Lake Windermere Community Based
Water Quality Monitoring Program

2019 Final Report

January 2020

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Executive Summary

The Lake Windermere Ambassadors direct a Community-Based Water Monitoring and Citizen-Science Education program within the Lake Windermere watershed. 2019 marked the thirteenth year of lake monitoring since the Lake Windermere Project began collecting water quality data in 2006.

In 2019, the Lake Windermere Ambassadors collected physical and chemical water quality parameters at three sample sites on Lake Windermere once weekly during the summer, from late May to September. The lake sampling regime included water temperature, turbidity/clarity, pH, conductivity, depth, and dissolved oxygen. Once monthly from May to September we collected Total Dissolved Phosphorus and Total Phosphorous. In addition, the LWA monitored substrate samplers at six sites on the east side of Lake Windermere for invasive mussels, as well as monitoring tributary flows and water quality at the outlet of Windermere Creek and Abel Creek. *E. coli* data was collected at public swim beaches weekly, from May until September, excluding weeks with a statutory holiday Monday, in partnership with the Interior Health Authority. Lastly, Goldeneye Ecological Services was contracted to complete an aquatic plant survey, and fall waterbird survey on Lake Windermere.

Findings from 2019 show that Lake Windermeres water quality continues to support aquatic life and recreation. The only parameter that deviated from the Ministry of Environment objectives was temperature on one occasion in June. Specific Conductivity and pH were both observed to be outside of the optimal range for aquatic life, but may have been impacted by faulty equipment. The three public swim beaches (Windermere, James Chabot Provincial Park, and Kinsmen) met Interior Health Authority guidelines for recreational quality during all sample collection dates in 2019. The annual aquatic plant survey found no invasive species in Lake Windermere for the tenth year of sampling. While overall there is a healthy abundance of vegetation throughout the lake there were a couple sites of concern that saw less healthy vegetation, particularly where sites saw higher boat traffic (Darvill, 2019). Further to last year's newly developed waterbird survey protocol and investigative report, this year's fall waterbird survey found 18 species observed, 889 individuals, with a number of them being rare sightings and species at risk. Invasive mussel larvae (veligers) were not detected in Lake Windermere as sampled for by the East Kootenay Invasive Species Council in 2019 (BC Conservation Officer Service, 2019).

Our major funders for this project and its final report include the Columbia Valley Local Conservation Fund, the District of Invermere, the Regional District of East Kootenay, the Columbia Basin Trust's Environment Large Grants program, LUSH Charity Foundation, and Royal Bank of Canada Foundation. Additional funding support for our 2019 programs came from the Columbia Valley Community Foundation, the Real Estate Foundation of BC, Canada Summer Jobs, the Columbia Basin Watershed Network, and BC Community Gaming Grants.

Questions about this report?

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1. Introduction

Lake Windermere is one of two headwaters lakes located at the source of the Columbia River in southeast British Columbia, Canada. The “lake” itself is not a true lake and rather a long widening of the Columbia River, with an average depth of ~3-4m (10-13ft).

Historically, Lake Windermere has supported several species of fish, and is used by hundreds of species of resident and migratory birds (McPherson and Hlushak, 2008). Birds, fish, and wildlife all depend on the lake and its outflows to the Columbia Wetlands, which are one of the longest intact wetlands in North America and a wetland of international importance (Ramsar, 2004).

Humans also depend on Lake Windermere for its social, cultural, environmental, and economic values. Not only is it a drinking water source, but the lake is heavily used for recreation, motorized and non-motorized, in the summer and winter, for business opportunities, and traditional values.

1.1 - Climate

Lake Windermere sits within the Southern Rocky Mountain Trench in the Interior Douglas Fir (IDF) biogeoclimatic zone (Braumandl and Curran, 2002). The region is temperate and experiences all four seasons, characterized by relatively mild, cool winters and dry, hot summers.

Average annual precipitation is in the range of 300-400 mm (Urban Systems 2012; District of Invermere 2017), and most rainfall historically occurs between May and June. Spring freshet usually occurs between late May and early July.

The warmest days of the year have historically been recorded in July and August. 2019 varied from 2017 and 2018, which had been noted as being hot summer years, with significant forest fire activity and minimal summer precipitation. During the 2019 summer season, the region saw increased precipitation, cooler temperatures, and limited forest fire activity.

1.2 - Watershed Characteristics

Lake Windermere sits at approximately 800masl, and is bordered east and west by two distinct mountain ranges, the Purcells and the Rockies. The lake flows from south to north as part of the main channel of the Columbia River, which exits Columbia Lake approximately 20km upstream. Lake Windermere flushes on average every 47 days, contributing to its relatively good water quality (McKean and Nordin, 1985).

The main tributary entering Lake Windermere is Windermere Creek, a fourth-order mountain stream that drains an area of approximately 90 km^2 (NHC, 2013). Some of the major developments within the Lake Windermere watershed include an active gypsum mine, railroad, roads and highway, agricultural and grazing activities, golf courses, ski hills, urban and residential development, and historical forest harvesting (McPherson et al., 2018).

1.3 - Community-Based Water Monitoring

Concerns about increased development and changes to Lake Windermere in the early 2000’s prompted the creation of a community-based water quality-monitoring program and watershed stewardship education initiative, in the form of the Lake Windermere Ambassadors.

The Lake Windermere Ambassadors (LWA) are a community-led, charitable non-profit society formed in 2010 with the mandate of protecting Lake Windermere in perpetuity. The LWA have overseen a Community-Based Water Monitoring program on Lake Windermere since their inception, using the assistance of volunteers, and substantial baseline data collected by Wildsight's Lake Windermere Project. Since 2010, the LWA have added to the monitoring program based on needs and available resources, including, tributary monitoring, invasive species monitoring, and wildlife surveys.

From 2006 to 2009, the Lake Windermere Project worked to assess the quality of Lake Windermere's waters for wildlife and human recreational uses. In 2010, the BC Ministry of Environment took those four years of data, and determined an updated list of Water Quality Objectives for Lake Windermere. These objectives are a benchmark against which the LWA can compare present conditions to evaluate if the lake water quality continues to be suitable for recreational and ecological needs.

By continuing to test lake water quality on a weekly basis in the summer, the LWA now have thirteen years of water quality data for Lake Windermere. This data allows the LWA to detect seasonal and annual changes in water quality, and to communicate information about Lake Windermere that will help inform sustainable watershed planning and restoration initiatives in the Upper Columbia watershed.

1.4 - Sample Sites

Water quality is sampled at three locations on Lake Windermere, which have been in the past monitored by the BC Ministry of Environment and by the Lake Windermere Project. These locations include North (Timber Ridge/Fort Point), Middle (Windermere) and South (Rushmere) sample sites (Figure 1).

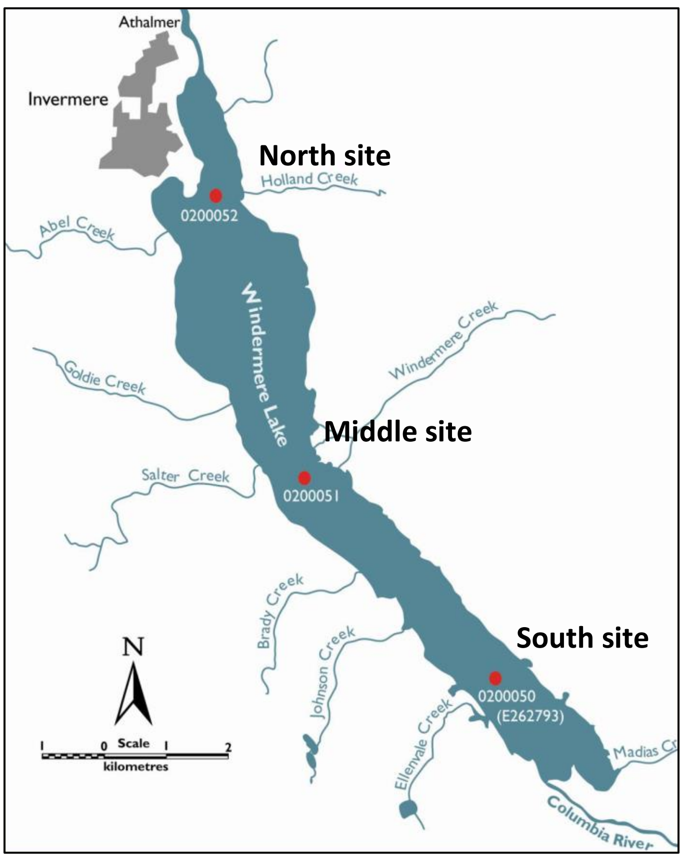


Figure 1: Lake Windermere Sampling Sites: North (0200052), Middle (0200051), and South (0200050). (Image Source: Neufeld et al., 2010)

2. Lake Windermere Water Quality Results

2.1 - Temperature

Overview

Water temperature is critically important to lake health as it has direct impacts on water chemistry (ex. Dissolved oxygen, specific conductivity, water density) and influences the rate of chemical and biological reactions. This effects the ability for aquatic life to grow, survive, and reproduce in an environment (Alberta Regional Aquatics Monitoring Program, 2008).

Due to the shallow depth of Lake Windermere, it has a naturally elevated temperature relative to other freshwater lakes (Neufeld et al., 2010). Unlike deep lakes, Lake Windermere does not stratify into different layers of temperature and density within the water column (McKean and Nordin, 1985).

Summer Student, Keri Malanchuk (right), and volunteer, Shelly Hopkins (left), measuring water temperature and specific conductivity

Warm and clear water makes Lake Windermere a desirable lake for human recreation. However, average summer water temperatures have historically exceeded the BC Ministry of Environment's (MOE) Temperature Guidelines for the protection of freshwater aquatic life (Neufeld et al., 2010). For example, many of the freshwater fish species observed in this lake have optimum temperature ranges below 18°C for rearing, spawning, and incubation (Ministry of Environment, 2017a), whereas historical monthly water temperatures in Lake Windermere have been recorded up to 25°C (Neufeld et al., 2010).

To adjust for the naturally warmer temperatures in Lake Windermere, the MOE set the maximum allowable average monthly water temperatures at 20°C, 25°C, and 23°C in June, July, and August respectively (Neufeld et al., 2010). These guidelines are based on the MOE recommendation that lake water temperatures should remain within ± 1°C of natural conditions.

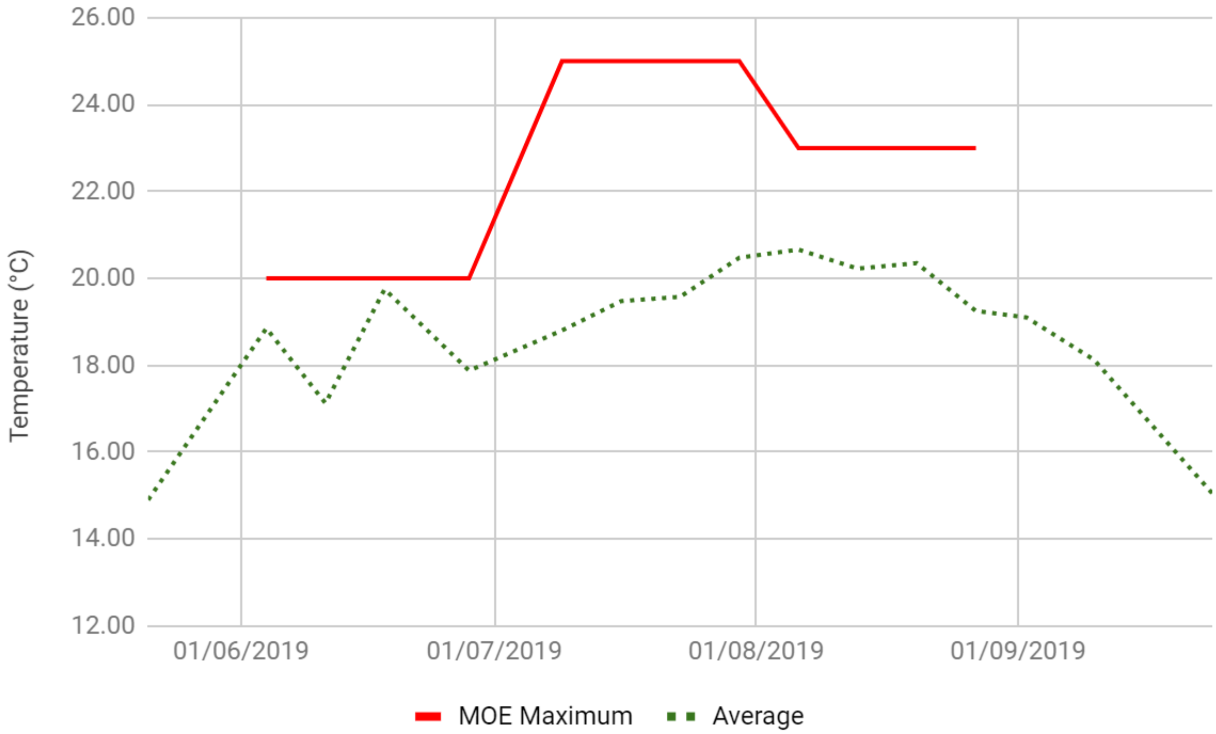
Results

During the 2019 summer season, there was only one instance where the water temperature exceeded the maximum threshold at the North and Middle sample stations. Average monthly temperatures remained consistently below the maximum threshold recommended by MOE (Figure 2a).

The highest temperature measured in 2019 was 22.6°C, recorded on August 6th at the North sample station (Figure 2b). For comparison, the highest temperature measured in 2018 was 23.6°C, on July 31st at the Middle sample site.

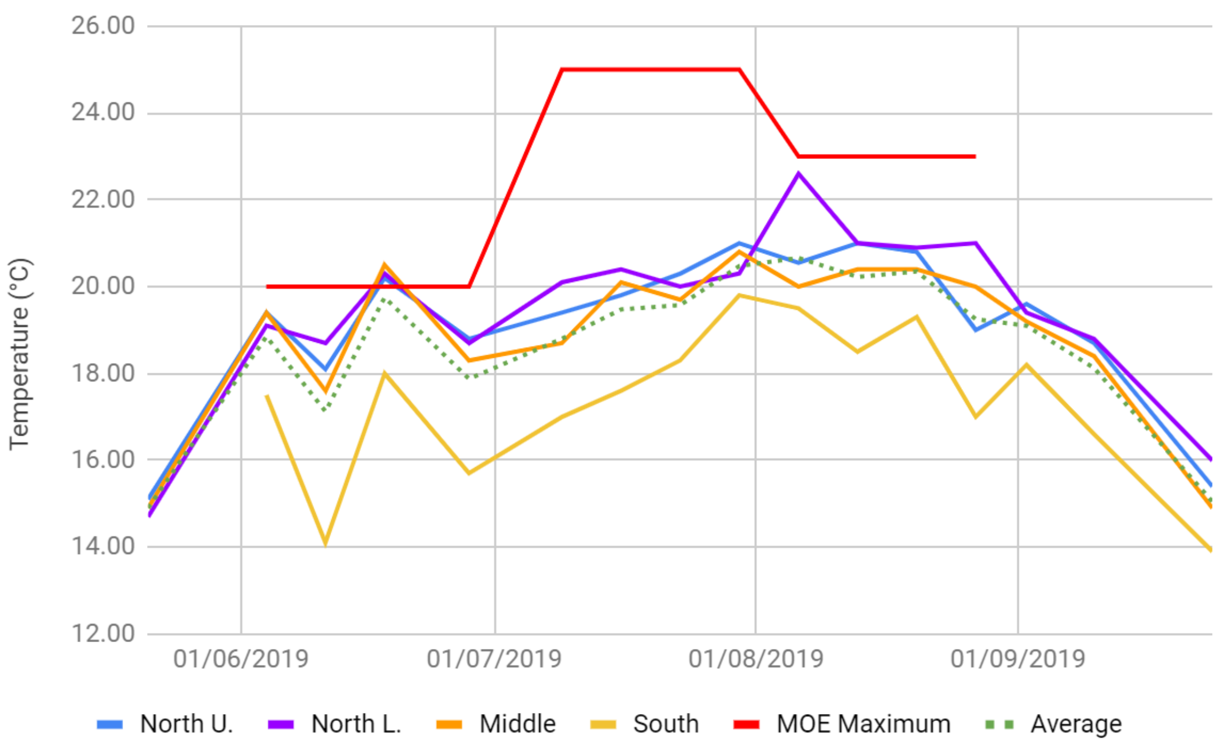
To address concerns related to sample time bias, we were able to install a continuous temperature logger located near the North sample site (Figure 2c). Data collected from this device indicated the highest temperature to be 21.89°C on August 9th, which remained in line with the results from our weekly monitoring.

(a)



26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
Temperature (°C)
01/06/2019
01/07/2019
01/08/2019
01/09/2019
MOE Maximum
Average

(b)



26.00
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Temperature (°C)
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(c)

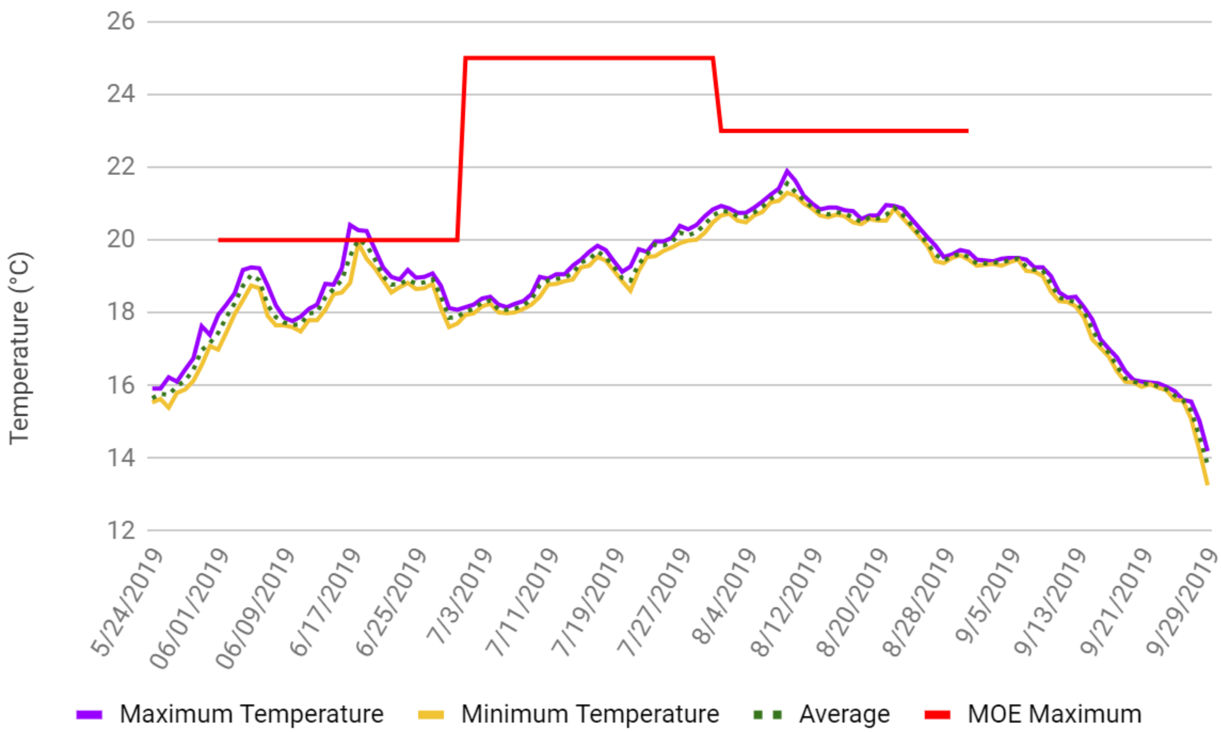


Figure 2: (a) Average water temperature for Lake Windermere, measured weekly from May 20 to September 24, 2019. (b) Water temperature results separated by sample site. (c) Water temperature measurements recorded by continuous temperature logger from May 24 to September 29, 2019.
Note: Lines are for interpretation only, and do not represent continuous measurements.

2.2 - Dissolved Oxygen

Program Coordinator, Shannon McGinty, performing DO Titration. Photo by Pat Morrow

Overview

Dissolved Oxygen (DO) is another name for the free oxygen gas that has dissolved in water. Some amount of DO is required for almost all species of aquatic life to survive, but too much or too little oxygen can harm aquatic life and negatively affect water quality (Ministry of Environment, 2017a).

Oxygen can be transferred to water from the atmosphere or produced by submerged aquatic plants during photosynthesis. It is then removed from the water by respiration in aquatic plants and animals, chemical reactions, and organic decomposition. For example, a large amount of decomposing plant material within a lake can decrease DO concentrations in the water, because the oxygen is consumed during the decomposition process (Neufeld et al., 2010).

The capacity for water to hold dissolved oxygen is inversely related to water temperature. Meaning, warmer water holds less oxygen, and cooler water holds more oxygen (Ministry of Environment, 2017a).

The MOE recommends that DO should never drop below an instantaneous minimum of 5 mg/L, and the guideline for an average of five samples taken over a 30-day period is 8 mg/L (Neufeld et al., 2010; Truelson, 1997). It is also recommended that DO not exceed a maximum of 15 mg/L, in order to prevent negative effects of toxicity (Neufeld et al., 2010).

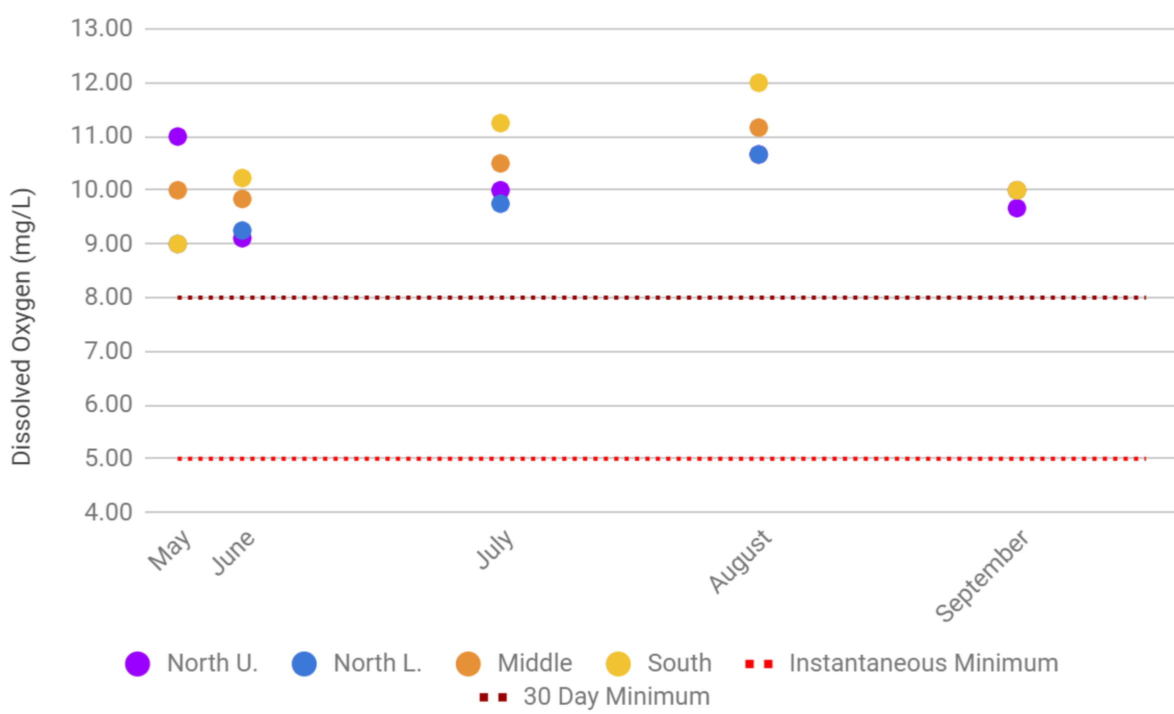
Results

During the 2019 summer season, DO values in Lake Windermere never dropped below the 5 mg/L minimum threshold recommended by MOE (Figure 3a). Instantaneous values ranged between a low of 8 mg/L and a high of 11.32 mg/L (Figure 3b).

The South sample site typically had higher DO values than the other sites. This may be due to the proximity to the Columbia wetlands, which have an abundance of aquatic plant life that are photosynthesizing and contributing oxygen to the water. It may also be due to the slightly cooler temperatures of water flowing out of the wetlands, since cooler water holds more oxygen.

It is important to acknowledge the Winkler titration method used for collecting DO results can come with significant human error if completed or interpreted incorrectly in the field. In previous years we have compared field titration results with readings from a YSI Pro20 Dissolved Oxygen meter, and found the titration results to be within ± 2mg/L of the calibrated meter. This is a significant variation, suggesting the LWA should invest in a DO meter to independently verify the titration readings performed by citizen scientists and ensure a higher level of accuracy in future.

(a)



(b)

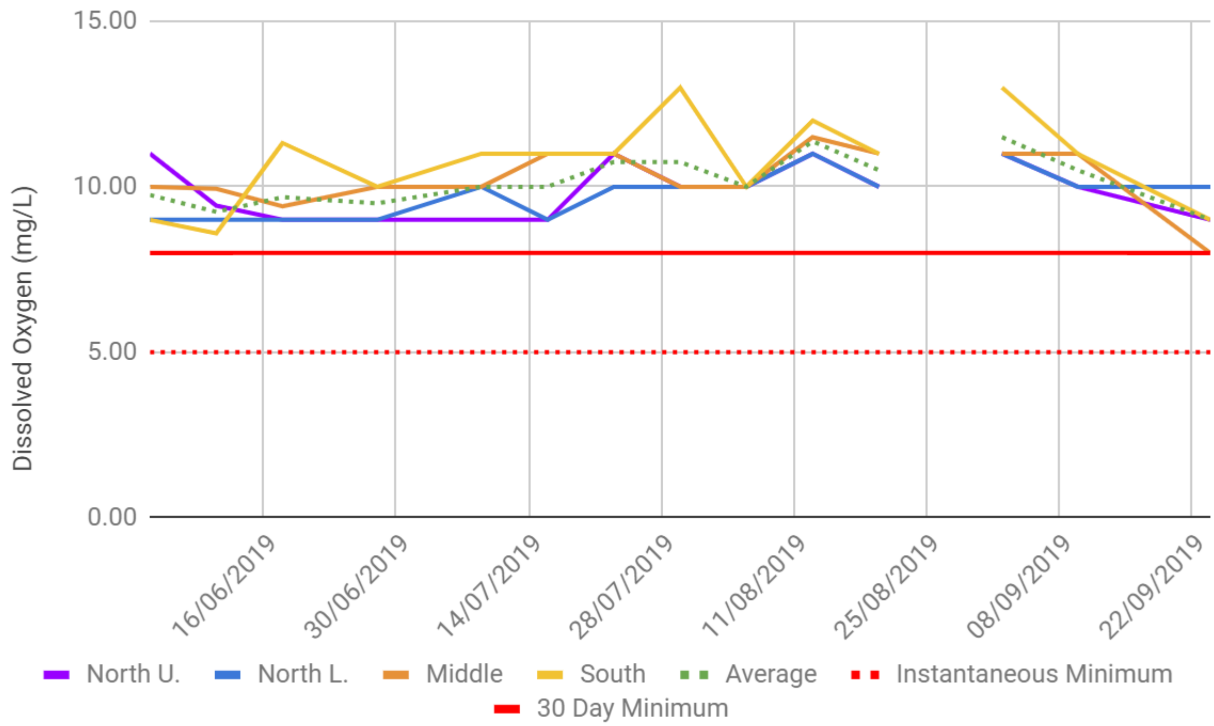


Figure 3: (a) 30-day mean values for dissolved oxygen, calculated for seventeen weeks between May 20 and September 24, 2019. (b) Weekly dissolved oxygen data for Lake Windermere, measured from May 20 to September 24, 2019 (missing data from the week of August 20, 2019).
Note: Lines are for interpretation only, and do not represent continuous measurements.

2.3 - Turbidity

Overview

Turbidity is a measure of the light scattered by particles suspended in water, and indicates the clarity of the water. When waters are highly turbid, such as when they are filled with lots of suspended sediment, light does not penetrate as easily to reach aquatic plants, which reduces photosynthesis. Fish can become stressed due to reduced ability to navigate, clogging of gills, and other physiological stressors (Ministry of Environment, 2017a).

Volunteer Terri Eacrett measuring Turbidity

Since aquatic life in Lake Windermere has adapted to seasonal flushes of sediment into the lake, the acceptable amount of turbidity depends on the time of year. The most turbid waters typically occur during "freshet" (the spring runoff period), or after heavy rainfalls.

The turbidity objectives for Lake Windermere are set to protect recreational water quality and aquatic life (Neufeld et al, 2010). During freshet (May 1 to August 15), in what is known as the "turbid flow period", the 95^{th} percentile of turbidity measurements taken in 5 days over a 30-day period should not exceed 5 NTU (turbidity units). During the "clear flow period" (August 16 to April 30), the maximum turbidity at any time should be less than or equal to 5 NTU. Additionally, the objective for "clear flow" is that the average of 5 samples over 30 days should not exceed 1 NTU (Neufeld et al, 2010).

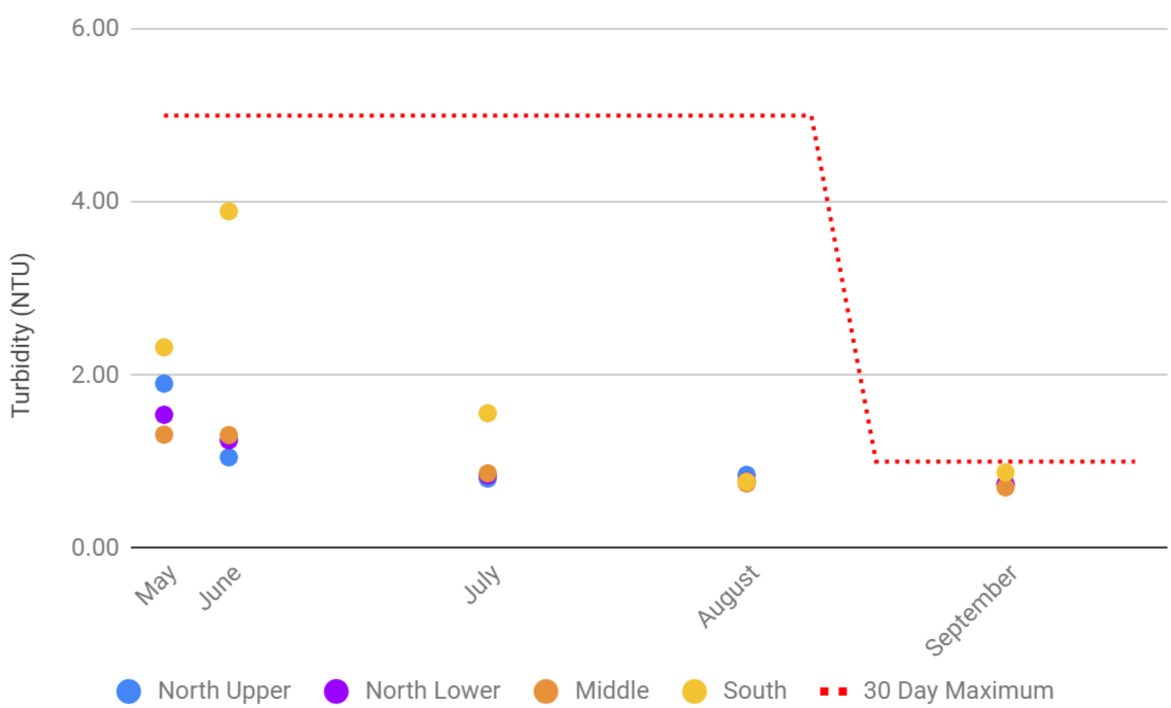
Results

Overall, turbidity in 2019 remained well within the acceptable ranges for recreational water quality and aquatic life. The mean 30-day turbidity values for 2019 did not exceed MOE Recommendations (Figure 4a).

The South sample site saw the highest peaks in turbidity (Figure 4b) likely due to sediment entering the Columbia River through Dutch Creek, and settling out in Lake Windermere. Wetlands usually help to attenuate high turbidity by slowing flows and allowing sediment to settle out; however, the sediment loads coming in through the wetlands in June may have been too high for this to occur. The result is that the South sample site exceeded maximum turbidity values on June 4th, with a reading of 6.75 (Figure 4b). This type of turbidity response is not uncommon for many river systems during freshet, because of the high volumes of meltwater runoff, which can erode lower-order stream channels and carry large amounts of sediment downstream.

During the clear flow period, we saw two instances where readings exceeded MOE objectives, August 20th North sample site 1.07 NTU and September 10th South sample site 1.08 NTU. This might have been due to the high wind events and rain showers in the seven days leading up to sampling, which could have caused sediment runoff into tributary streams and heavy mixing of the lake water to occur because of wave action.

(a)



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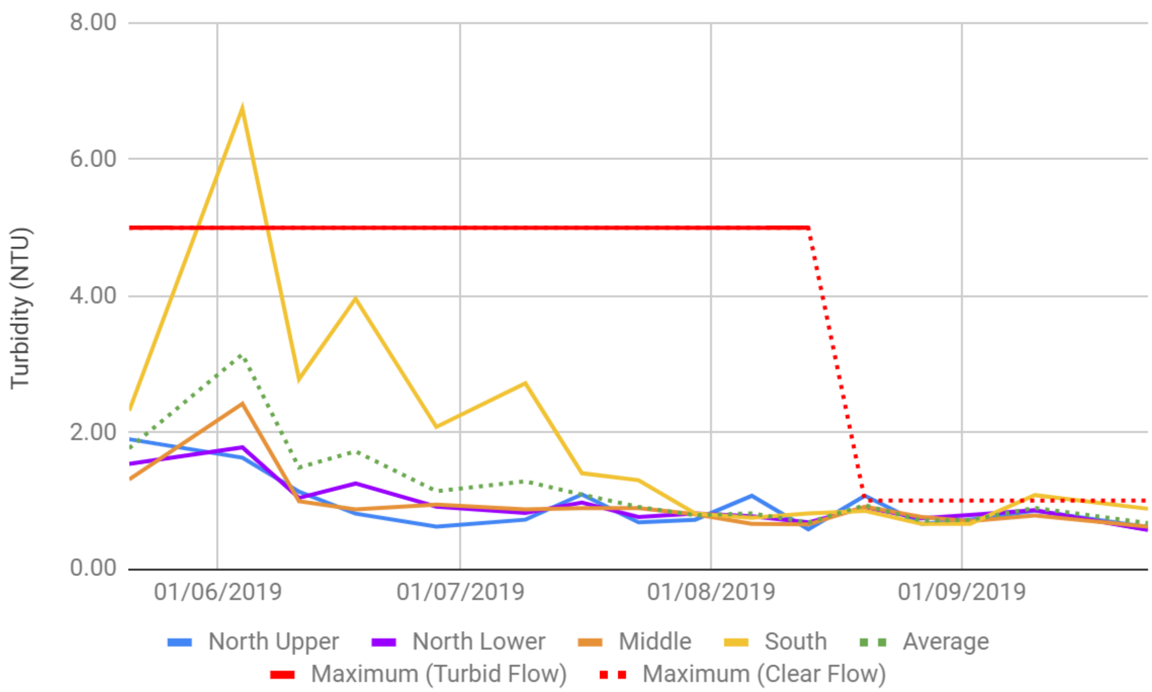
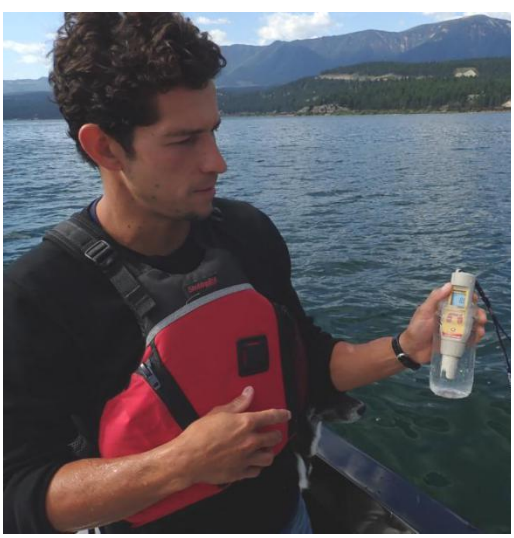


Figure 4: (a) 30-day mean values of turbidity for Lake Windermere, measured weekly from May 14 to September 24, 2019. (b) Weekly turbidity results separated by sample site.
Note: Lines are for interpretation only, and do not represent continuous measurements.

2.4 - pH

Overview

pH is a measure of the free hydrogen ion concentration (H^+) of a solution. pH is reported on a scale from 0 to 14. Solutions with a pH between 0-7 represent an acidic environment, and solutions with a pH between 7-14 represent a basic or alkaline environment.



Volunteer Lorin Inglis measuring pH

pH is reported in logarithmic units, meaning a change in one unit of pH represents a ten-fold change in the actual pH of the solution. For instance, water with a pH of 4.5 is ten times more acidic than water with a pH of 5.5, while water with a pH of 3.5 is one hundred times more acidic than water with a pH of 5.5.

The pH of natural lakes is rarely neutral, because of the presence of dissolved salts and carbonates, aquatic plants, and the mineral composition of the surrounding soils. pH can fluctuate daily as well as seasonally.

Many aquatic species are sensitive to sudden changes in pH, however most species have adapted to deal with the natural pH fluctuations of a lake that are spread over time. If the pH of a lake changes dramatically within a short time frame, it could be an indicator of a pollution event or some other form of disturbance.

The water in Lake Windermere consistently trends towards slightly alkaline (pH values around 8.5), which is characteristic of lakes fed by water flowing over limestone bedrock materials present in the Canadian Rockies (BC Ministry of Health, 2007; Rollins, 2004). There is no MOE Objective set for pH in Lake Windermere; however, the majority of aquatic organisms prefer a habitat where pH stays within 6.5-9.0 (Neufeld et al, 2010).

Results

pH measured in 2019 was comparable to measurements taken in 2018, which ranged from 8.0 to 9.0. pH measurements for 2019 were recorded to be between 6.80 and 9.10 with an increasing trend as the summer went on (Figure 5a). pH may have an inverse relationship with turbidity, with less turbidity, there are fewer particles available to scatter sunlight that enters the water, and with greater amounts of light reaching submerged aquatic plants then sunlight would not be a limiting factor to photosynthesis or plant growth. This could have increased the bulk photosynthetic rate within the lake, removing more CO_2 from the water and causing the pH to rise over time.

pH is a difficult parameter to accurately measure in the field and the equipment used by the LWA is over ten years old. On May 21st it was observed that from the South sample site to the North sample site there was a change in 1 unit of pH, this is highly unlikely in a lake of this size. It is suspected that readings may not be entirely accurate and it is suggested that lab tests be done to determine the level of accuracy. If this information is found to be accurate it is recommended to look further into the cause of the increase.

(a)

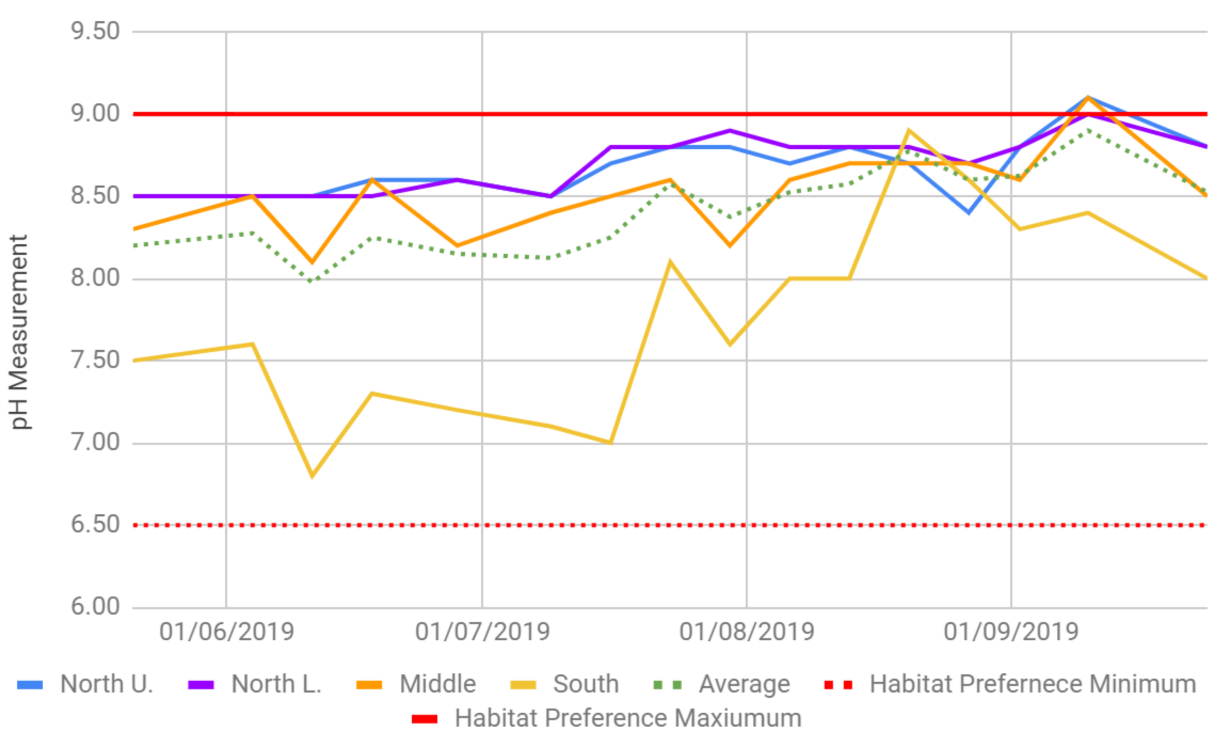


Figure 5: (a) Average pH for Lake Windermere as measured weekly between May 20 and September 24, 2019. *Note: Lines are for interpretation only, and do not represent continuous measurements.*

2.5 - Specific Conductivity

Overview

Specific conductivity measures the ability of water to conduct an electrical current. It is affected by the presence and mobility of ions in the water. Conductive ions include dissolved salts and inorganic compounds, like chlorides, sulfides, and carbonates. For this reason, a measure of conductivity in water may be used as an indicator of water pollution.

Conductivity of water is directly related to water temperature, the warmer the water, the faster the mobility of the ions, and so the higher the conductivity (Behar, 1997). To account for this, we measure the Specific Conductivity which is corrected for the temperature. Specific conductivity of water is also affected by the bedrock geology of the surrounding area, with more weathering-prone bedrock (such as limestones or clays) giving rise to higher conductivity values than more stable bedrock (such as granite).

Volunteer Kris Nickerson measuring water temperature and specific conductivity

Specific conductivity can provide insights about pollutants such as sewage (because the addition of chloride, phosphate, and nitrate rapidly increases conductivity), road salts (high in chloride salts), or an oil spill (oil's organic nature and higher resistance to conducting electricity will reduce the conductivity).

Since specific conductivity values have remained consistent over time in Lake Windermere (on average between 200-300 µS/cm), there are no MOE objectives. It is, however, still important to monitor and observe if changes in conductivity are occurring which might negatively affect aquatic health. Freshwater streams can support diverse aquatic life with a conductivity range of 150 - 300 µS/cm (Behar, 1997; Weaver and Northrup, 2016). Therefore, readings above or below these values should be treated with caution and possibly investigated further.

Results

Specific conductivity in Lake Windermere ranged between 169.90 to 361.60 µS/cm in 2019 (Figure 6a). Specific conductivity was lowest at the South sample site, which is near the outlet of the southern wetlands.

Data gaps on August 6th and 27th are due to equipment failure; a temporary fix solved this problem for August 13th and 20th, but after the second failure it was determined our equipment was no longer sufficient. An identical unit was borrowed from Columbia Lake Stewardship Society for the remaining September sampling sessions.

(a)

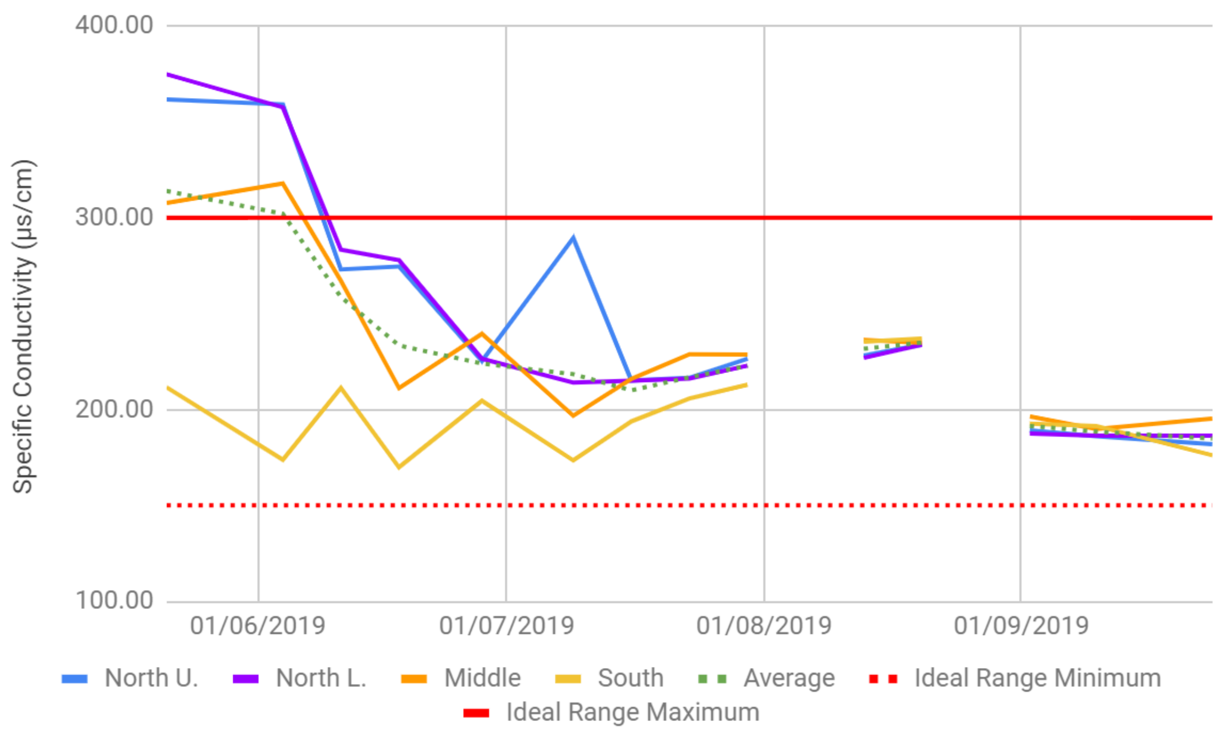
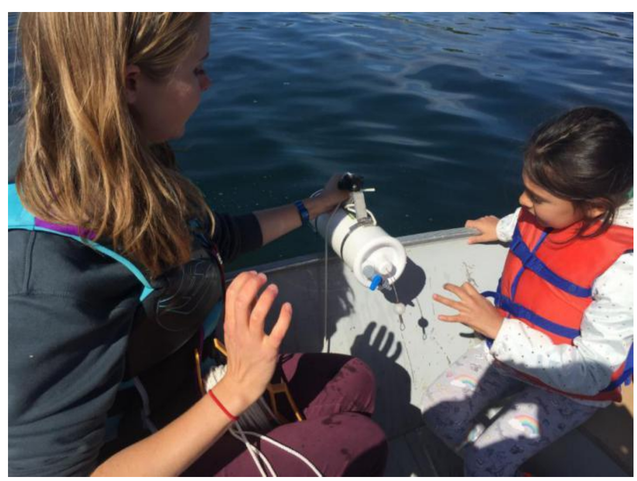


Figure 6: (a) Weekly specific conductance values separated by sample site measured from May 20 to September 24, 2019 (missing data from the week of August 6 and 27, 2019).
Note: Lines are for interpretation only, and do not represent continuous measurements.

2.6 - Phosphorus

Overview

Phosphorus (P) is a nutrient essential for life. P is used by plants and aquatic animals for processes involved in photosynthesis and metabolism. When present in low quantities, this nutrient can limit the growth of aquatic life. When present in high quantities, it can lead to excessive algae growth and overproduction of bacteria, which can severely compromise other forms of aquatic life and human health.



Summer Student, Keri Malanchuk, demonstrating to volunteer, Emma Albano, how to use a Van Dorn to collect water sample form depths below the surface

P exists in two main forms in water: dissolved and particulate. Dissolved P is readily available to algae and aquatic plants for growth and photosynthesis (US EPA, 2012). Particulate P is attached to particles in the water, and is not always available to aquatic plants or animals. "Total P" is a combined measurement of both the dissolved and particulate forms, and is often the parameter monitored during water quality objective studies.

Two major human-caused inputs of P to waterways in North America include agricultural runoff and wastewater. Within the Lake Windermere watershed, possible sources of P to the tributaries and the lake include: agricultural runoff, golf course and resort fertilizer runoff, waterfront lawn & garden fertilizer runoff, municipal stormwater runoff containing detergents and other phosphate-bearing chemicals, or leaky shoreline septic systems. Natural sources of P include nutrient cycling when plants and animals die and decompose, and soil mineral transport.

Historic sampling results indicate that Lake Windermere is "oligotrophic." This means that low nutrient levels and clear waters have been the norm in this lake, and phosphorous is often limiting to the growth of aquatic life. As recently as 2015, however, the LWA found that water samples just after ice-off were significantly exceeding the MOE recommendations for total phosphorous concentrations in Lake Windermere. The Ministry of Environment (MOE) recommends Total Phosphorus in Lake Windermere not exceed a concentration of 10 µg/L (0.01 mg/L) in order to protect drinking water sources and aquatic life.

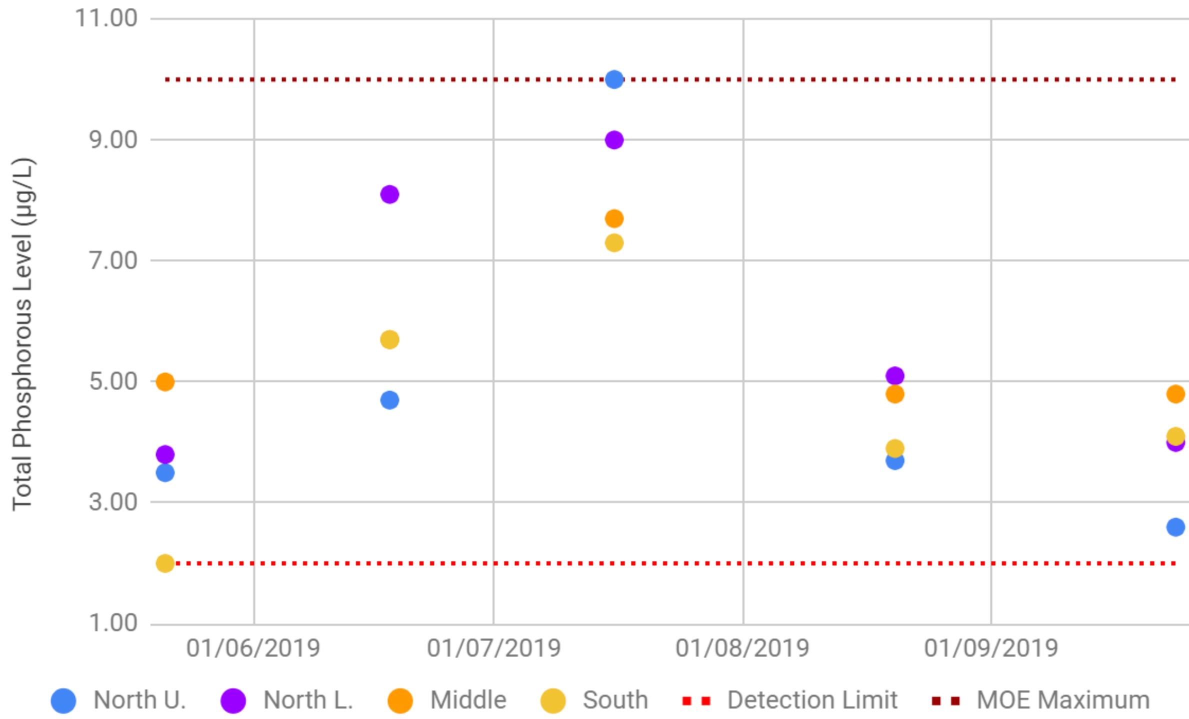
Results

2019 saw favourable results for Total and Dissolved P levels. The highest recorded value for Total P was 10.00 µg/L at the North sample site on July 16th, and the lowest value being 2.00 µg/L on May 21st at the South sample site (Figure 7a).

It is expected that Total Phosphorous be higher when turbidity is highest, this was not seen to be the case during the 2019 Sampling Season. This may indicate that throughout the season the sources of phosphorous to the Lake Windermere system fluctuated. It is difficult to point to the source of phosphorous as it occurs both naturally and through human inputs. It is important to continue to watch this trend for future management strategies.

The highest ever-recorded value of Total P by the LWA was 67 µg/L, on August 20th 2013 at the Middle sample site. This was more than six times the recommended limit, and prompted the LWA to increase monitoring for phosphorous. Since that date, twelve samples have exceeded for Total P and six have exceeded for Dissolved P (Figure 7c)

(a)


11.00
9.00
7.00
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3.00
1.00
Total Phosphorous Level (µg/L)
01/06/2019
01/07/2019
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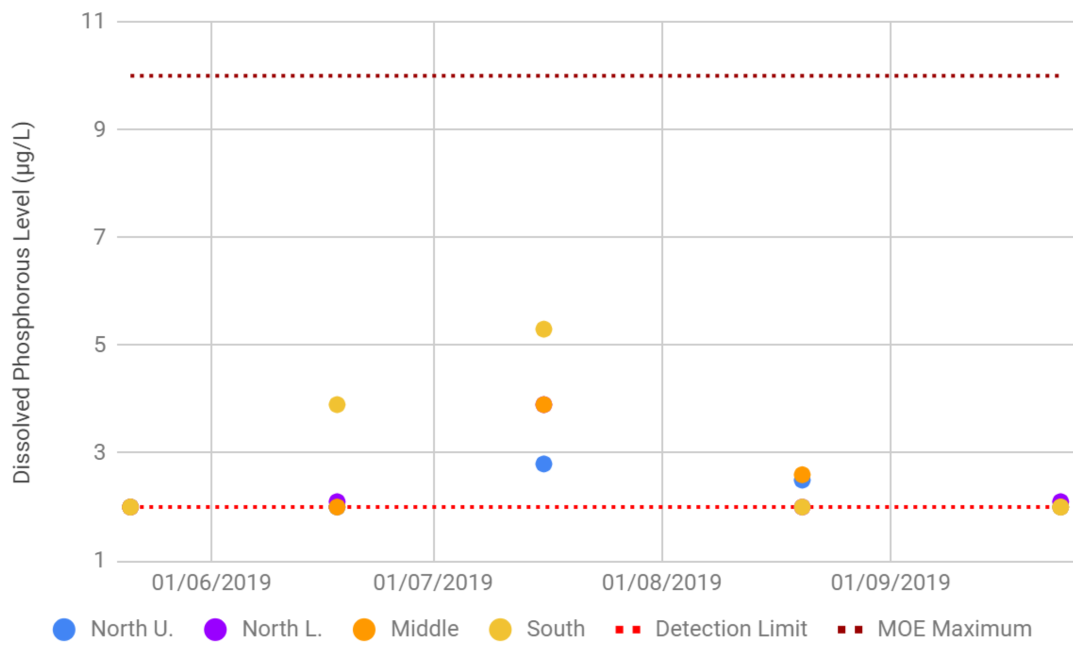
01/09/2019
North U.
North L.
Middle
South
Detection Limit
MOE Maximum

(b)


11
9
7
5
3
1
Dissolved Phosphorous Level (µg/L)
01/06/2019
01/07/2019
01/08/2019
01/09/2019
North U.
North L.
Middle
South
Detection Limit
MOE Maximum

(c)

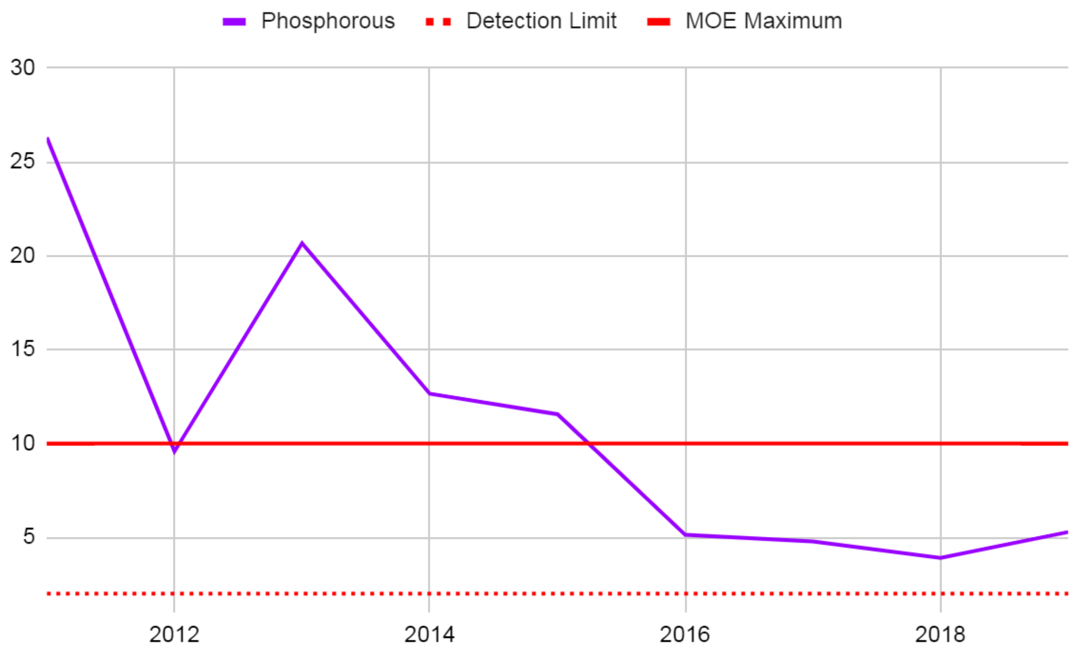


Figure 7: (a) Monthly Total Phosphorus, collected from Lake Windermere between May 21 and September 24, 2019. (b) Monthly Dissolved Phosphorous, collected from Lake Windermere between May 21 and September 24, 2019. (c) Average Total Phosphorous data, 2011-2019.
Note: Lines are for interpretation only, and do not represent continuous measurements. The "Detection limit" is the limit at which the extraction procedure can detect phosphorous in water; values below this line were considered "undetectable".

2.7 - Secchi Depth

Program Coordinator, Shannon McGinty, taking a Secchi reading on Dorothy Lake during an algae bloom in mind June 2019.

Overview

Secchi depth, like turbidity, is a measure of the suspended particles in the water. These suspended particles can be a combination of zooplankton, phytoplankton, algae, pollutants, or sediment (clay and silt).

Clear water lets a beam of light penetrate more deeply into the lake than murky water. Sunlight is needed for aquatic plants to photosynthesize, and for phytoplankton to grow and reproduce (Ministry of Environment, 2017a).

Secchi data collected year after year can provide information about trends in water clarity. Secchi depth generally follows the inverse pattern of turbidity — that is, when turbidity is high, the Secchi depth is low because it is difficult to see deep into the water.

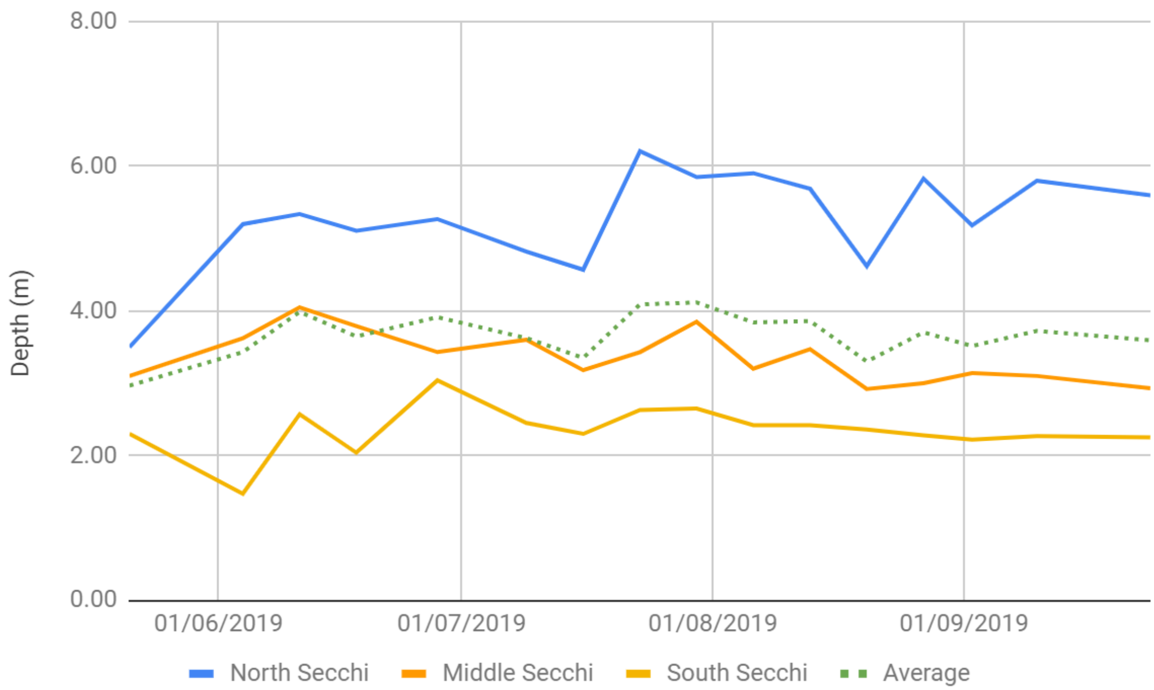
There is no objective set for Secchi depth in Lake Windermere (Neufeld et al., 2010). Following the objectives for turbidity, we should expect the Secchi depth to be lower in the spring during freshet, and higher in the summer as the lake flushes out over time.

Results

The average Secchi depth in 2019 across all sample sites was 3.67m (Figure 8a). Secchi depth was highest from July 23rd to September 24th, which corresponded with a low turbidity at this site during this time (Figure 8b).

Secchi depth tends to appear lower in the South sample site, simply because this site is much shallower than the North site. We can compare Secchi depth to Total depth to get a more accurate picture of how clear the water column is (Figure 8b); if the Secchi depth is the same as total depth, that means we were able to see all the way to the bottom of the lake. This is most common at the South sample site near the end of summer, when the water level gets lower and it is easier to see the bottom of the lake.

(a)



(b)

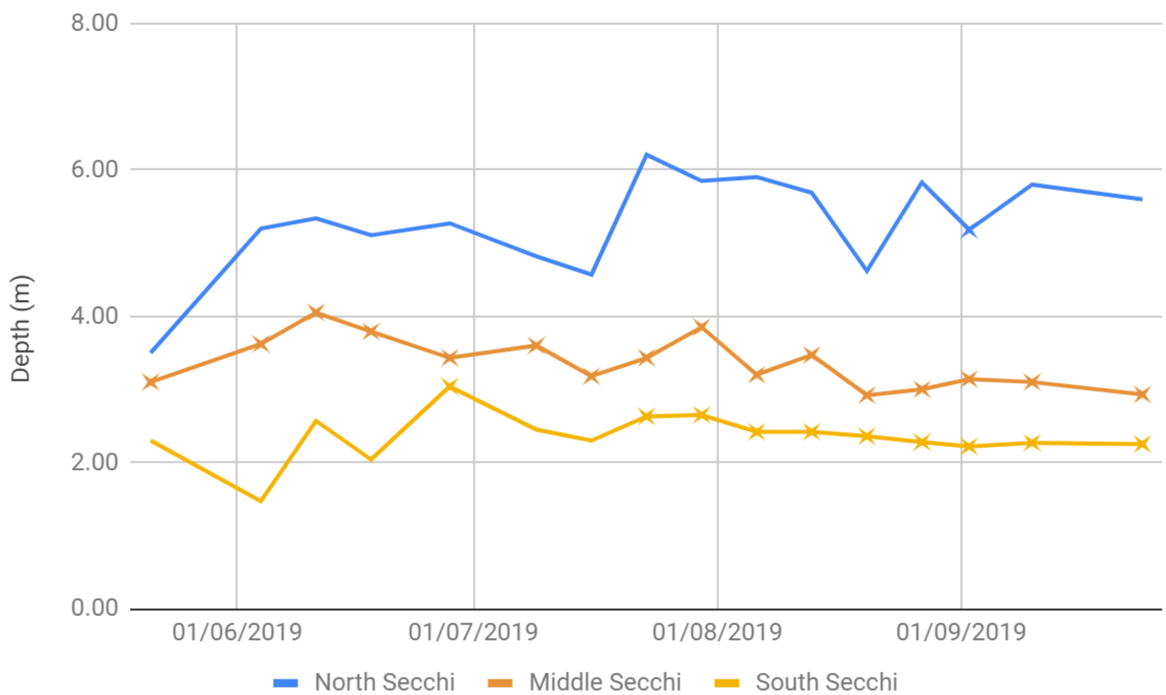
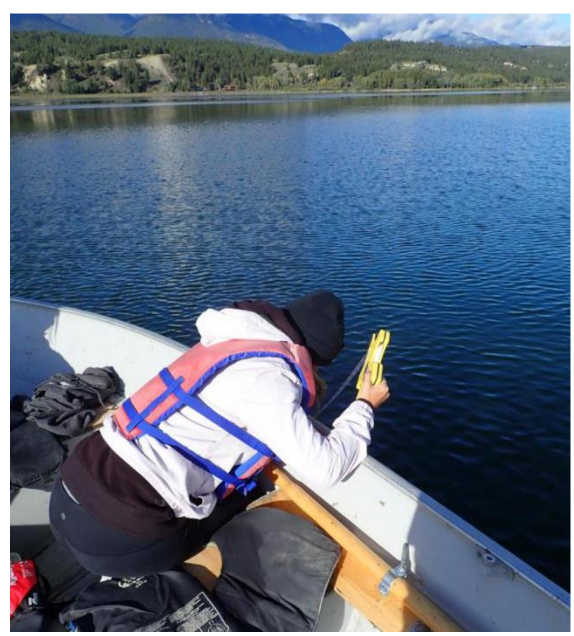


Figure 8: (a) Secchi depth (in metres) measured weekly for the sampling period May 21 to September 24, 2019. (b) Secchi and Total depth at each sample site, "X" represents where Secchi depth was same as Total depth. *Note: Lines are for interpretation only, and do not represent continuous measurements.*

2.8 - Total Depth

Overview

Lake Windermere is a widening of the main Columbia River channel, meaning it is different from typical lakes you might find in southern BC. The main difference is that it is very shallow - on average, between 3-4m depth in mid-summer. It also flushes much more quickly than an average lake, and has a better capacity to carry sediments and nutrients downstream because of this faster flow.



Volunteer Megan Lochhead measuring lake depth

We do report the average water depth for all three sample sites in the lake, but this is not very representative of Lake Windermere as a whole. This is because the South end, where water flows in from the Columbia Wetlands, tends to be much shallower than the other two sites. The North sample site is measured at the deepest point in the lake, on average between 6-7m in depth.

In deeper lakes, the water will separate into layers with cooler denser water falling to the bottom. When water is separated into lighter and denser layers like this, it is called "stratification". Lake

Windermere does not stratify, so we usually don't see a very large difference between the North Upper and North Lower water quality samples.

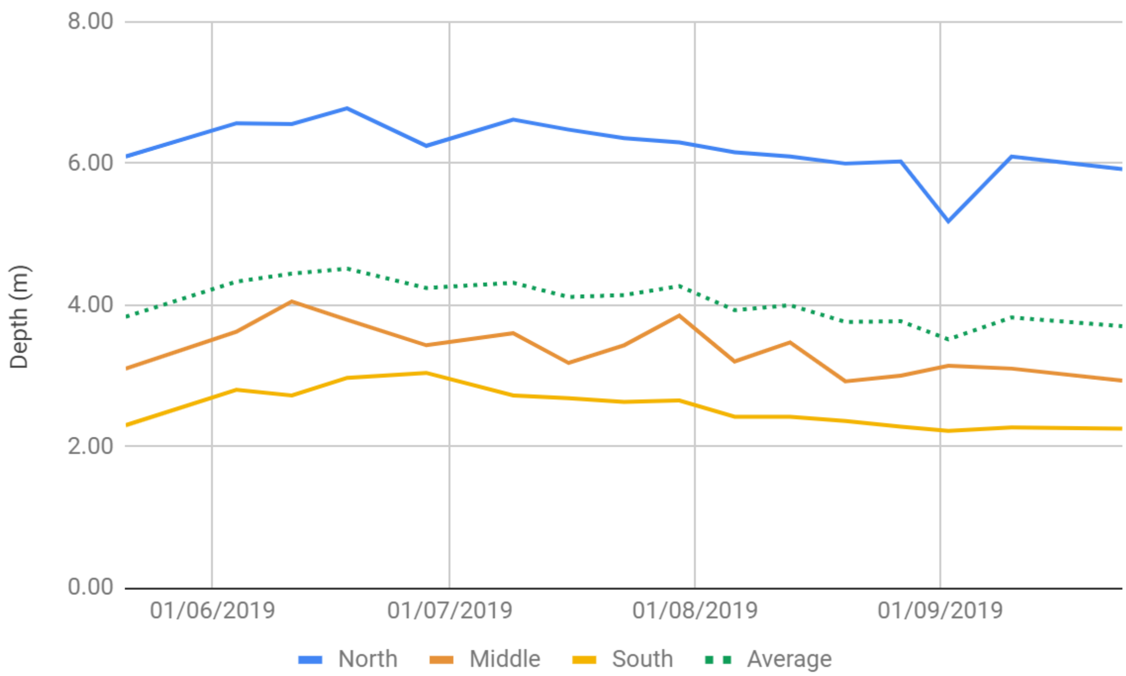
Depth can be an important consideration for aquatic life as well as for recreational boaters and drinking water users. Shallow water poses more risks because boaters can more easily be caught on sediment bars or clog their motors with aquatic vegetation growing up from the bottom of the lake. Shallower water also warms up more quickly, which can pose issues for drinking water quality and for the survival of aquatic life. There is no objective set for lake depth in Lake Windermere, but levels below 2m generally cause concern.

Results

Lake depth in 2019 followed the expected trend of being higher in spring during freshet, and gradually declining through the late summer due to less input from snowmelt runoff/precipitation and increased evaporation effects (Figure 9a). This trend was less pronounced than previous years due to a low snow pack winter, and increased precipitation throughout the summer season.

The deepest value, measured at the North sample site, was 6.78m on June 18th. The highest recorded value at this site since monitoring began in 2006 has been 7.3m, recorded in July 2012 and June 2013. Steeper rates of decline in water level have been recorded in recent years (Figure 9b). 2019 did not see as steep of a rate of decline as 2017 or 2018, but was observed to be an abnormal year based on recent weather patterns.

(a)



(b)

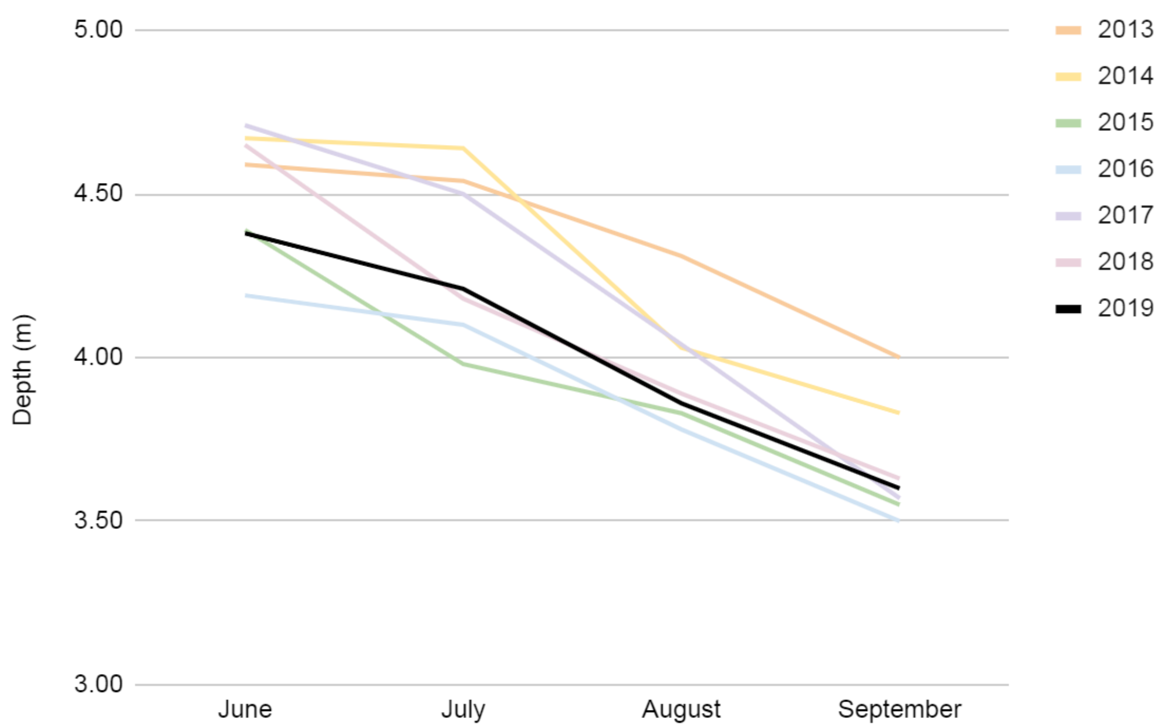


Figure 9: (a) Lake depth (in metres) measured weekly for the sampling period May 21 to September 24 2019. (b) Average lake depth across all sites, 2013-2019.
Note: Lines are for interpretation only, and do not represent continuous measurements. Middle site moved locations in 2013, data collected prior to this date is not comparable.

3. Aquatic Plant Survey, Invasive Mussel and Veliger Sampling

Summer Student, Keri Malanchuk, checking substrate sampler at Lakeview Meadows

3.1 - Background

Being relatively clear and shallow throughout the summer, Lake Windermere allows for good light penetration, which helps promote aquatic plant growth beneath the surface. Aquatic plants improve water quality by filtering out nutrients that might otherwise be used for algae blooms, and by trapping sediments that would be disturbed by motorized boat and wave action. Without rooted aquatic plants to help hold sediment in place, increased turbidity can result which degrades water quality (Rideau Valley Conservation Authority, 2016). Excess plant growth, however, can impede motorized boating and provide shaded habitat for predatory fish species such as largemouth bass.

Zebra and quagga mussel species have already caused significant environmental, social, and economic damage throughout North America due to their rapid spread and devastation of entire lake ecosystems (Darvill, 2017). Until recently, invasive mussels were mostly confined to Eastern Canada and the Southern United States; however, in 2016, invasive mussels were detected in two reservoirs in Montana (Ministry of Environment, 2017b) and in 2013 were found introduced in Lake Winnipeg, Manitoba (Lake Winnipeg Foundation, n.d.). This proximity to BC has increased the risk that an infected boat can pass through the border into BC waters, and Lake Windermere's proximity to two main borders of the province as well as its high recreational use further increase this risk of introduction.

Biologist, Rachel Darvill, identifying plants during AIS Inventory Project

Invasive species out-compete most other native species if allowed to establish. This often results in a loss of biodiversity and native species, which can have a cascading effect on water quality and fish & wildlife populations. The introduction and spread of invasive aquatic plants or mussels would not only be devastating to the economy, ecology and biodiversity of Lake Windermere, but to the entire Columbia Valley.

The LWA initiated an Aquatic Invasive Species (AIS) Inventory Project in 2009, which has seen an annual plant and veliger (mussel larvae) sampling occur on the lake in all years except 2013. Rachel Darvill (Goldeneye Ecological Services) was the lead biologist for aquatic plant sampling while Danny Smart (East Kootenay Invasive Plant Council) led the veliger sampling in 2019. In 2019, LWA installed six substrate samplers along the east side of Lake Windermere that were monitored monthly from June to August for zebra and quagga mussels.

3.2 - 2019 Sample Results

The 2019 survey marked the tenth year of invasive species sampling and included eleven lake-bottom (offshore) sampling locations and six shoreline-sampling locations, all at high-risk areas for invasive introduction around the lake.

No invasive species (plants, mussel larvae or mussels) were found during the offshore, shoreline plant surveys, substrate sampler monitoring, or the veliger testing.

It was noted that some survey sites (ex. Baltac Beach, Bayshore Condos, and Tretheway Docks) were almost completely devoid of aquatic plant communities (Darvill, 2019). The full 2019 AIS Inventory Report, published by Rachel Darvill, can be found on the LWA website under "Documents".

Boat scars on lake bottom observed by Rachel Darvill during aerial swan surveys for Columbia Wetlands Waterbird Surveys. Photo by Rachel Darvill.

4. Waterbirds

4.1 - Background

In 2018, LWA conducted their first Waterbird Survey, complete with a report highlighting the findings. This project was taken on to learn more about the bird populations using Lake Windermere. It was found that Lake Windermere provides significant bird habitat for large migrant flocks and breeding birds (Darvill, 2018). The lake is especially important for large flocks of migratory birds, such as American coots (Fulica americana), as well as four species of grebe - three of which are considered at-risk species (Darvill, 2018).

The LWA and Goldeneye Ecological Services undertook a boat survey in September 2019 to continue learning about bird populations on Lake Windermere.

4.2 - 2019 Sample Results

During the 2 hour and 48 minute survey 889 individuals were recorded, from a total of 18 different species. Of these sightings, the Surf Scooter, Cackling Goose, Greater Scaups, and large number of both Pied-billed Grebes and Red-necked Grebe's were rare sightings. Lastly, the Surf Scoter, California Gull, Horned Grebe, Western Grebe are all considered to be species at-risk that were recorded during this survey. The full survey inventory can be found here.

It is strongly recommended that management strategies be designed that can work to accommodate both human-use values and bird conservation for Lake Windermere. Specific recommendations to achieve this balance of conservation and human uses include:

- undertaking additional breeding season and fall migratory bird studies for Lake Windermere,
- factoring waterbird and wetland conservation into land-use decisions for Lake Windermere,
- improving signage about motorized boating regulations in the Columbia Wetlands WMA, and
- improving public education about the use of eBird and the importance of conserving habitat values of Lake Windermere for migratory and at-risk bird species.

5. Swim Beach Water Quality

5.1 - Background

Escherichia coli (E. coli) is a type of fecal coliform bacteria found in the intestines of most healthy animals. *E. coli* in water can be an indicator of sewage or animal waste contamination, or it may come naturally from the soil. Most strains of *E. coli* are harmless, though some can produce toxins that cause illness in people. The count of *E. coli* colonies per 100mL of water is a common way to measure how much bacteria is present in the water; however, it is important to know that this value represents a total count of all colonies, and does not necessarily contain any strains that are capable of producing toxins that affect humans. A higher *E. coli* count simply increases the probability that the water may contain a toxin-producing strain.

The LWA have an ongoing agreement with the Interior Health Authority (IHA) to collect public beach water samples, samples are analyzed by the IHA laboratory for *E. coli* bacteria, in compliance with Health Canada Guidelines. This assesses whether swim beach water quality meets recognized health standards.

Samples are collected at three public beaches around the lake: James Chabot Provincial Park (Athalmer), Kinsmen Beach (Invermere), and Windermere Beach (Windermere).

The Health Canada Guidelines for recreational water used for “primary contact” activities (e.g., swimming):

- Geometric Mean Concentration (minimum of five samples taken over 30 days): ≤200 *E. coli*/100mL
- Single Sample Maximum Concentration: ≤400 *E. coli*/100mL

5.2 - 2019 Sample Results

The geometric mean did not exceed the Health Canada recommended limit of 200 colonies of *E. coli*/100 mL for any of the public beaches tested, nor did any single sample exceed 400 colonies of *E. coli*/100 mL. For Lake Windermere, the highest geometric mean values over a 30-day period were as follows:

James Chabot Provincial Park	15.5 *E. coli*/100 mL
Kinsmen Beach	27.17 *E. coli*/100 mL
Windermere Beach	8.67 *E. coli*/100 mL

The highest single sample in 2019 was 65 *E. coli* /100mL, recorded on August 12th at the East side of Kinsmen Beach. This is a popular dog swimming area, which might explain the slightly higher bacterial concentration at this location.

Results of swim beach sampling are updated throughout the summer season and can be found by searching for Kinsmen, James Chabot or Windermere beaches at https://www.interiorhealth.ca/YourEnvironment/DrinkingWater/Pages/WaterSamples.aspx

6. Tributary inflow - Windermere and Abel Creek

6.1 - Background

Besides the main Columbia River channel, Windermere Creek is the major source of inflow into Lake Windermere. This tributary stream drains an area of approximately 90 km^2, and provides important fish spawning habitat (NHC, 2013). While Abel Creek is a much smaller tributary than Windermere Creek monitoring efforts are made as Abel Creek runs into Lake Windermere from the Paddy Ryan Lakes Reservoir used by the District of Invermere.

From 2007 to 2018, the Columbia Basin Water Quality Monitoring Program (CBWQM) ran on Windermere Creek. This project oversaw scientific data collection in streams of the East and West Kootenay, through fieldwork that was undertaken by local volunteers and non-profit organizations. LWA have continued monitoring of Windermere Creek, and additionally now monitor Abel Creek as well as a continuation of this project.

Water chemistry follows similar protocols and uses the same equipment as the lake water quality monitoring, with data collected for dissolved oxygen, specific conductivity, pH, turbidity, and temperature.

Flow/velocity measurements are crude, and taken using a meter stick to obtain surface velocity based upon the principle of conversion of kinetic to potential energy. This overestimates average channel flow, but underestimates actual surface flow due to friction. While not exact, if measured carefully and repeated the same way each time, this measurement can give us a general idea on how flow volumes change seasonally within a given area of stream.

In 2018, the LWA obtained four HOBO U20-L Water Level Loggers. In September 2018, the first logger was installed in a stilling well in Windermere Creek; the second was installed in April 2019 in Abel Creek. The third will be installed on the Athalmer Bridge at the outflow of the Columbia River from Lake Windermere.

The fourth is used as an atmospheric pressure gauge located at the LWA Office. These loggers measure water temperature and pressure to provide a reading on flow measurements to be used in compliment with surface velocity measurements.

2019 creek sampling results are still being analyzed and will be provided in a supplementary report.

Program Coordinator, Shannon McGinty, collecting eDNA Sample on Windermere Creek.

7. Acknowledgements

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- District of Invermere
- Regional District of East Kootenay
- Columbia Basin Trust's Environment Large Grants program
- LUSH Charity Foundation
- Royal Bank of Canada Foundation
- Columbia Valley Community Foundation
- Real Estate Foundation of BC
- Canada Summer Jobs
- Columbia Basin Watershed Network
- BC Community Gaming Grants

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- Tara Booty
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- Terri Eacrett
- Tina Friedenberg
- Gavin Jacobs
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- Erika S
- Stacey and Dyaln McIntosh
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- Baiba and Pat Morrow
- Shawna McKay
- Meaghan Lochland

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- Norm Zirnhelt, BC Lakes Stewardship Society
- Rick Nordin, BC Lakes Stewardship Society
- Bill Thompson, Columbia Lake Stewardship Society
- Tom Dance, Columbia Lake Stewardship Society

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Appendix A

Sampling methodology

Water Quality

Lake Windermere is sampled following the BC Ministry of Environment Water Quality Assessment and Objectives for Lake Windermere (Neufeld et al. 2010). Water quality laboratory analysis was completed by CARO Analytical (Kelowna, BC). The following water quality data were collected at all three sample sites:

a. Weekly (May - September) - in situ (field measured) data including depth, Secchi depth, water temperature, specific conductivity, pH, dissolved oxygen (DO), and turbidity.
b. Monthly (April - September) - Total Phosphorous and Total Dissolved Phosphorous.

The North site was sampled at two depths (Upper and Lower) since this is the deepest part of the lake. The Upper water sample was collected at arms' reach approximately 30cm below the surface, while the Lower water sample was collected 1m above the lake bottom using a vertical VanDorn sampler. The Middle and South sites were sampled at arms' reach 30cm below the surface only.

Water sampling took place within a four-hour timeframe on Tuesday mornings, from May to September 2019. Volunteer citizen scientists were joined by at least one trained LWA staff member for all lake excursions and assisted with field data collection.

Lake Sample sites were first located by boat using a hand-held Garmin eTrex20 GPS and preprogrammed coordinates that align with the sample sites in Figure 1. Once at a sample site, depth and Secchi depth measurements were taken using a weighted Secchi disk and meter line. Water temperature and conductivity were read using a YSI Pro30 conductivity meter. pH was read using a Eutech Waterproof pHTestr 10. Dissolved Oxygen was collected using the Winkler titration method with a Hach Model OX-2P (0.2-20mg/L) Test Kit. Turbidity was read using a Hach 2100Q Portable Turbidimeter calibrated to 10 NTU.

When monthly phosphorous samples were collected, a cooler containing sample bottles was brought on board the boat. Water samples were collected into bottles, which were then kept, on ice while being shipped via ACE Courier to CARO laboratories in Kelowna for analysis.

Aquatic Plants

Please see Darvill (2019).

Waterbirds

Please see Darvill (2018).

Swim Beaches

Bacteriology samples were collected on Mondays between June and early September (excluding long weekend holidays) before 1:00pm from three public beaches (Windermere (3 site), James Chabot (3 sites), and Kinsmen (3 sites)). Sample bottles were filled using a triple-rinsed beaker dipped inverted below the water's surface then turned upright within the middle of the water column. Filled bottles were immediately kept on ice until delivery to the Invermere Health Unit located at 110 10 St, Invermere, BC with a copy of each associated requisition form. From there, custody of samples was transferred to the IHA and samples were sent to their labs for analysis.

Data analysis and QA/QC

Raw data were first subjected to a quality control evaluation, to assess the accuracy and validity of the laboratory and field methods. Field sampling protocols followed those outlined above.

Water Quality

For in situ data collection, water quality instruments were calibrated once monthly as per manufacturer's specifications and expired or outdated solutions were discarded and replaced. All data was reviewed by the LWA for consistency and anomalies before being analyzed. Data was analyzed by plotting parameters over time in Google Sheets, for the current sampling year and past sampling years whenever possible. Geometric means of samples were taken where indicated, and included all samples taken within a 30-day period between start and end of sampling.

CARO laboratory's analysis for Total and Total Dissolved Phosphorous was completed using Persulfate Digestion / Automated Colorimetry (Ascorbic Acid) referencing the Guidelines for Canadian Drinking Water Quality (Health Canada Feb 2017). CARO assessed accuracy through use of laboratory control samples, trip blanks, and duplicate samples.

Aquatic Plants

Please see Darvill (2019).

Waterbirds

Please see Darvill (2018).

Swim Beaches

Sample results were obtained from the Interior Health Authority (IHA) and analyzed for geometric mean as well as individual sample result over time. Please contact the IHA if you have specific questions about their QA/QC protocol for lab samples.

https://www.interiorhealth.ca/FindUs/_layouts/FindUs/info.aspx?type=Location&loc=Invermere%20Health%20Centre&svc=&ploc=