2018 and 2019 Offutt Lake Water Quality Report

Prepared by Thurston County Environmental Health Division

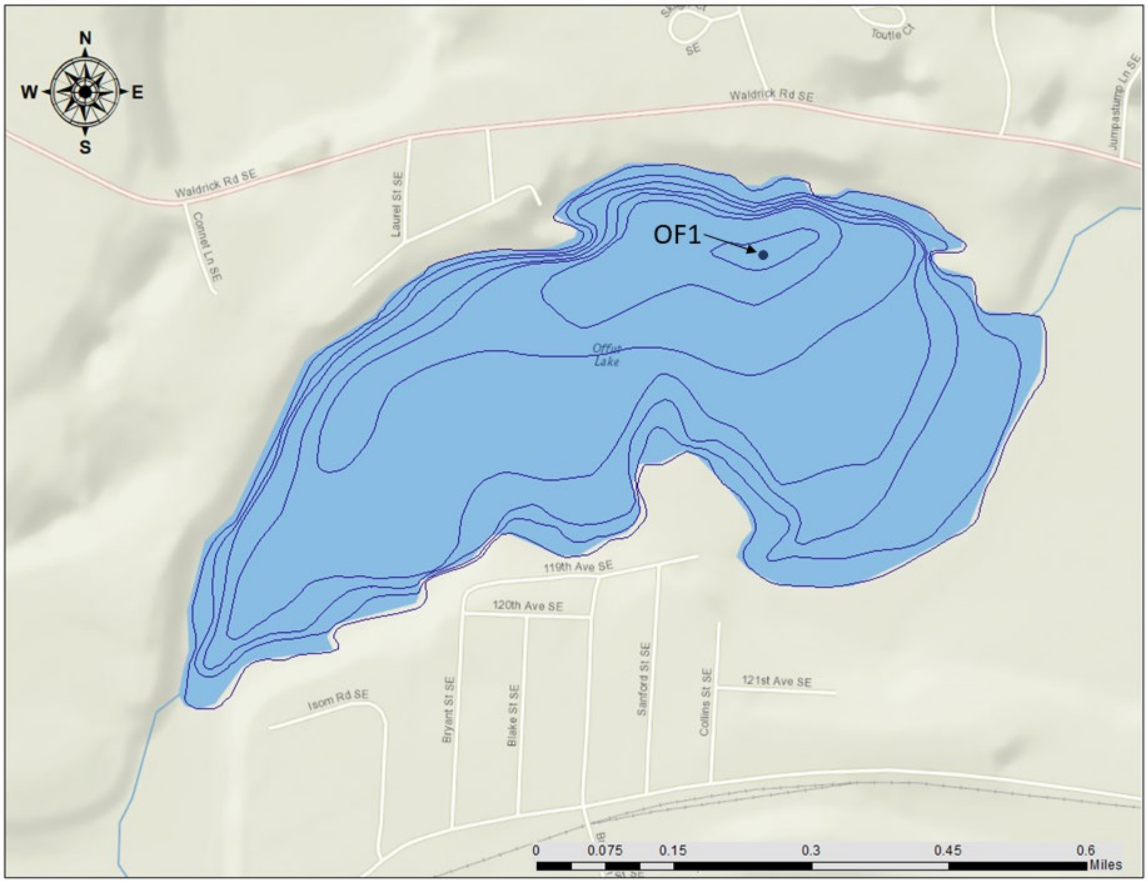


Figure 1. Offutt Lake map showing location of sample site OF1.

PART OF DESCHUTES RIVER WATERSHED

- **SHORELINE LENGTH**: 2.9 miles
- **LAKE SIZE**: 0.30 square miles (195 acres)
- **BASIN SIZE**: 2.7 square miles
- **MEAN DEPTH**: 4.6 meters (15 feet)
- **MAXIMUM DEPTH**: 7.6 meters (25 feet)
- **VOLUME**: 2,900 acre-feet

PRIMARY LAND USES:
The Offutt (also spelled Offut) Lake watershed is primarily suburban residential with some undeveloped forest cover primarily in wetland areas. The sample site OF1 is near a private swim area on the northern side of the lake (Figure 1).

PRIMARY LAKE USE:
Offutt Lake is used for fishing, swimming, and boating (5 mph).

PUBLIC ACCESS:
The Washington Department of Fish and Wildlife operates one public boat launch on the north side of the lake off 116th Ave SE.

GENERAL TOPOGRAPHY:
Offutt Lake is a Puget Sound lowland lake at an elevation of 234 feet above mean sea level.

GENERAL WATER QUALITY:
Fair – The average of three TSI values categorized Offutt Lake is eutrophic in 2018 and mesotrophic 2019. The surface TP concentration exceeded the action level for mesotrophic lakes both years. Based on the surface TP concentration alone, Offutt lake would be classified as eutrophic in both 2018 and 2019. There were multiple reports of algal blooms with surface scum in 2018, but none of the samples exceeded the Washington Advisory level for algal toxins.

DESCRIPTION

Offutt Lake is located eleven miles south of Olympia in Thurston County, Washington. This relatively shallow lake (maximum depth 7.6 meters) has one small perennial inlet stream and one outlet stream that flows to the Deschutes River. The lake is also fed by several springs (Bortleson et al., 1976).

Approximately 60% of the shoreline has been developed, primarily for single-family residences. Most of the development is on the north and south shorelines, with 45 to 50 developed parcels on each side. The Offutt Lake Resort, along with other community and commercial properties are on the south shore. The undeveloped eastern shore (20% of the total shoreline) has wetlands and both submerged and emergent aquatic macrophytes. The remaining 20% of shoreline on the western side of the lake is bordered by larger parcels of undeveloped land that supports forest and grasslands.

Soils in the watershed include:

- Everette very gravelly sandy loam (3 to 30%): deep excessively drained soil on terraces and outwash plains
- Spanaway gravelly sandy loam (3 to 15% slopes): very deep, somewhat excessively drained soil on terraces
- Godfrey silty clay loam (0 to 3 % slope): deep, poorly drained soil in depressions on flood plains
- Mukilteo muck (0 to 2% slope): very deep, very poorly drained soils in upland depressions

The Washington Department of Fish and Wildlife (WDFW) maintains a public boat ramp on the north side of the lake which is open year-round. WDFW stocks with rainbow trout, cutthroat trout, and occasionally brown trout. The most abundant fish is largemouth bass, followed by rainbow trout. The lake also supports populations of yellow perch, brown bullhead catfish, pumpkinseed sunfish, largescale suckers, redside shiner, and sculpin. Coho salmon have been collected in Offutt lake and may have entered the lake as smolts when the Deschutes River flooded (Couto and Caromile, 2007). In 2006, Offutt Lake was listed as Category 5 (polluted waters requiring clean-up) for polychlorinated biphenyls (PCBs) and Category 2 (waters of concern) for 2,3,7,8-tetrachlorodibenzo-P-dioxin (2,3,7,8-TCDD, also referred to simply as dioxin) in fish tissue. These listings are a result of a 2006 toxicology study of largemouth bass, rainbow trout, and yellow perch.

METHODS

In 2018 and 2019, Thurston County Environmental Health (TCEH) conducted monthly monitoring at Offutt Lake from May to October. Figure 1 shows the sample site OF1, located in the deepest part of the lake. Table 1 lists the types of data collected (TCEH, 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 (3 to 4 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.

RESULTS

Weather Conditions

Weather conditions during the 2018 and 2019 sample season are provided in Table 2.

Table 2. Weather on 2018 and 2019 sample days and the average, minimum, and maximum air temperatures for each month from Camelot-KWAOLYMP150 weather station.

Month	2018 Weather on Sample Day	2018 Temperature (° C) Monthly Average (Low/High)	2019 Weather on Sample Day	2019 Temperature (° C) Monthly Average (Low/High)
May	Fair (21°C); 0-3 mph Variable wind	13 (2/31)	Partly cloudy, (13°C); 0-5 mph S wind	13 (2/30)
June	Mostly cloudy (19°C); 0-6 mph SSW wind	14 (4/32)	Partly cloudy, (18°C); 0-13 mph W wind	15 (4/33)
July	Partly cloudy, (23°C); 0-7 mph W wind	19 (6/34)	Partly cloudy, (13°C); 0-5 mph S wind	19 (8/32)
August	Hazy from wildfire smoke, (27°C); 0-5 mph NNE wind	18 (7/35)	Fair (22°C); 0-6 mph ENE wind	18 (7/33)
September	Fair (18°C); 0-6 mph Variable wind	13 (2/29)	Cloudy (18°C); 0-8 mph WSW wind	14 (-1/26)
October	Cloudy (11°C); 0 mph Calm	9 (0/22)	Fair to partly cloudy (14°C); 0-8 mph WSW wind	8 (-6/18)

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 Offutt Lake changed over the sample seasons in 2018 and 2019 (Figures 3 to 7).

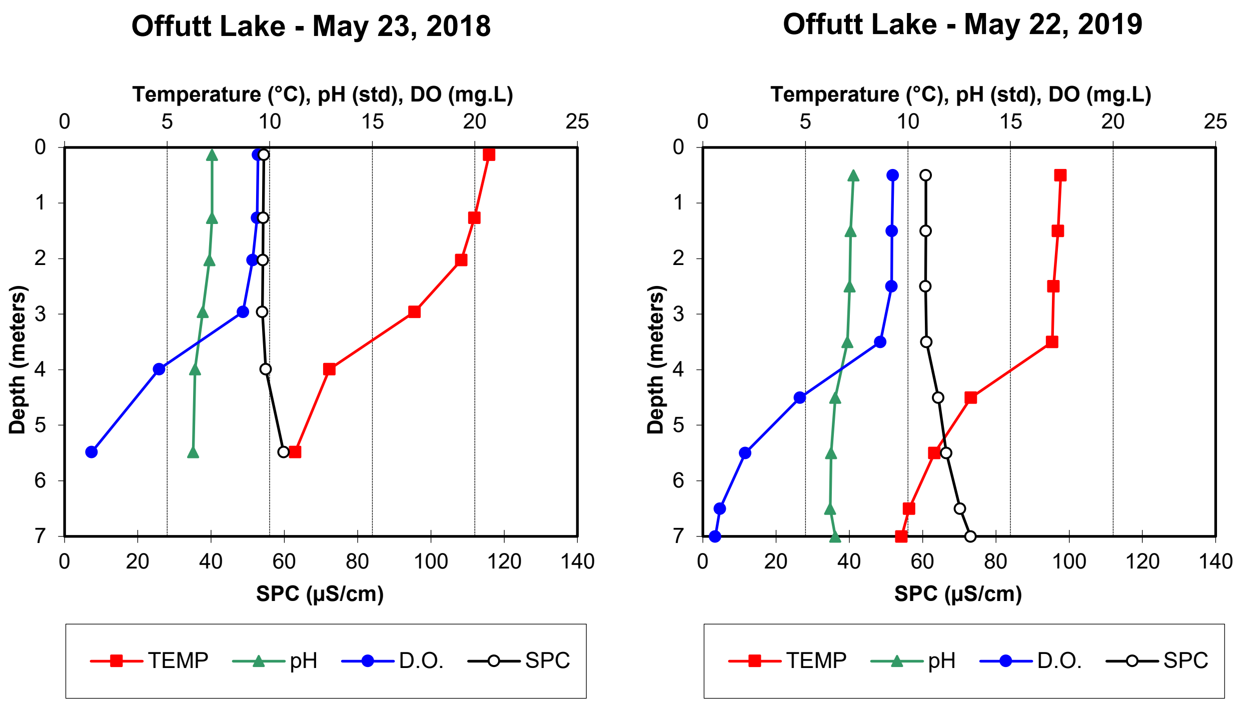


Figure 3. Vertical water quality profiles for OF1 collected in May 2018 and 2019.

In May, a layer of warm water floated on a layer of cooler, denser water below. Stratification was starting, but the layers were not yet well defined. In 2018, the sample day was 8°C warmer and the upper water column was 3°C warmer compared to 2019.

- May 2018 Epilimnion – Temp 20.3°C; DO 9.4 mg/L
- May 2018 Hypolimnion – Temp 11.2°C; DO 1.3 mg/L

In 2019, upper layer was cooler and extended two meters deeper than in May 2018. Uniform temperature in this upper layer indicates mixing. Below 3 meters depth, the profile shows sharp density difference in deeper water.

- May 2019 Epilimnion – Temp 17.3°C; DO 9.2 mg/L
- May 2019 Hypolimnion – Temp 9.9°C; DO 0.7 mg/L

In both 2018 and 2019, a clinograde DO curve was forming. The epilimnion had much higher DO because this layer gained oxygen from the atmosphere and photosynthesis. Oxygen consuming processes or advection of low oxygen groundwater produced anoxic conditions in the hypolimnion.

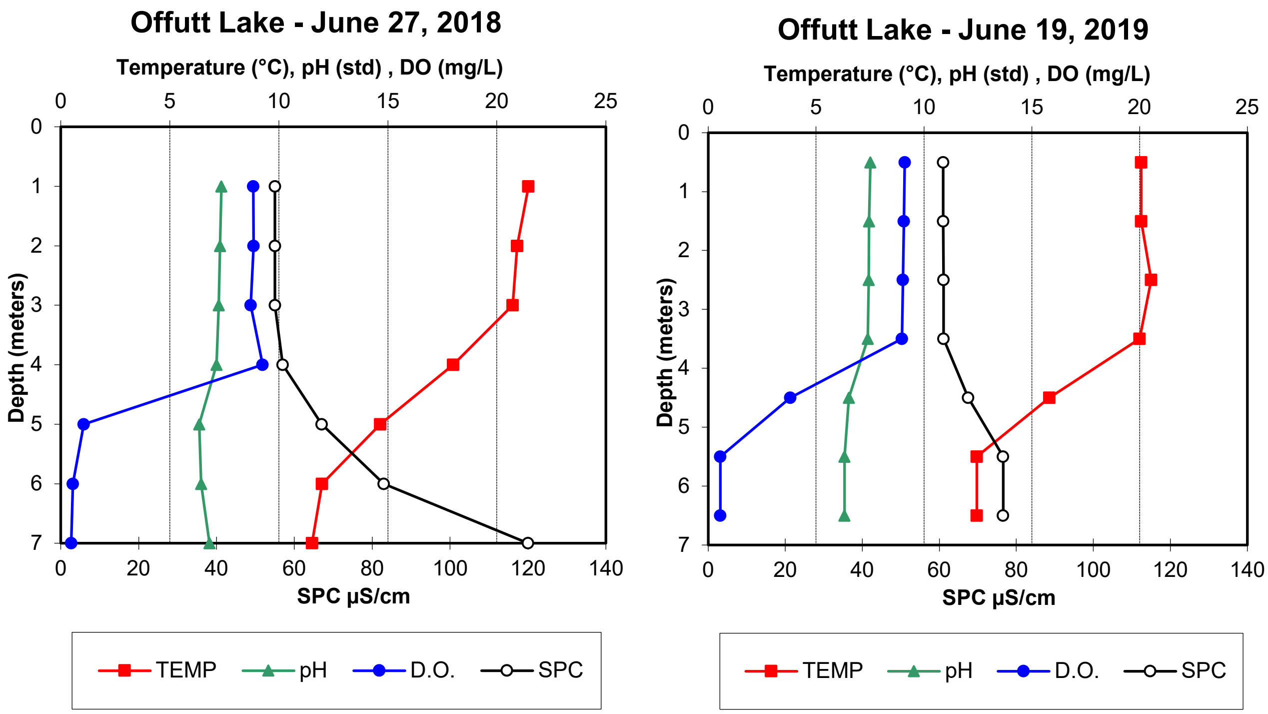


Figure 4. Vertical water quality profiles for OF1 collected in June 2018 and 2019.

In June, the average daily air temperature increased, heating the epilimnion. This heat was retained because the overnight air temperature remained warmer, as well (Table 2). In June 2018, the epilimnion grew over two meters deeper than it was in May.

- June 2018 Epilimnion – Temp 21.0°C; DO 8.8 mg/L
- June 2018 Hypolimnion – Temp 11.8°C; DO 0.5 mg/L

The dissolved oxygen (DO) profile was a weak positive heterograde curve. The water column was sufficiently transparent (3.4 meters Secchi depth) to permit photosynthesis in deeper water, where excess oxygen accumulated due to the reduced mixing of the water column (Wetzel, 1983).

In 2019, the epilimnion depth remained about the same depth (3.5 meters) throughout stratification.

- June 2019 Epilimnion – Temp 20.2°C; DO 9.1 mg/L
- June 2019 Hypolimnion – Temp 12.5°C; DO 0.6 mg/L

The DO curve was clinograde in June 2019. The concentration of DO in the hypolimnion was low due to redox processes in the hypolimnion, which was isolated from more oxygenated water above by density differences during thermal stratification.

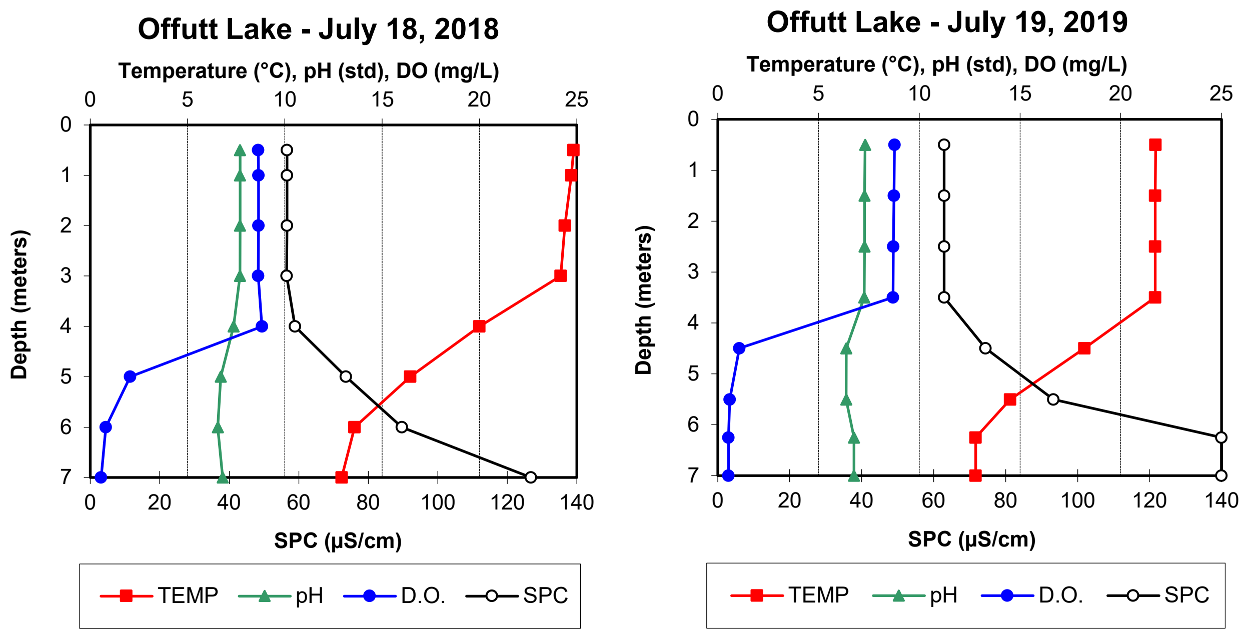


Figure 5. Vertical water quality profiles for OF1 collected in July 2018 and 2019.

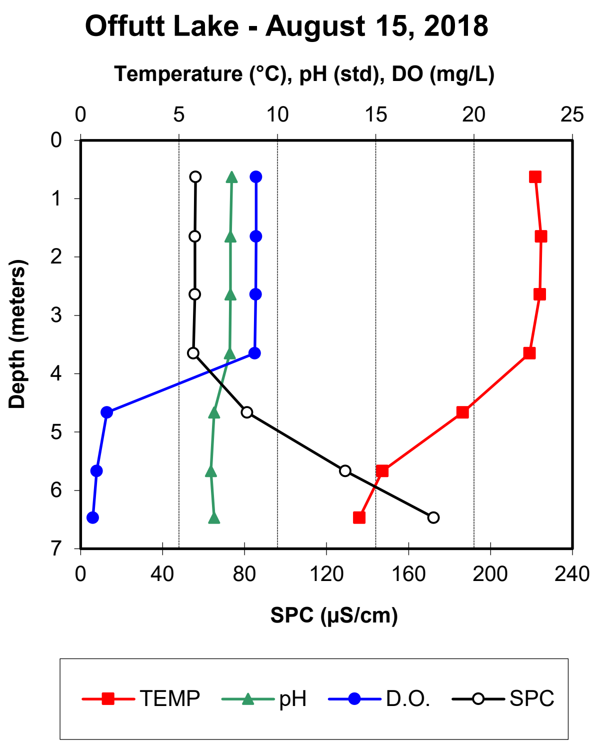
Average air temperatures reached the summer maximum in July (Table 2), likewise epilimnion water temperatures peaked. Three distinct layers were readily discernable, indicating that density differences hindered mixing of the water column. The temperature difference between the epilimnion and hypolimnion was greatest in July in both 2018 and 2019 (Figure 5).

- 2018 July Epilimnion – Temp 24.5°C; DO 8.6 mg/L
- 2018 July Hypolimnion – Temp 13.3°C; DO 0.7 mg/L

In 2018, the dissolved oxygen (DO) profile was a very weak positive heterograde curve. Transparency remained relatively high (3.4 meters Secchi depth) in July, which permitted photosynthesis in deeper water. The oxygen supply was marginally higher in the cooler water in the metalimnion.

The DO curve was clinograde in June 2019. The concentration of DO in the hypolimnion was low, which was isolated from more oxygenated water above by density differences during thermal stratification.

- 2019 July Epilimnion – Temp 21.7°C; DO 8.7 mg/L
- 2019 July Hypolimnion – Temp 13.7°C; DO 0.6 mg/L



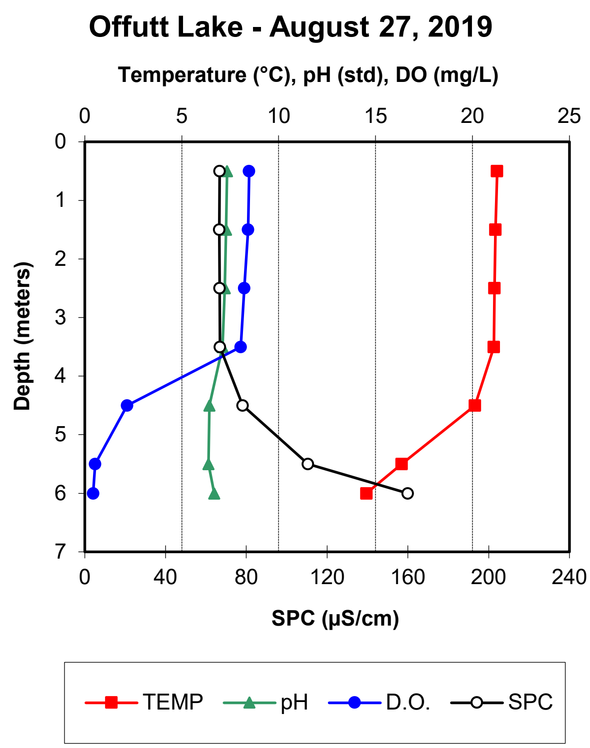


Figure 6. Vertical water quality profiles for OF1 collected in August 2018 and 2019.

The average air temperature cooled slightly in August, as did the temperature in the epilimnion. In 2018, the epilimnion reached a depth of 3.6 meters.

- 2018 August Epilimnion – Temp 23.2°C; DO 8.9 mg/L
- 2018 August Hypolimnion – Temp 16.3°C; DO 0.9 mg/L

In 2019, the epilimnion remained approximately the same depth (3.5 meters) from May until August.

- 2019 August Epilimnion – Temp 21.2°C; DO 8.3 mg/L
- 2019 August Hypolimnion – Temp 15.4°C; DO 0.5 mg/L

A clinograde curve was evident in August 2018 and 2019. Contact with the atmosphere and photosynthesis contributed to oxygen in the epilimnion. The hypolimnion was cut-off from the surface oxygen supply. Anoxic conditions were likely due to redox processes, like decomposition and advection of low oxygen groundwater.

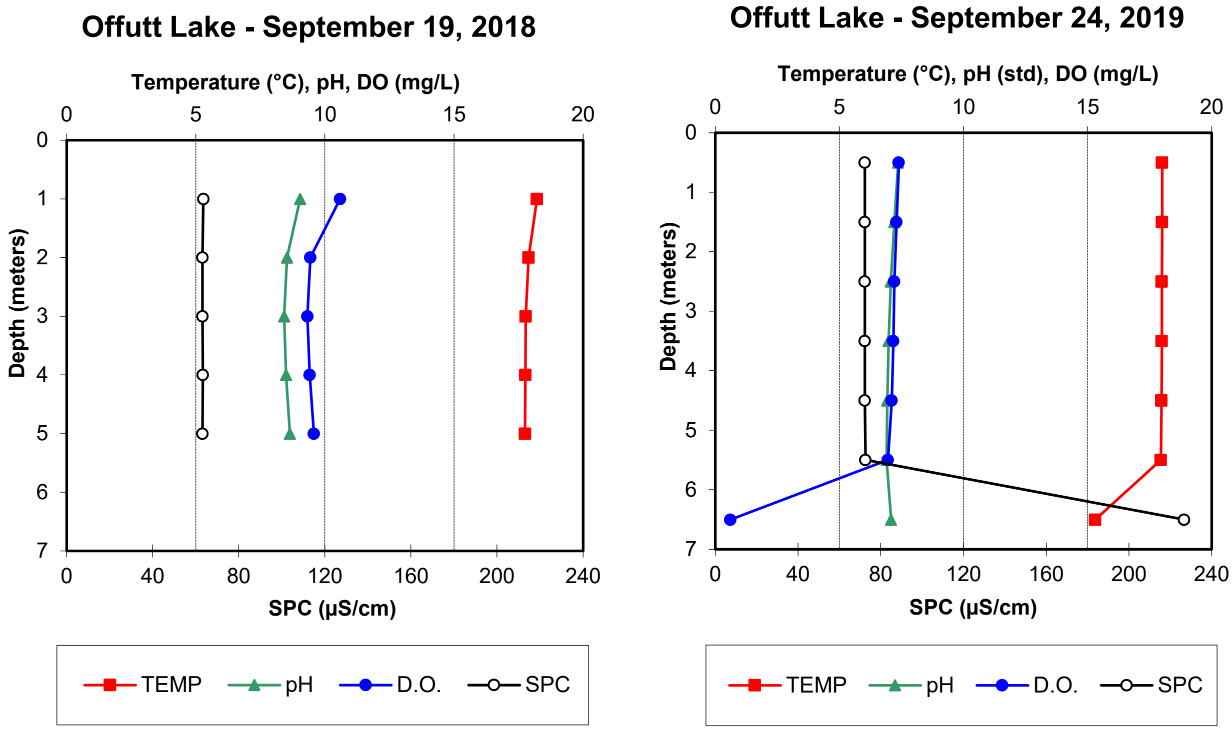


Figure 7. Vertical water quality profiles from OF1 collected in September 2018 and 2019.

In September, average air temperatures declined, especially overnight. The water columns began to mix. In 2018, the lake turned over and only the upper meter of surface water remained warmer and more oxygenated. Internal loading provided a phosphorus boost in in this phosphorus-limited lake. As a result, productivity boomed, and photosynthesis combined with cooler temperatures produced the maximum DO concentration for the season.

- September Photic Zone (Secchi Depth 0.8 meters) – Temp 18.2°C; DO 10.6 mg/L
- September Bottom Measurement (5 meters) – Temp 17.7°C; DO 9.6 mg/L

In 2019, the bottom of Offutt Lake was cold and anoxic. The lake had mixed to 5.5 meters depth. In contrast the 2018 sample season, the minimum DO concentration for the sample season occurred September. The surface oxygen supply declined each successive month from May until September.

- September Photic Zone (Secchi Depth 1.8 meters) – Temp 18.0°C; DO 7.4 mg/L
- September Bottom Measurement (5 meters) – Temp 15.3°C; DO 0.6 mg/L

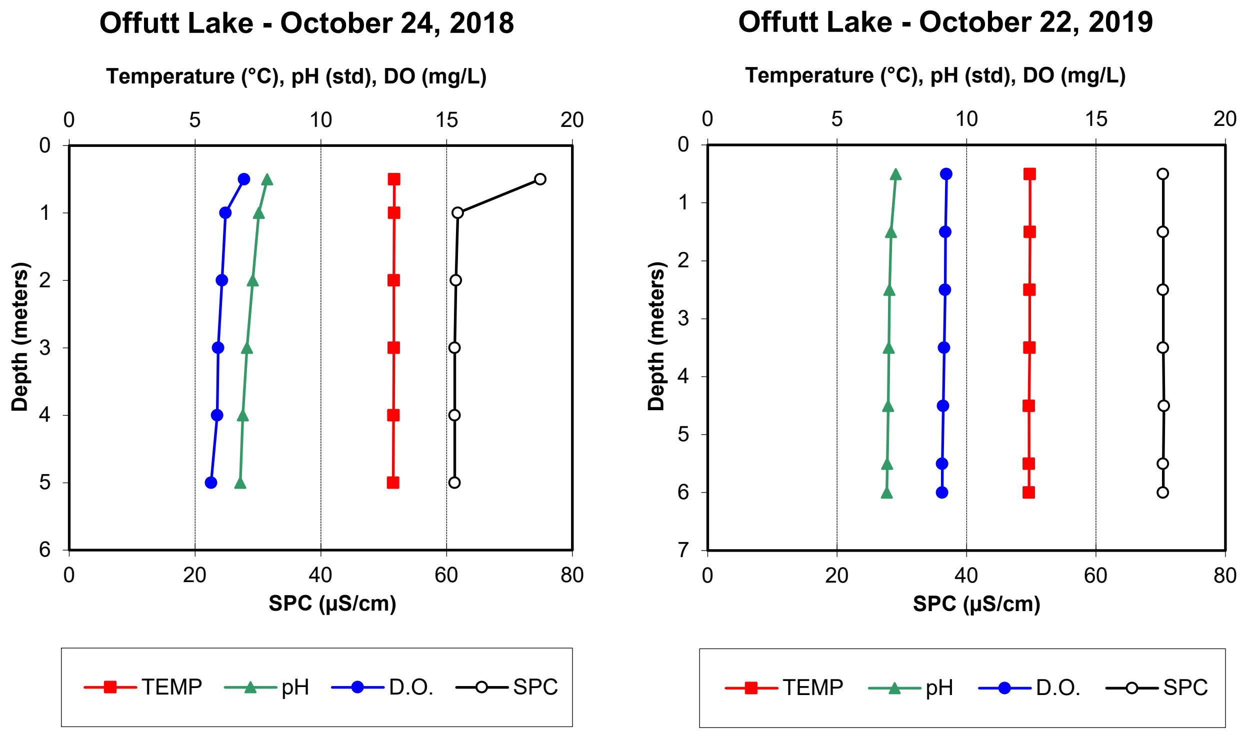


Figure 8. Vertical water quality profiles from OF1 collected in October 2018 and 2019.

In October, the weather turned colder. The surface water continued to cool and sink, diminishing vertical differences of water quality parameters. Offutt Lake was isothermal. The minimum surface temperature for the season occurred in October.

- October Photic Zone (Secchi Depth 2.1 meters) – Temp 12.9°C; DO 6.4 mg/L
- October Bottom Measurement (4.5 meters) – Temp 12.9°C; DO 5.6 mg/L

In October 2019, Offutt Lake completely turned over. The surface DO reached the maximum for the season, likely a result of cooler temperatures as productivity was below average.

- October Photic Zone (Secchi Depth 3.4 meters) – Temp 12.4°C; DO 9.2 mg/L
- October Bottom Measurement (4.5 meters) – Temp 12.4°C; DO 9.1 mg/L

Water Transparency and Color

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.

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.

Figures 9 and 10 show the Secchi depth (bar length), color (color of the bar), and chlorophyll-a concentration (purple line) at OF1 for 2018 and 2019.

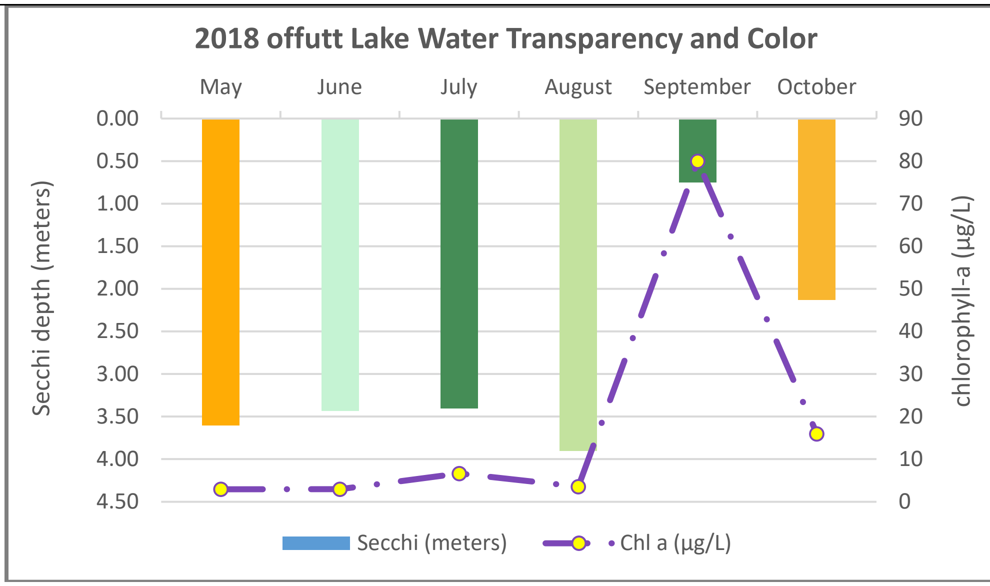


Figure 9. Water color, Secchi depths, and chlorophyll-a concentrations at OF1 in 2018.

In 2018, the mean transparency for the sample season was 2.9 meters (median 3.4 meters). Secchi depth was negatively correlated with the chlorophyll-a concentration. Productivity, as measured by the chlorophyll-a concentration, was lowest (mean 4.1 µg/L) in the early summer (May to August), when the mean Secchi depth was 3.6 meters. In September, when Offutt Lake turned over, internal loading increased the surface phosphorus by five times above the early summer mean, causing productivity to spike almost twenty times greater. Transparency plummeted from 3.6 meters (mean for May to August) to 0.8 meters in September during an algal bloom.

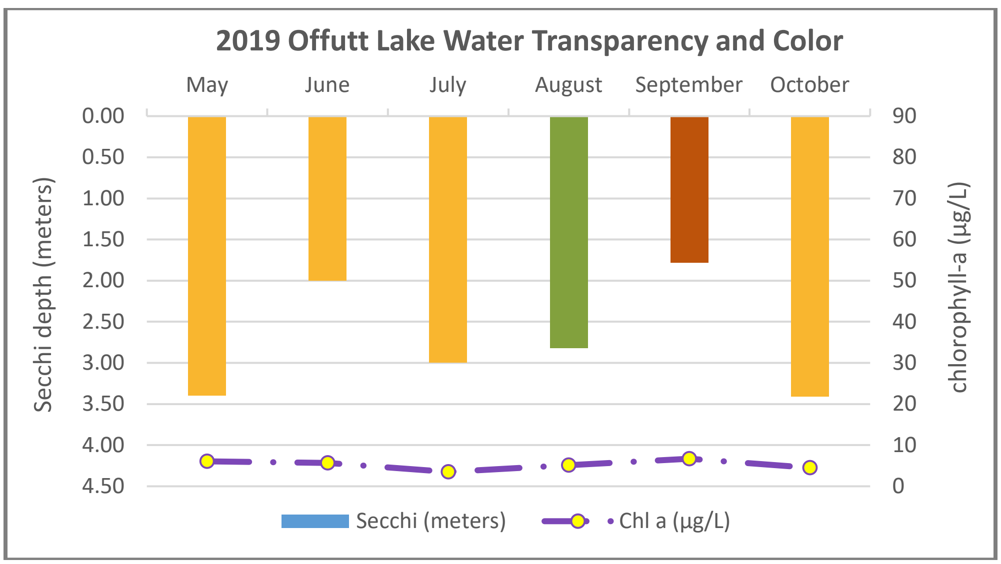


Figure 10. Water color, Secchi depths, and chlorophyll-a concentrations at OF1 in 2019.

For the 2019 season, the greatest Secchi depth (3.4 meters) occurred in May and October. The mean transparency was 2.7 meters (median 2.9 meters). Like 2018, the lowest transparency of the sample season occurred in September 2019, but the lake had not yet completely turned over. The surface TP in September 2019 was lower, less than three times higher than the early summer average.

The color of the water (shown as the bar color in Figures 10 and 11), based on the reference Custer Color Strip, varied more in 2018 compared to 2019. Lake color was likely affected by changes in the algae and cyanobacteria communities; phytoplankton identification would provide more information about productivity and phytoplankton assemblages.

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). 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). The ratio of chlorophyll-a to phaeophytin-a has been used as an indicator of the physiological condition of phytoplankton in the sample.

2018 and 2019 Productivity Data

In 2018, the concentration of chlorophyll-a crested after turnover in September (Figure 11) and remained higher than average in October. Transparency was lowest these two months; transparency was negatively correlated (R^2=0.86) to productivity (Appendix C). The surface supply of oxygen (10.6 mg/L) was highest in September, when productivity peaked. Phaeophytin-a spiked twice, once in June and again in September.

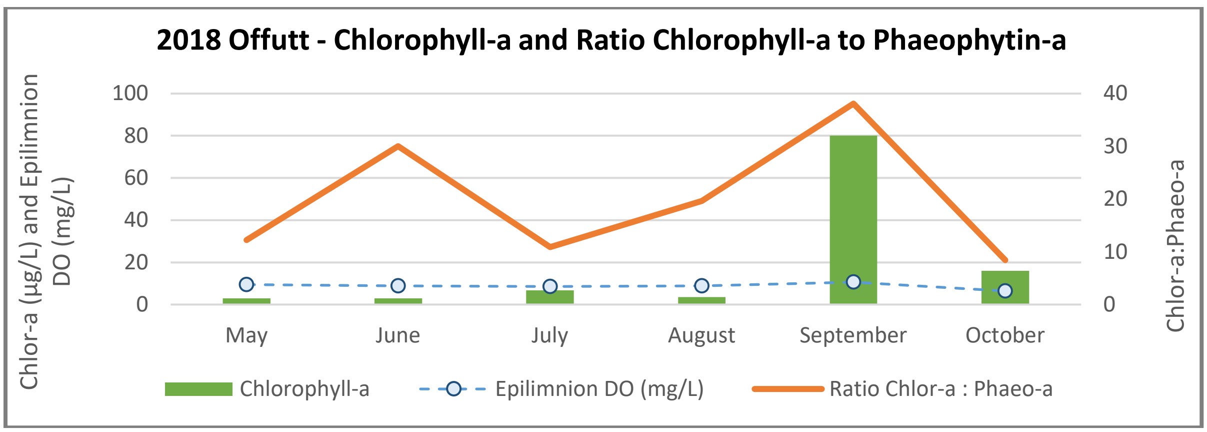


Figure 11. Chlorophyll-a concentration, ratio of chlorophyll-a to phaeophytin-a pigments, and DO concentration in the photic zone or epilimnion collected at OF1 in 2018.

Much like the 2018 sample season, productivity increased in September 2019 (Figure 12). The concentration of phaeophytin-a was highest in September, as well. Unlike 2018, the surface oxygen supply in September 2019 was at the minimal concentration (7.4 mg/L) for the sample season. Surface DO in May was 9.2 mg/L. It declined each successive month until the increase in October back to 9.2 mg/L. Transparency was not correlated to productivity (Appendix C).

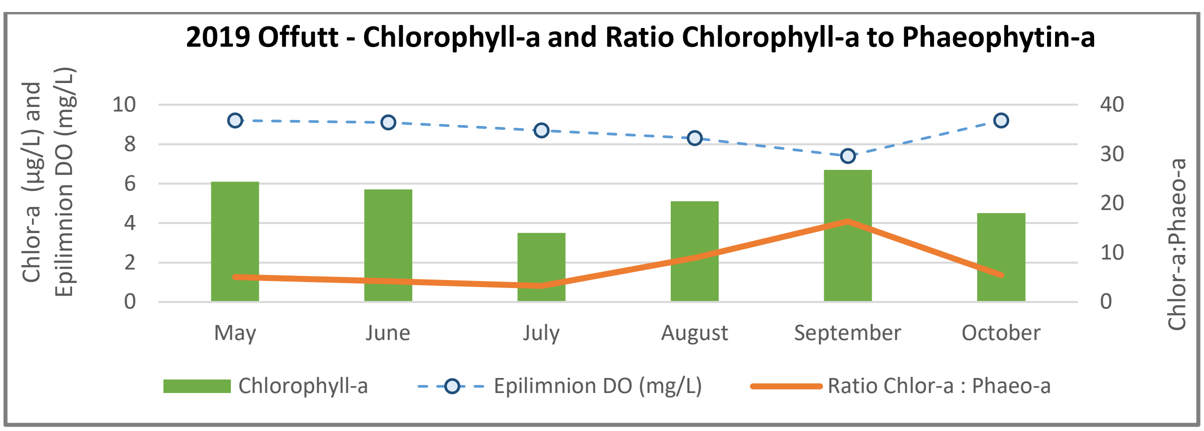


Figure 12. Chlorophyll-a concentration, ratio of chlorophyll-a to phaeophytin-a pigments, and DO concentration in the photic zone or epilimnion collected at OF1 in 2019.

Offutt Lake 2018 and 2019

In 2018, citizens reported algal blooms with surface scum in May, July, September, and October. During these blooms, TCEH collected five samples, which were tested algal toxins. None of the samples exceeded the Washington State Toxic Algae Advisory Level for microcystin, anatoxin-a, cylindrospermopsin, or saxitoxin. Offutt Lake was not sampled for toxic algae in 2019.

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). Figures 13 and 14 shows the total phosphorus (TP) and total nitrogen (TN) present in the surface waters at OF1 in 2018 and 2019.

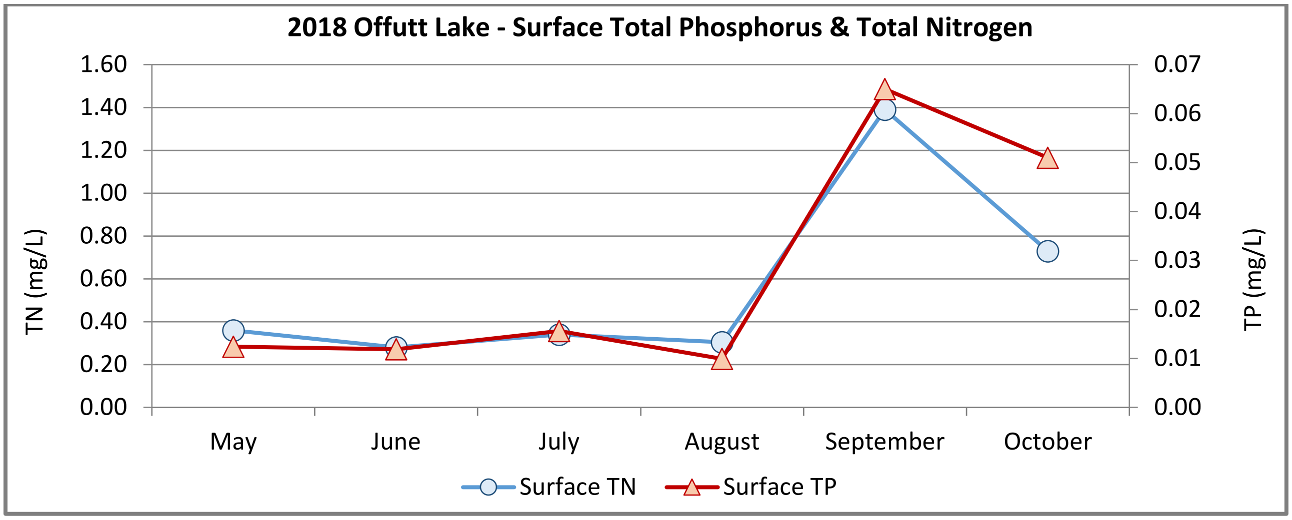


Figure 13. 2018 surface concentration of TP and TN at OF1.

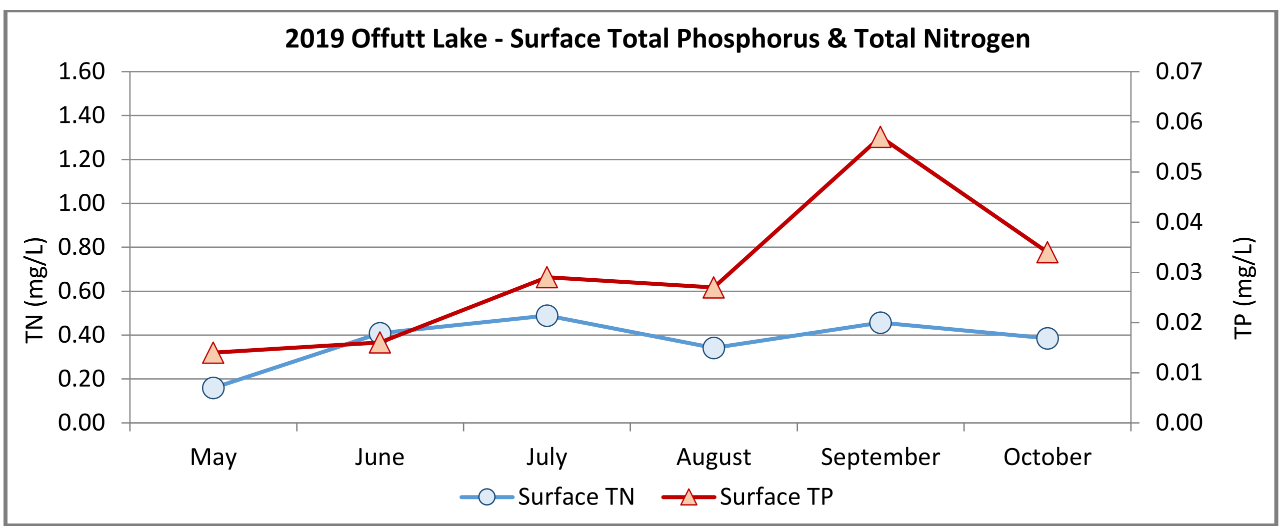


Figure 14. 2019 surface concentration of TP and TN at OF1.

In both 2018 and 2019, concentration of TP at the surface peaked when the water column began to mix in September. Thermal stratification reduced internal loading to surface waters from June to August; changes in the phytoplankton community and external sources likely affect nutrient levels 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). Figures 15 and 16 display the surface and bottom TP concentrations.

In 2018, the concentration was higher at the bottom from June to August. Three defined layers were recognizable in the vertical profiles during those three months indicating thermal stratification. During stratification, the hypolimnion was mostly stagnant, not mixing with the oxygenated water above. At the same time, oxygen in the hypolimnion was consumed by redox processes like decomposition. Due to the lack of oxygen near the bottom, phosphorus stored in the sediments was released into the water column. This phosphorus accumulated in the hypolimnion, until turn-over in September, when the water column mixed and productivity boomed.

In 2018, the TP concentrations were:

- 2018 TP Surface Mean 0.028 mg/L
- 2018 TP Surface Median 0.014 mg/L
- 2018 TP Surface Std Dev 0.022 mg/L
- 2018 TP Bottom Mean 0.195 mg/L
- 2018 TP Bottom Median 0.123 mg/L
- 2018 TP Bottom Std Dev 0.181 mg/L

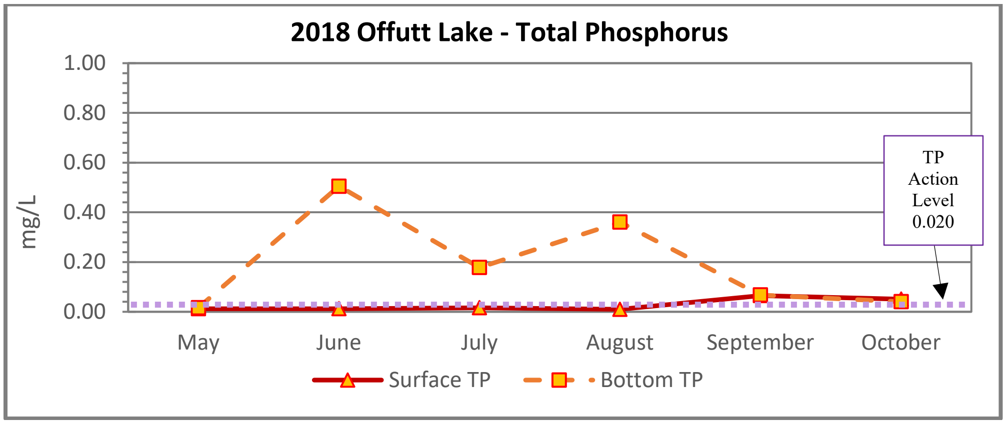


Figure 15. Concentration of Total Phosphorus at the surface and bottom at OF1 in 2018.

In 2019, the TP concentration at the bottom steadily increased from May to September. The bottom strata fully mixed with the rest of the water column in October. In 2019, the TP concentrations were:

- 2019 TP Surface Mean 0.030 mg/L
- 2019 TP Surface Median 0.028 mg/L
- 2019 TP Surface Std Dev 0.014 mg/L
- 2019 TP Bottom Mean 0.308 mg/L
- 2019 TP Bottom Median 0.251 mg/L
- 2019 TP Bottom Std Dev 0.276 mg/L

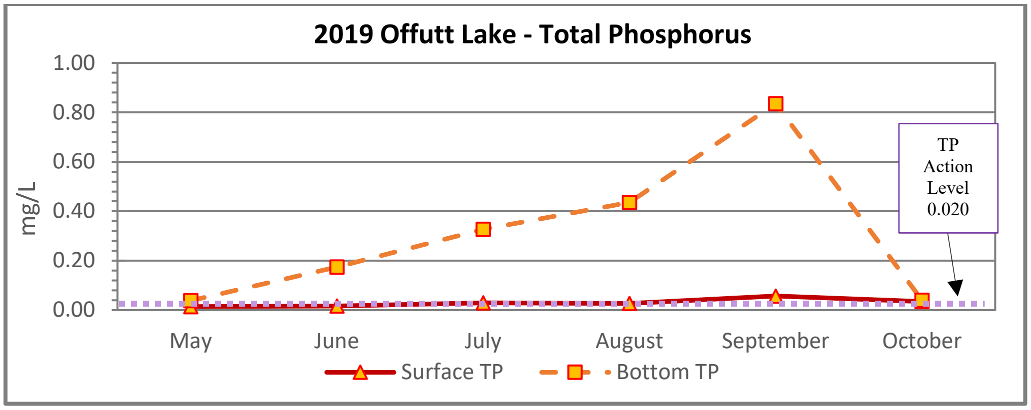


Figure 16. Concentration of Total Phosphorus at the surface and bottom at OF1 in 2019.

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. In 2018, the surface TN was more variable, and the surface maximum, which occurred after turn-over, was 180% higher than the 2019 maximum.

In 2018 TN concentrations were:

- 2018 TN Surface Mean 0.567 mg/L
- 2018 TN Surface Median 0.350 mg/L
- 2018 TN Surface Std Dev 0.398 mg/L
- 2018 TN Bottom Mean 0.745 mg/L
- 2018 TN Bottom Median 0.655 mg/L
- 2018 TN Bottom Std Dev 0.305 mg/

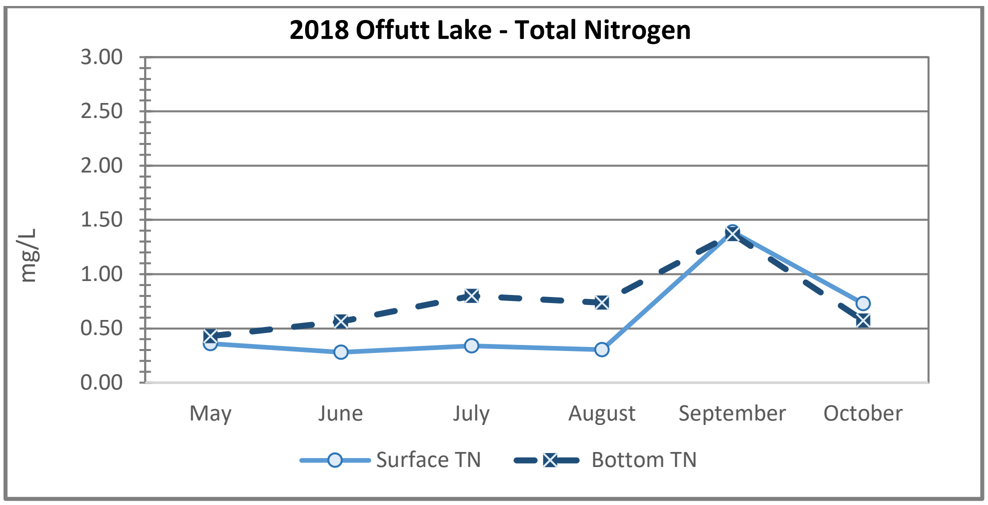


Figure 17. Concentration of Total Nitrogen at the surface and bottom at OF1 in 2018.

In 2019, TN concentrations were:

- 2019 TN Surface Mean 0.373 mg/L
- 2019 TN Surface Median 0.397 mg/L
- 2019 TN Surface Std Dev 0.107 mg/L
- 2019 TN Bottom Mean 0.897 mg/L
- 2019 TN Bottom Median 0.725 mg/L
- 2019 TN Bottom Std Dev 0.720 mg/L

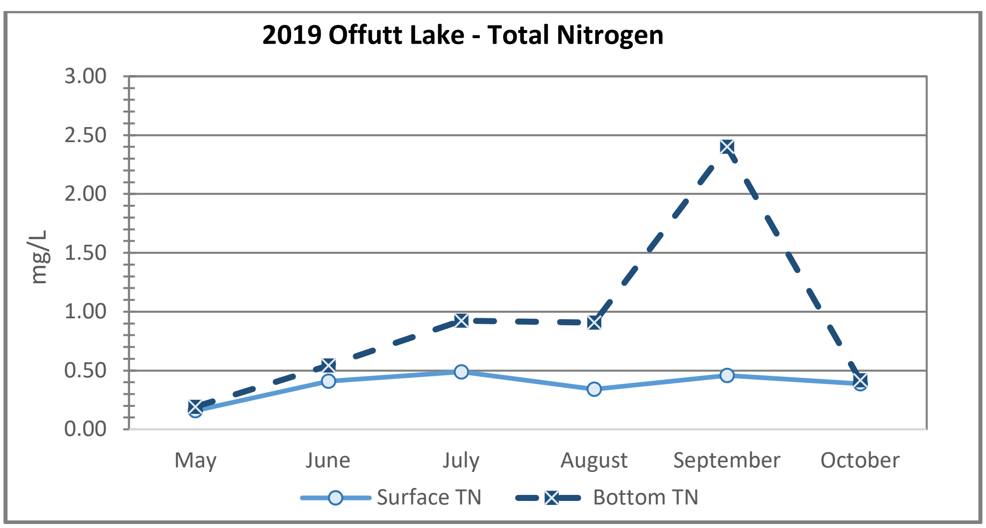


Figure 18. Concentration of Total Nitrogen at the surface and bottom at OF1 in 2019.

The median surface TN was higher in 2019. The total nitrogen concentration was higher at the bottom during stratification because the hypolimnion was hypoxic; ammonia-nitrogen was released from the bottom sediments and accumulated in the hypolimnion. In September 2019, the anoxic bottom layer had not yet mixed with the rest of the water column and the TN concentration peaked.

Nitrogen to Phosphorus Ratios

To prevent dominance by cyanobacteria (blue-green algae), the TN to TP ratio (TN:TP) should be above 10:1 (Moore and Hicks, 2004). Figure 19 shows the TN to TP ratio at OF1. Offutt Lake was phosphorus limited in 2018 and 2019.

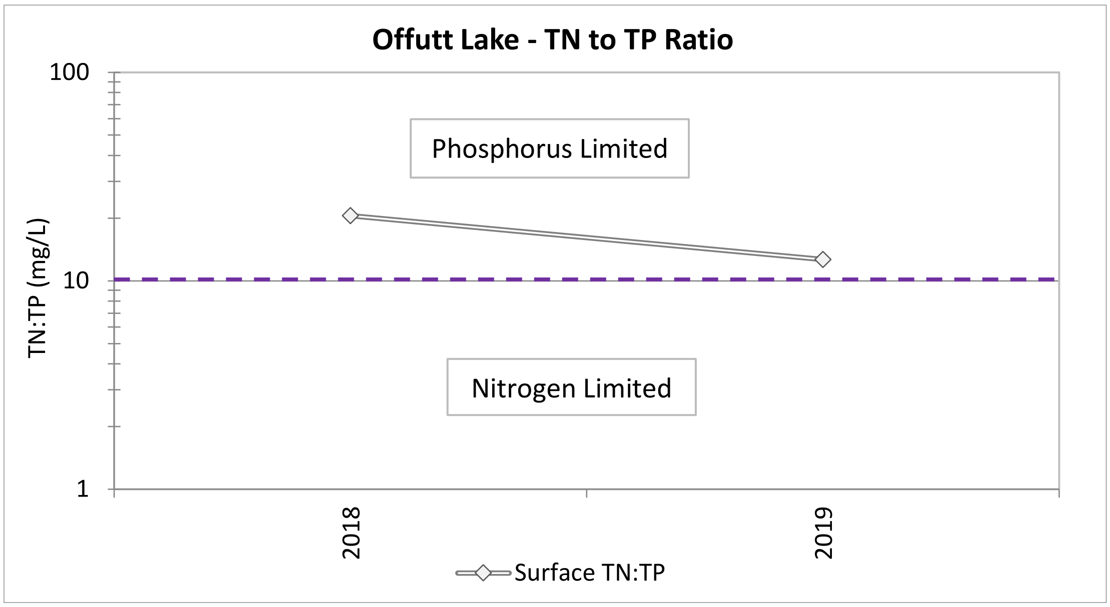


Figure 19. TN:TP at OF1 in 2018 and 2019.

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 OF1, the TSI results were:

- 2018 Chlorophyll-a: 59 eutrophic
- 2018 Total Phosphorus: 52 eutrophic
- 2018 Secchi Disk: 45 mesotrophic
- 2019 Chlorophyll-a: 47 mesotrophic
- 2019 Total Phosphorus: 53 eutrophic
- 2019 Secchi Disk: 45 mesotrophic

Offutt Lake was categorized as:

- Eutrophic in 2018: Average TSI 52
- Mesotrophic in 2019: Average TSI 48

Offutt Lake 2018 and 2019

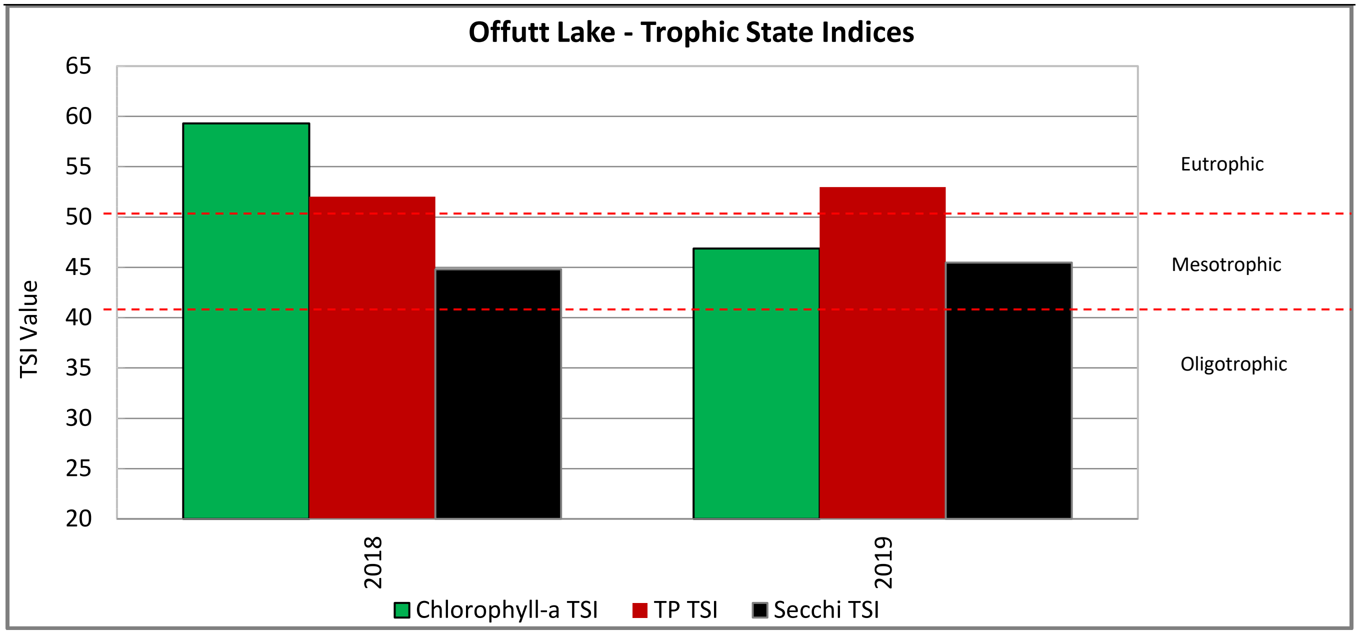


Figure 20. OF1 Trophic State Index in 2018 and 2019.

SUMMARY

Thermal Stratification

In both 2018 and 2019, the water column at Offutt Lake began to stratify in May and three distinct layers were apparent from June to August. In September 2018, Offutt Lake turned over. In 2019, the upper three-quarters of the water column had mixed in September, and the lake completely turned-over by October.

Transparency

In 2018, the mean transparency was 2.9 meters (range from 0.8 to 3.9 meters), and was negatively correlated to the concentration of chlorophyll-a. In 2019, the mean transparency was 2.7 meters (range 1.8 to 3.4 meters). Transparency was not correlated to productivity.

Chlorophyll-a and Lower Productivity Trends

In 2018, the mean concentration of chlorophyll-a was 18.7 µg/L (range 2.9 to 80.0 µg/L). In 2019, the mean chlorophyll-a concentration was 5.3 µg/L (range 3.5 to 6.7 µg/L). In both years, the highest productivity occurred in September. Algal blooms with surface scum were reported in May, July, September, and October 2018. During these blooms, TCEH collected five samples which were tested algal toxins. None of the samples exceeded the Washington State Toxic Algae Advisory Level for microcystin, anatoxin-a, cylindrospermopsin, or saxitoxin. No samples for algal toxins were collected in 2019.

Nutrients and Trends

The average surface TP concentration was 0.028 mg/L in 2018 and 0.030 mg/L in 2019. This level of TP was above the action level (0.020 mg/L) for lower mesotrophic lakes in the Puget Sound Lowlands ecoregion.

In 2018, the average surface TN concentration was 0.567 mg/L (range 0.279 to 1.390 mg/L). Surface TN increased over 100% in September 2018 when the lake turned over. In 2019, the mean surface TN concentration was lower (0.373 mg/L, range 0.159 to 0.489 mg/L) and lacked the dramatic increase after turnover like in 2018.

Lake Classifications

Based on an average of the three TSI variables, the Offutt Lake site OF1 was classified as

- eutrophic in 2018
- mesotrophic in 2019

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: sarah.ashworth@co.thurston.wa.us

For correction, questions, and 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
Appendix B. Quality Assurance/Quality Control
Appendix C. Correlation Transparency to Productivity

Appendix A. Raw data

Table A-1 Raw data collected at the Offutt Lake site OF1 in 2018.

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)
5/23/2018	10:44	6.50	3.60	8	6.0	0.012	0.017	0.359	0.429	2.9	0.2
6/27/2018	11:07	7.30	3.43	2	6.8	0.012	0.505	0.280	0.562	3.0	<0.1
7/18/2018	13:10	7.60	3.40	4	7.0	0.016	0.178	0.340	0.798	6.7	0.6
8/15/2018	11:09	6.60	3.90	6	6.0	0.010	0.374	0.279	0.777	3.5	0.3
8/15/2018 QA	**11:09**	-	-	-	-	**0.010**	**0.347**	**0.329**	**0.698**	**3.7**	**<0.1**
9/19/2018	11:45	5.65	0.75	4	5.0	0.065	0.068	1.390	1.370	80.0	2.1
10/24/2018	10:44	5.92	2.13	7	5.4	0.051	0.040	0.730	0.573	16.0	1.9

Table A-2 Raw data collected at the Offutt Lake site OF1 in 2019.

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)
5/22/2019	9:27	7.47	3.40	7	7.0	0.014	0.038	0.159	0.192	6.1	<0.1
6/19/2019	9:48	6.73	2.00	7	5.5	0.016	0.174	0.408	0.542	5.7	1.0
7/24/2019	9:59	6.55	3.00	7	6.25	0.029	0.327	0.489	0.922	3.5	1.9
8/27/2019	9:39	6.41	2.82	3	6.0	0.027	0.436	0.341	0.908	5.1	1.5
9/24/2019	9:57	6.91	1.78	10	6.5	0.057	0.835	0.457	2.400	6.7	2.9
10/22/2019	9:49	6.33	3.41	7	6.0	0.034	0.040	0.386	0.418	4.5	1.3

Appendix B. Quality Assurance/Quality Control

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 Offutt Lake sample days in 2018.

End Date	Percent Difference SPC (µS/cm)	Percent Difference ODO (% sat)	Percent Difference pH (std units)
5/23/2018	-6.13	0.14	-0.29
6/28/2018	0.02	-0.46	0.57
7/18/2018	0.06	0.83	-1.71
8/15/2018	0.18	-0.20	-1.00
10/1/2018	0.09	-0.30	-0.86
10/29/2018	0.98	-0.67	-0.14
Mean Percent Difference	**-0.80**	**-0.11**	**-0.57**

Table B-2. Instrument drift for Offutt Lake sample days in 2019.

End Date	Percent Difference SPC (µS/cm)	Percent Difference ODO (% sat)	Percent Difference pH (std units)
5/23/2019	-0.71	-0.03	0.14
6/20/2019	-0.18	0.05	0.57
7/26/2019	-0.62	0.09	-0.43
8/28/2019	0.11	-0.30	0.00
9/25/2019	0.20	-0.24	0.00
10/23/2019	0.76	0.16	-0.14
Mean Percent Difference	**-0.07**	**-0.04**	**0.02**

Table B-3 Replicate precision for samples collected at the Offutt Lake site OF1 in 2018.

Site	Datetime	sample	field replicate	Relative Percent Difference
OF1 Surface TP	8/15/2018 11:09	0.010	0.010	0.000
OF1 Bottom TP	8/15/2018 11:09	0.374	0.347	7.490
			Relative Standard Deviation TP samples:	***3.64***
OF1 Surface TN	8/15/2018 11:09	0.279	0.329	16.447
OF1 Bottom TN	8/15/2018 11:09	0.777	0.698	10.712
			Relative Standard Deviation TN samples:	***6.19***
OF1 Chlor-a	8/15/2018 11:09	3.50	3.70	5.556
			Relative Standard Deviation Chlor-a samples:	**2.78**
OF1 Phaeo-a	8/15/2018 11:09	0.30	0.10	100.000
			Relative Standard Deviation Phae-a samples:	**50.00**

Appendix C. Correlation Transparency to Productivity

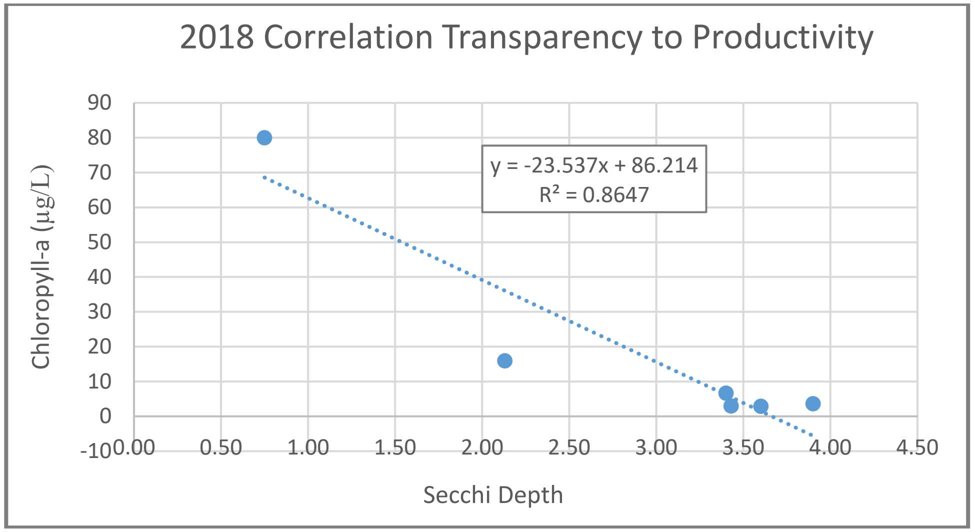

Figure C-1. Correlation between transparency and productivity in 2018.

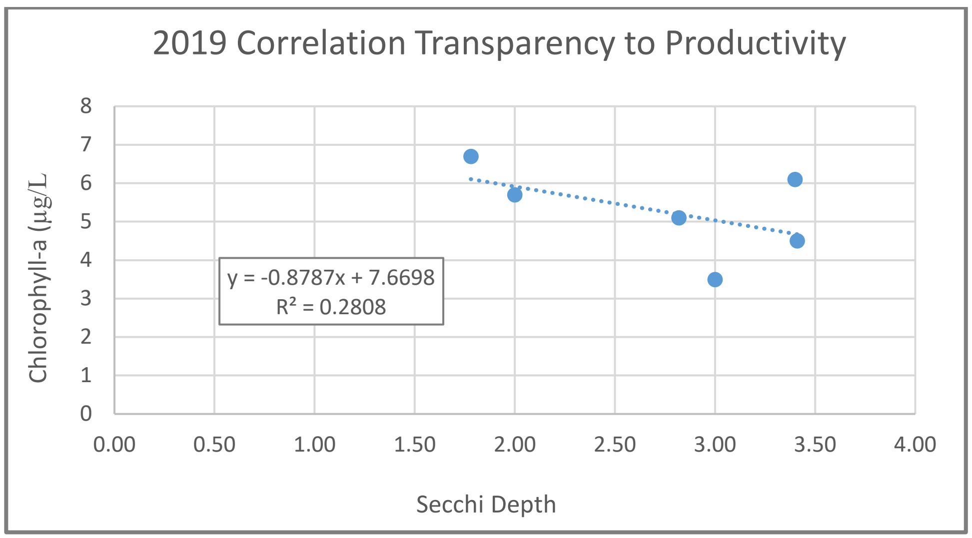

Figure C-2. Correlation between transparency and productivity in 2019.