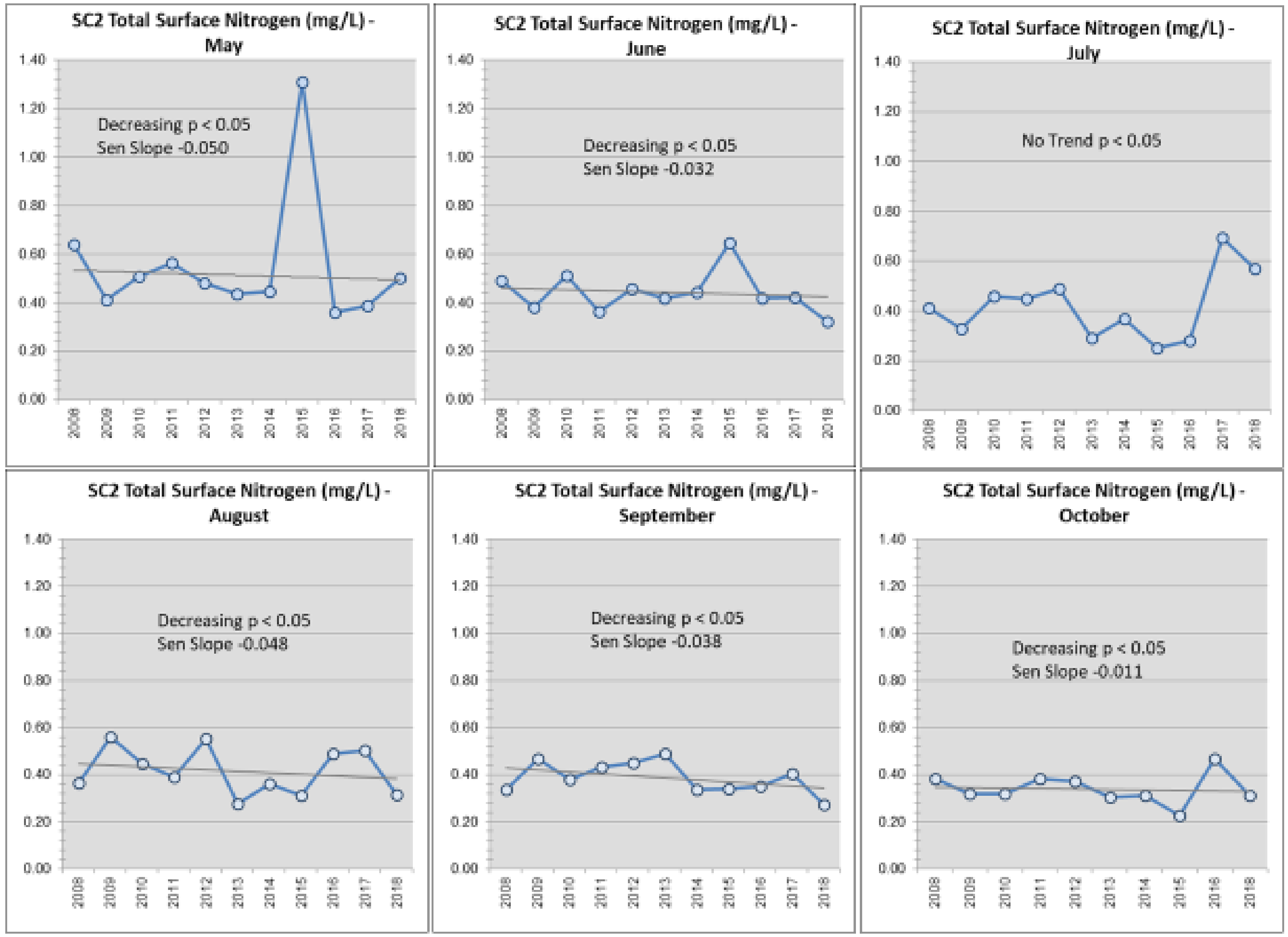
Surface
Temperature
(°C)



Trends
2008 to 2018

Lake St. Clair
Site SC2

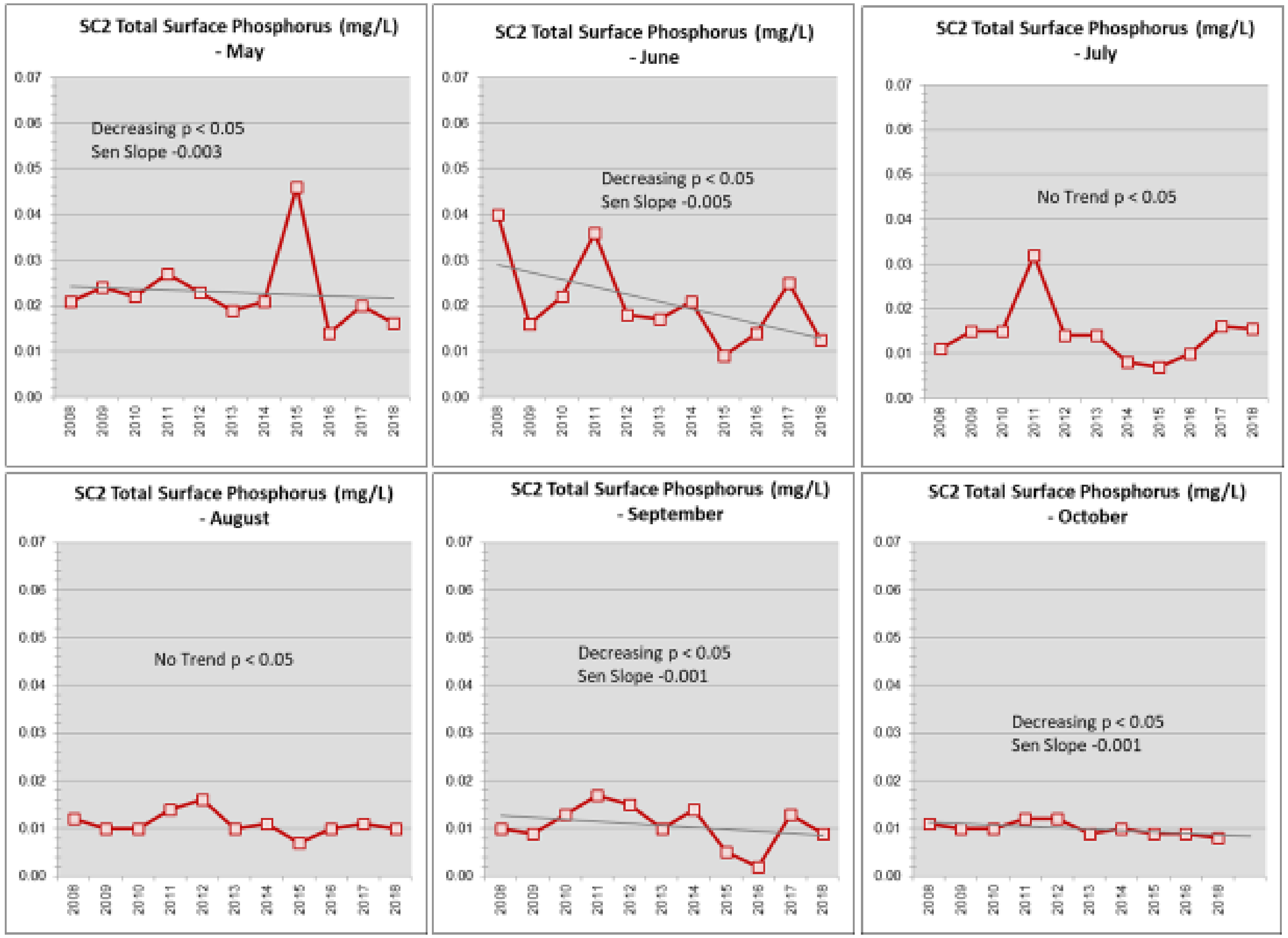
Total Nitrogen (TN) concentration (mg/L)



Trends
2008 to 2018

Lake St. Clair
Site SC2

Total Phosphorus
(TP)
concentration
(mg/L)



Trends
2008 to 2018

Lake St. Clair
Site SP2

TSI Values