Lake Windermere Community Based Water Quality Monitoring Program

2021Final Report

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Lake Windermere Water Stewardship Assistant 2021.

The Lake Windermere Ambassadors direct a Community-Based Water Monitoring and Citizen-Science Education program within the Lake Windermere watershed. 2021 marked the Fifteenth year of lake monitoring since the Lake Windermere Project began collecting water quality data in 2006.

In 2021, the Lake Windermere Ambassadors water quality monitoring program 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. Total Dissolved Phosphorus and Total Phosphorous were collected monthly from May to September. In addition, the LWA monitored substrate samplers at six sites on the east side of Lake Windermere for invasive mussels. Tributary flows and water quality were monitored at Windermere Creek and Abel Creek outlets. In partnership with the Interior Health Authority, *E. coli* data was collected at public swim beaches weekly, from May until September, excluding weeks with a statutory holiday Monday. Lastly, Goldeneye Ecological Services was contracted to complete an aquatic plant and fall waterbird survey on Lake Windermere.

Findings from 2021 show that Lake Windermere's water quality supports aquatic life and recreation. Five of the eight parameters deviated from the Ministry of Environment objectives, including Temperature, Dissolved Oxygen, Turbidity, Specific Conductivity, and phosphorus levels. 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 2021. The annual aquatic plant survey found no invasive species in Lake Windermere for the eleventh year of sampling. While overall, there is a healthy abundance of vegetation throughout the lake, there were a couple of sites of concern that saw less healthy vegetation, mainly where sites saw higher boat traffic (Darvill, 2019). The newly developed waterbird survey protocol and the investigative report found 18 species observed, 889 individuals, with several of them being rare sightings and species at risk. Invasive mussel larvae (veligers) were not detected in Lake Windermere as sampled 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, Columbia Basin Trust, LUSH Charity Foundation, EcoCanada, BC Community Gaming Grants, BC Hydro, the Columbia Valley Community Foundation and the Royal Bank of Canada Foundation. Additional funding support for our 2019 programs came from the Real Estate Foundation of BC, Canada Summer Jobs, and the Columbia Basin Watershed Network.

Questions about the report?

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1. Introduction

Lake Windermere is one of two headwater lakes of the Columbia River in Southeast British Columbia, Canada. The lake is a long widening of the Columbia River, with an average depth of ~3-4m (10-13ft).

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

Humans also depend on Lake Windermere for 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) bio geoclimatic 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 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. The 2021 season varied from 2020 and 2019, which were hot summers. In 2021 there was significant forest fire activity, minimal summer precipitation, and a heat dome where air temperatures in June exceeded 45ºC, which meant the hottest days were recorded outside of the typical months of July or August.

Lake Windermere Ambassador Water Stewardship Assistants for the 2021 Monitoring season.

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 begins at the North Shore of 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 with a watershed that drains an area of approximately 90 km² (NHC, 2013). Some of the significant developments within the Lake Windermere watershed include an active gypsum mine, active and historical forest harvesting, forest service roads, roads and a highway, agricultural and grazing activities, golf courses, and urban and residential development (McPherson et al., 2014).

1.3 Community-Based Water Monitoring

Concerns about increased development and changes to Lake Windermere in the early 2000s 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) is a community-led, charitable non-profit society formed in 2010 to protect Lake Windermere in perpetuity. The LWA has overseen a Community-Based Water Monitoring program on Lake Windermere since their inception, using the assistance of volunteers and essential 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 compares present conditions to evaluate whether the lake water quality is suitable for recreational and ecological needs. By testing lake water quality weekly in the summer, the LWA has 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 to help inform sustainable watershed planning and restoration initiatives in the Upper Columbia watershed.

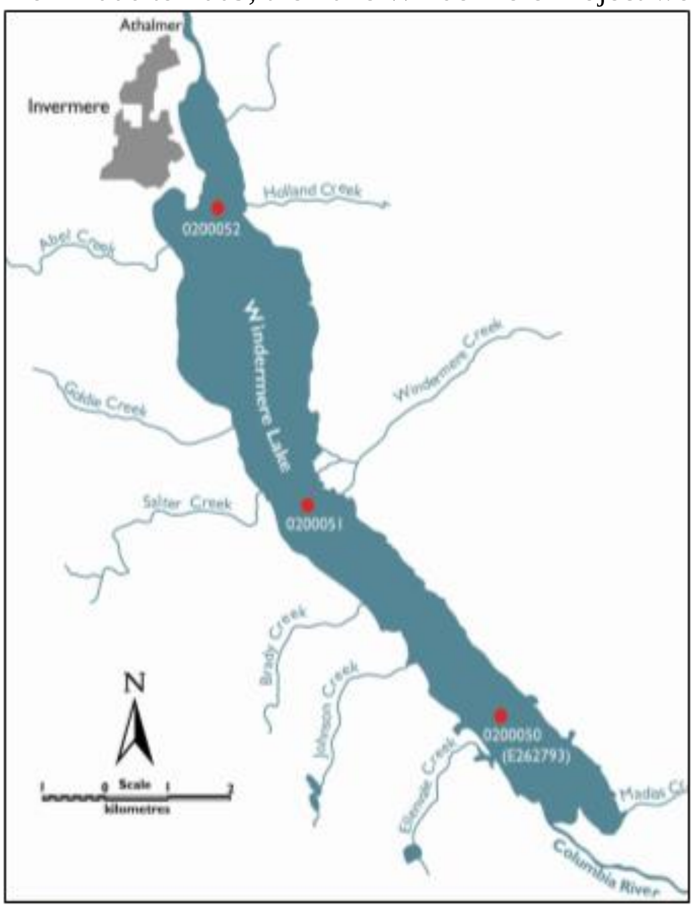

Figure 7: Lake Windermere Sampling Sites: North (0200052), Middle (0200051), and South (0200050).

1.4 Sample Sites

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

2. Lake Windermere Water Quality Results

2.1 Temperature

Overview

Water temperature is critically essential to lake health as it directly impacts water chemistry (ex., dissolved oxygen, specific conductivity, water density) and influences the rate of chemical and biological reactions. Which, in turn, impacts the ability of aquatic life to grow, survive, and reproduce in a given 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).

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 protecting freshwater aquatic life (Neufeld et al., 2010). For example, many freshwater fish species observed in this lake have optimum temperatures below 18°C for rearing, spawning, and incubation (Ministry of Environment, 2017a). In contrast, 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 (Ministry of Environment) has 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.

Water Stewardship assistant and citizen science volunteer using YSI ProDSS Probe to monitor water temperature.

Results

The 2021 season had the highest water temperature average recorded over the past ten years, which was 19.7°C. The second-highest seasonal average water temperature was recorded in 2015 and was 19.0°C. Scorching air temperatures were recorded over the last two weeks of June, which caused an increase in the water temperatures. The hottest water temperature recorded throughout the season was on June 29th and was 24.3°C. The average recorded water temperatures for all sample sites on June 29th exceeded the maximum allowable temperature of 20°C and reached 23°C (Figure 2a). However, due to the extensive range in average recorded temperatures throughout June, with cooler temperatures at the start of the month, the average monthly temperature for June was 19.3°C, just below the 20°C maximum monthly average recommended by MOE (Figure 2a).

The highest temperature measured in 2021 was 24.3°C, recorded on June 29th at the Middle sample station (Figure 2b). The highest temperature measured in 2020 was 22.6°C on August 8th at the North sample site. A continuous temperature logger was installed in 2020 near the North sample site to address concerns related to sample time bias (Figure 2b). However, the temperatures were significantly lower than the field samples, and the maximum and minimum temperatures stayed the same. As a result of the difference in recorded temperatures between the manual samples and the continuous temperature logger, it is believed that the continuous temperature logger was submerged in sediment which prevented it from collecting accurate data. It might be useful before installing it in the future to calibrate and check the temperature logger as well.

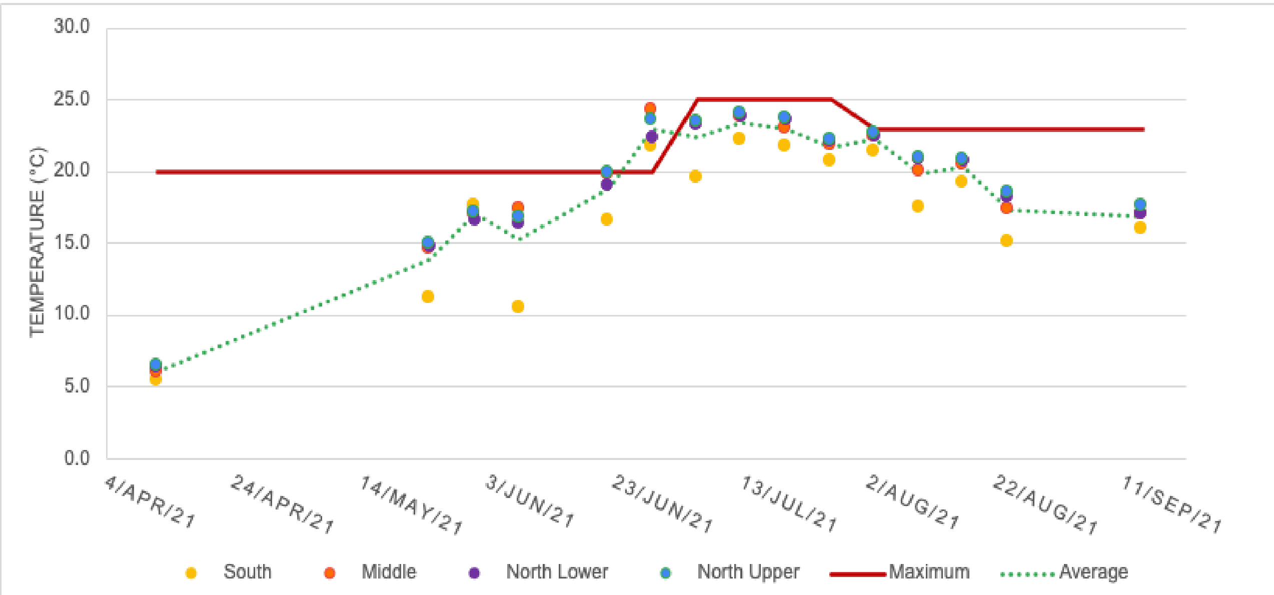

Figure 8a: Average Lake Windermere water temperatures are recorded weekly at the three sample sites from April 4th to September 11th, 2021.

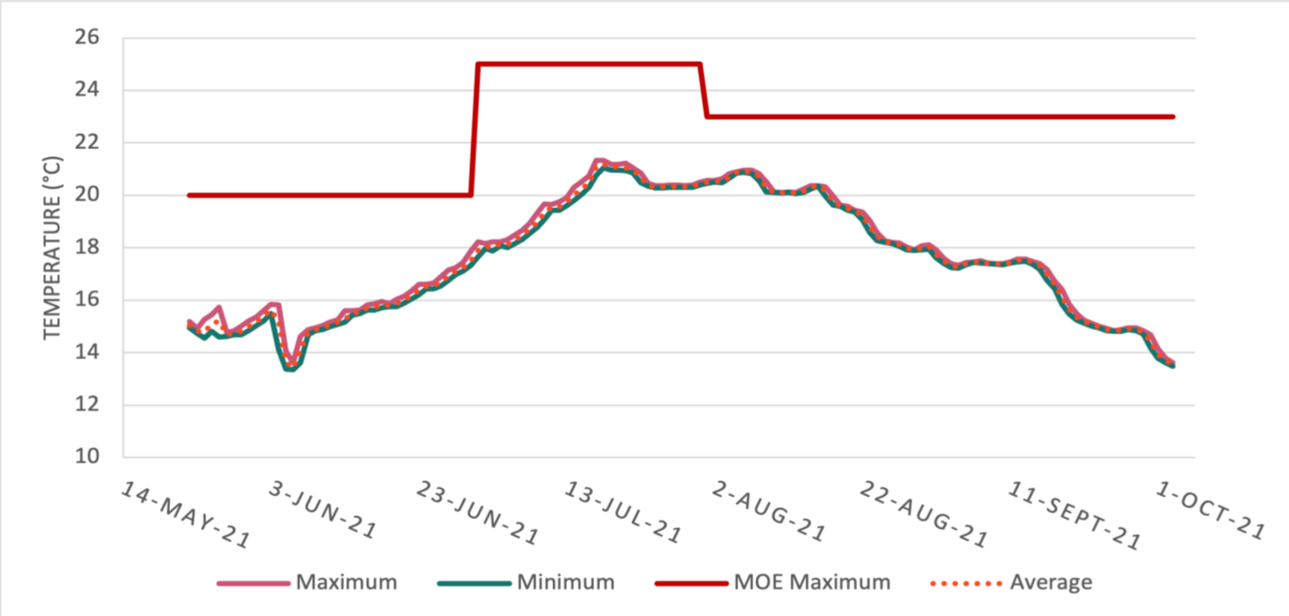

Figure 2b: Continuous temperature logger, water temperatures recorded every day between May 23rd and November 3rd, 2021.

2.2 Dissolved Oxygen

Overview

Dissolved Oxygen (DO) is another name for the free oxygen gas 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).

Water Stewardship Assistant using YSI ProDSS probe to measure DO.

Oxygen can be transferred to water from the atmosphere or produced by submerged aquatic plants and phytoplankton during photosynthesis. It is then removed from the water by respiration, chemical reactions, and organic decomposition in aquatic plants and animals. For example, a large amount of decomposing plant material within a lake can decrease DO concentrations in the water because 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. The inverse relationship between water temperature and dissolved oxygen means warmer water holds less oxygen than cooler water which holds more oxygen (Ministry of Environment, 2017a). Warmer waters also directly influence the rates of biogeochemical reactions and transformation processes within the water column and sediment bed. Temperatures increase metabolic rates, affecting BOD decay, sediment oxygen demand, nitrification, photosynthesis, and respiration, decreasing dissolved oxygen levels (Harvey et al., 2011).

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

Results

During the 2021 summer season, the average DO values over the five sites over 30 days fell below the MOE 8 mg/L minimum threshold for an extended period, between the beginning of July to the end of August. However, the DO values did not drop below the instantaneous minimum of 5mg/L, nor did they exceed the 15mg/L maximum recommended by MOE (Figure 3a).

The Instantaneous values ranged between a low of 5.70 mg/L recorded on August 3rd at the North Upper sample site, and a high of 12.69mg/L recorded on April 12th at the North Lower sample site. (Figure 3a). Although DO did not fall below the instantaneous minimum of 5mg/L, it is essential to note it was below 6mg/L for two sample weeks in a row and exclusively at the North Upper and Lower Sites.

An analysis was conducted on the correlation between water temperatures and DO, resulting in a negative (inverse) correlation of -0.81. (Figure 3b). The correlation between the increase in water temperatures at the end of June and the decrease in DO is significant and coincides with Figure 3c. This correlation could indicate that the initial decrease in DO is related to the initial increase in temperature. However, the DO was sustained below the minimum 8 mg/L average for an extended period, which could be related less to the immediate effects of temperature and more to temperatures impacts on the rate of biogeochemical reactions and metabolic rates in the water column (Figure 3c).

The highest DO values were recorded at the South sample site. These high values 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, which holds more oxygen.

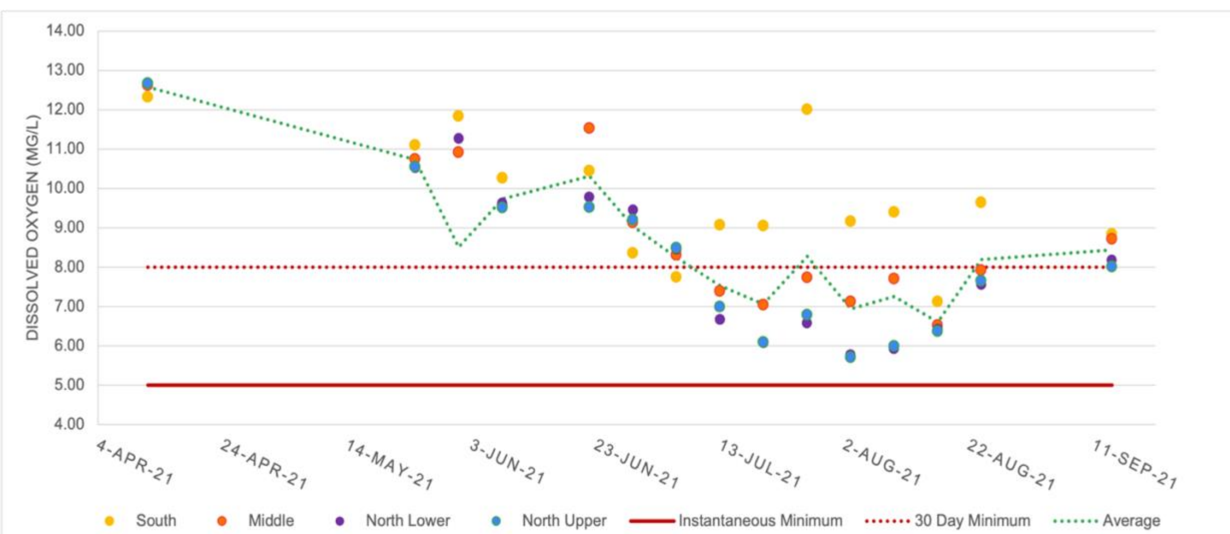

Figure 9a: Lake Windermere Dissolved Oxygen levels; instantaneous DO values, average DO over 30-days and all five sites, and MOE minimum allowable DO instantaneous and average values.

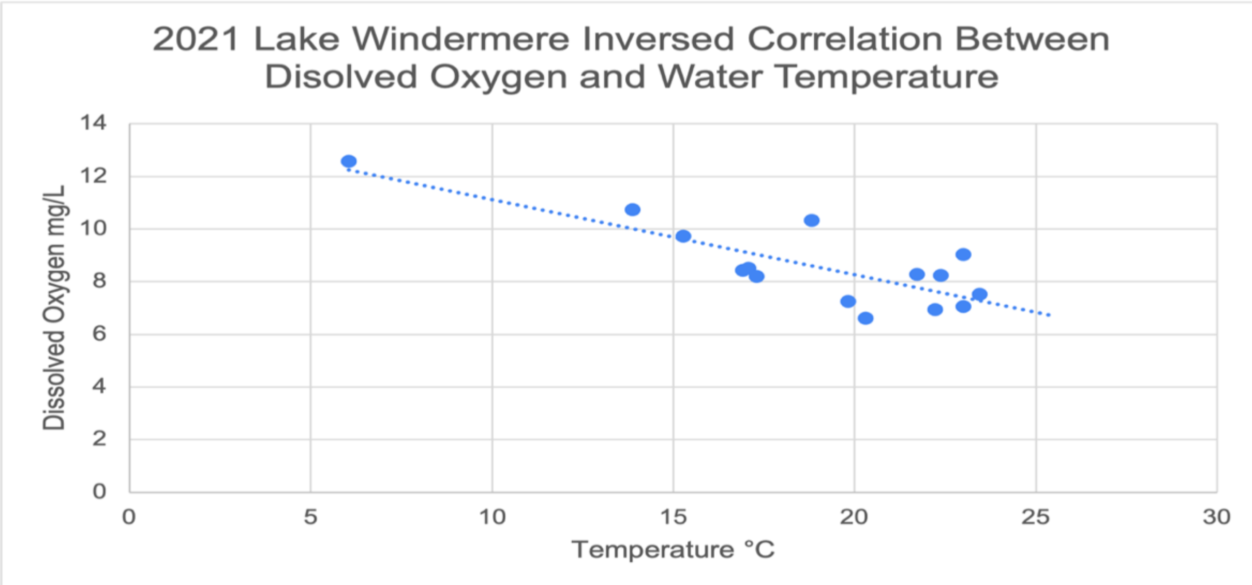

Figure 3b: Lake Windermere Inverse Correlation between Dissolved Oxygen and Water Temperature Averages.

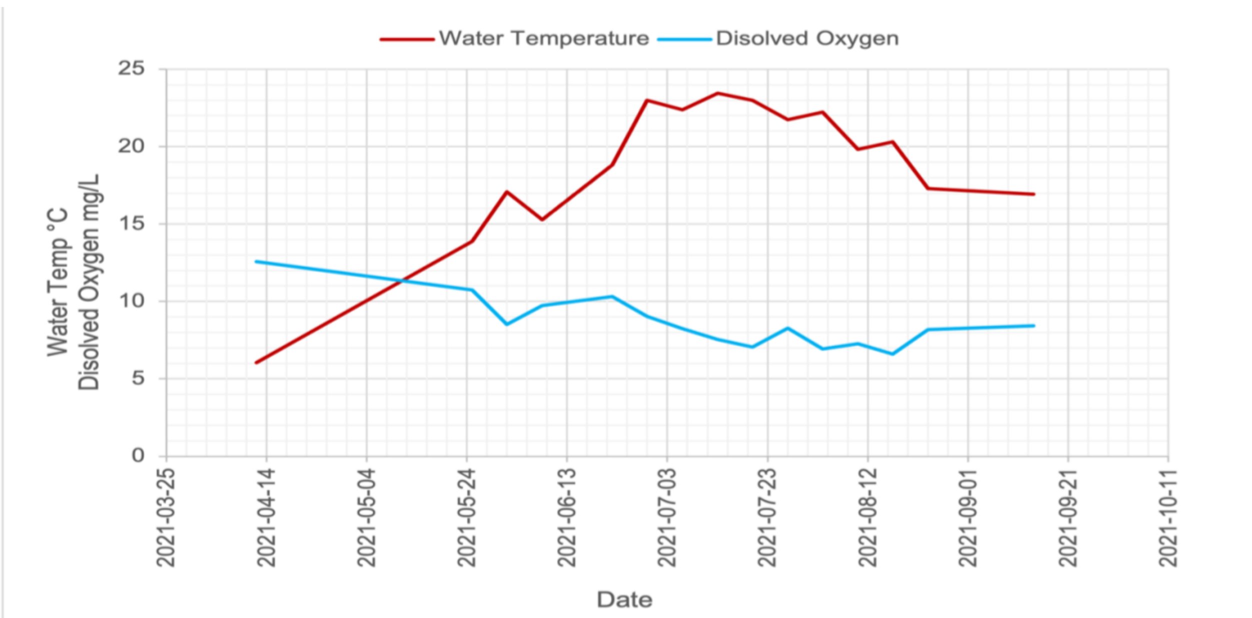

Figure 3c: Lake Windermere 2021 Average Water Temperatures and DO Values.

2.3 Turbidity

Overview

Turbidity is a measure of the light scattered by particles suspended in water and indicates the clarity of the water. Suspended particles in the water consist of silt, clay, organics, algae, and other microorganisms. These particles may carry pathogens and chemicals harmful to human health and reduce light penetration, thus affecting primary and secondary productivity. When light cannot penetrate easily to reach aquatic plants, this reduces their rate of photosynthesis, reducing the amount of oxygen in the water. Fish can also become stressed due to reduced ability to navigate, find prey, clogging of gills, and other physiological stressors (Ministry of Environment, 2017a).

Water Stewardship Assistants 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).

The turbid-flow period coincides with freshet and commences when the accumulated snowpack melts in the spring, increasing streamflow. It ends in the summer when the snow in the watershed has melted, flows return to normal and water levels are more stable. The turbid flow period occurs between May 1st to August 15th. The MOE turbid-flow maximum indicates that the 95th percentile of turbidity measurements taken in 5 days over 30 days should not exceed 5 NTU (turbidity units).

The clear-flow period is set between August 16th through April 30th. During this time, turbidity values tend to be very low, with any elevated values resulting from rain events and physical disturbances of stream banks. The MOE maximum turbidity at clear flow should be <5 NTU. The mean turbidity (based on a minimum of five weekly samples collected within 30 days) during the clear-flow (non-freshet) period should be <1 NTU.

Results

Turbidity in 2021 did not remain within the acceptable ranges for recreational water quality and aquatic life. The mean 30-day turbidity values for 2021 did exceed MOE recommendations for turbid flow on June 8th and exceeded the MOE recommendations for clear flow on September 14th, 2021 (Figure 4a).

The South sample site saw the highest peak in Turbidity on June 8th at 22.6 NTU and the second-highest peak on June 22nd with 10.30 NTU (Figure 4a). The 2021 turbidity peak was significantly lower than the peak turbidity of 2020, which was 42.1 NTU and occurred on June 9th at the Middle Site. This 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.

The turbidimeter used by the Water Stewardship Assistant to measure turbidity.

Eleven instances were recorded during the turbid flow period where readings exceeded MOE objectives (Figure 4a). The highest three occurred during the turbid-flow period, and the remainder during the particular flow period. Two of the turbid-flow readings occurred at the South sample site, likely due to sediment entering the Columbia River through Dutch Creek and settling in Lake Windermere. The third turbid-flow reading occurred at the North Upper site near the wetlands. Wetlands usually help attenuate high Turbidity by slowing flows and allowing sediment to settle; however, the sediment loads coming in through the wetlands in the 2021 freshet may have been too high for this to occur.

The average across all sites exceeded the MOE clear flow mean 30-day turbidity values of < 1 NTU. Nine out of twelve samples taken during the clear flow period exceeded the MOE recommended average. Two out of the three sample days were greater than or equal 1 NTU. This increase in Turbidity could be related to increased rain events throughout August (Figure 4b).

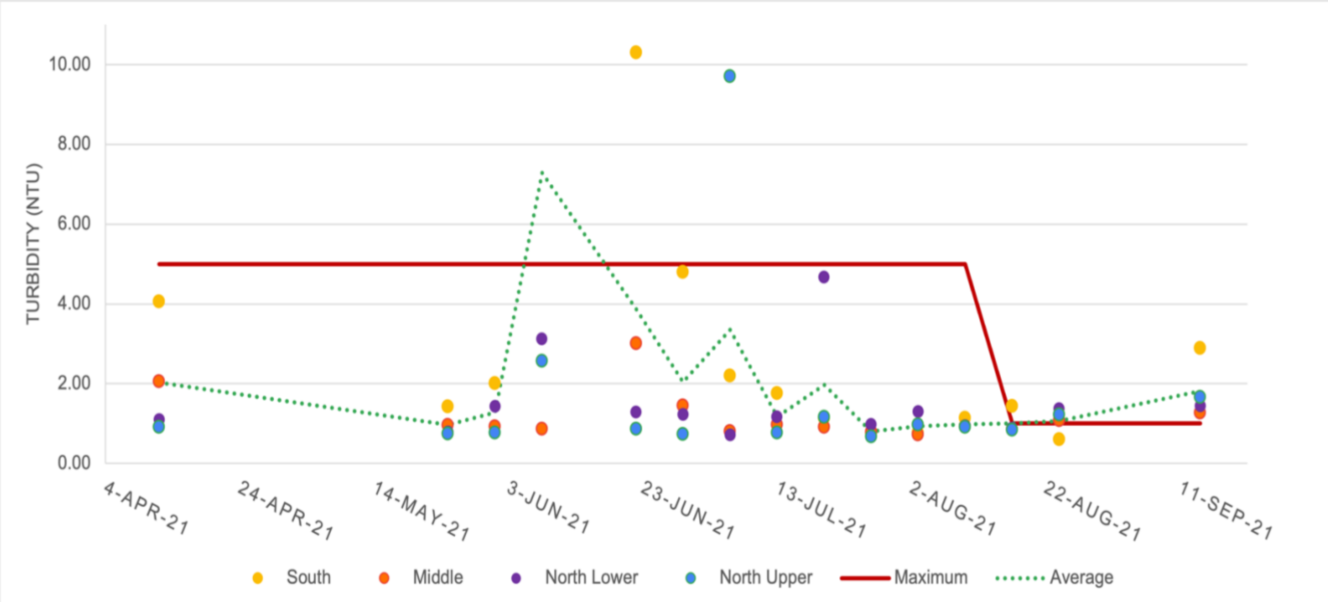

Figure 10a: Lake Windermere 2022 Turbidity (NTU) Levels; mean 30-day Turbidity, recommended maximums, and site-specific measurements.

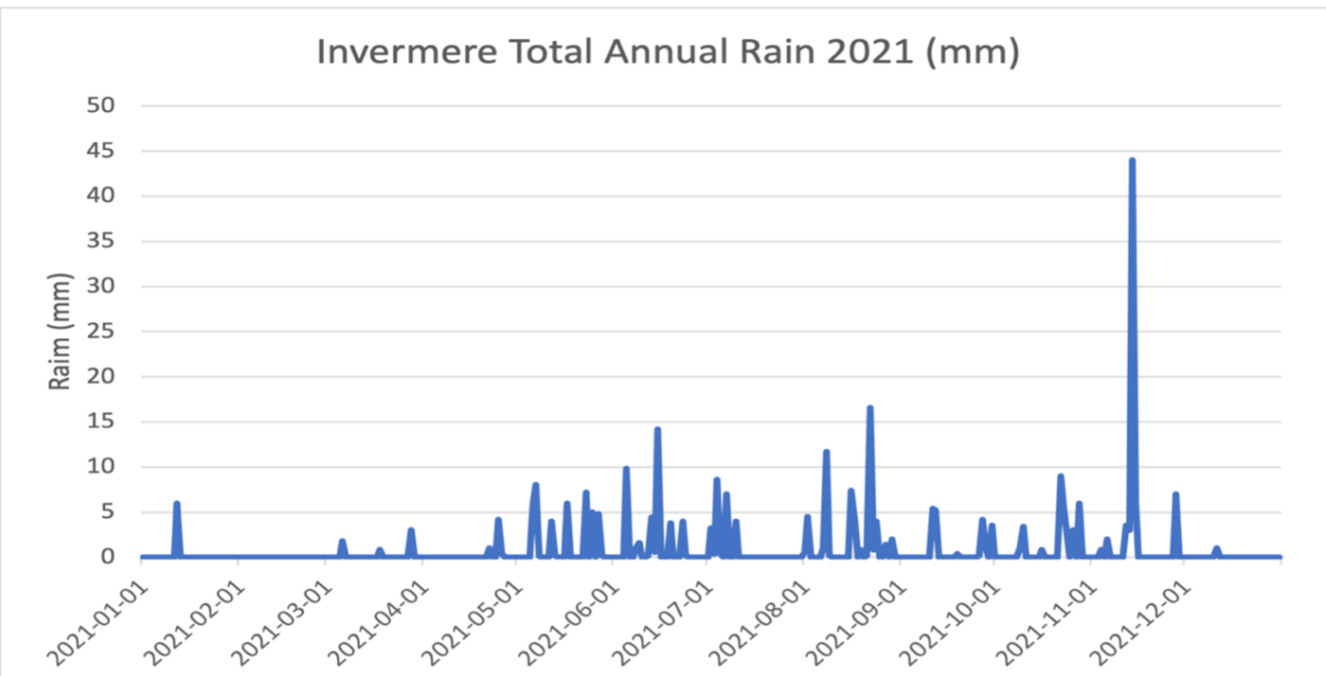

Figure 4b: Invermere Total Annual precipitation, 2021.

2.4 pH

Overview

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

Citizen Science volunteer measuring pH.

The pH of natural lakes is rarely neutral because 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 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). No MOE objective is set for pH in Lake Windermere; however, most aquatic organisms prefer a habitat where pH stays within 6.5-9.0 (Neufeld et al., 2010).

Results

pH measured in 2021 was comparable to measurements taken in 2020. The pH measurements for 2021 ranged from 7.1 to 8.5. pH measurements for 2021 were recorded to be between 7.9 and 8.8, with a slightly decreasing trend between June to August (Figure 5a). There were no significant dramatic changes in pH during 2021; however, on July 7th, there was a minor spike specifically at the Southern Sampling site. The site recorded a season-high pH of 8.78. It is important to note that Turbidity was recorded at its lowest point (figure 4a). It is also important to note that the location of the south sample site is close to the Fairmont wetlands. The wetlands have the capability to produce a high oxygen output and can increase the pH, especially if the Turbidity is low.

pH may have an inverse relationship with Turbidity. With less Turbidity, fewer particles are available to scatter sunlight that enters the water. The increased amounts of light reaching submerged aquatic plants mean that sunlight would not be a limiting factor to photosynthesis or plant growth. Therefore, a decrease in Turbidity increases 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 complex parameter to measure in the field accurately, and the equipment used by the LWA is over ten years old. Since 2020, monthly pH samples have been sent to CARO Laboratories as a form of quality assurance (Figure 5b). It found significant differences between field and lab measurements. Some of these inaccuracies could be caused by transportation, and that pH sampling equipment needs to be updated.

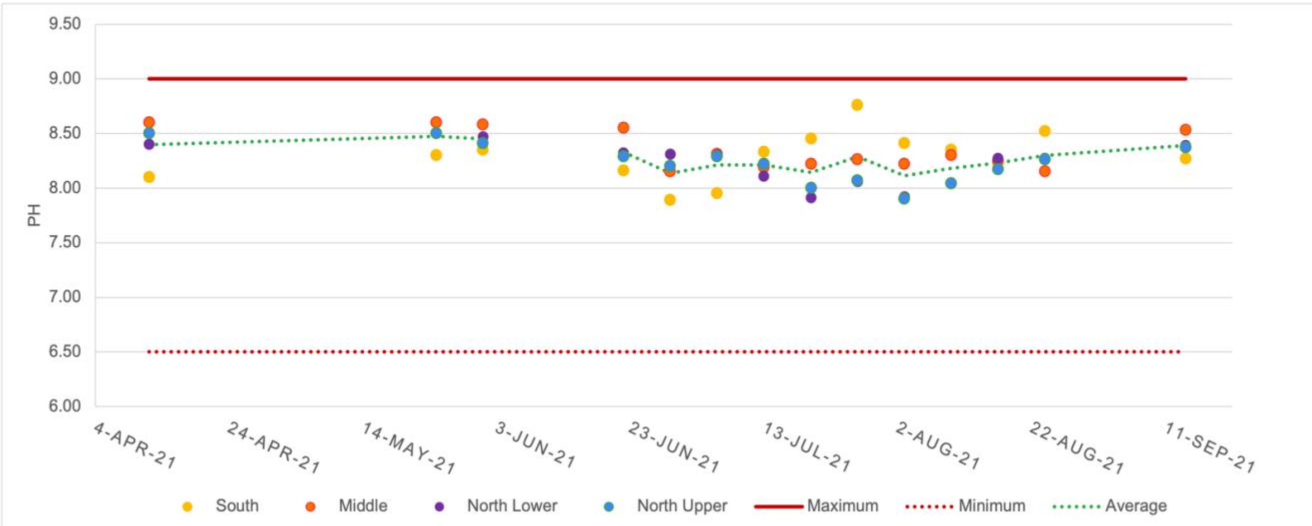

Figure 11a: Lake Windermere pH recordings, 2021. Maximum and minimum MOE requirements.

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, sulphides, and carbonates. For this reason, a measure of conductivity in water may be used as an indicator of water pollution.

Water conductivity 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). Specific Conductivity is reported at a standard temperature (20C). Water's specific conductivity is also affected by the bedrock geology of the surrounding area. The Lake Windermere watershed is surrounded by weathering-prone bedrock (such as limestone or clay), giving higher conductivity values than more stable bedrock (such as granite). The effects of water temperature on specific conductivity are corrected when using the device.

Water stewardship assistant measuring specific conductivity using the YSI ProDSS.

Results

The results of Specific conductivity in Lake Windermere ranged between 170.5 to 409.0 µS/cm in 2021 (Figure 6a). The sample site with the lowest Specific conductivity was the South sample site, near the outlet of the southern wetland. The ideal Range Maximum for the first week was exceeded at all sites. Both north sites exceeded the maximum for the first four consecutive weeks at the start of the summer.

The Average exceeded the maximum for the first two weeks and was measured just below the recommended maximum in the third week. These measurements are consistent with 2020 data. Following mid-June, measurements remained well within the Ideal Range of Minimum and Maximum. South site recoded the lowest measurements throughout the summer.

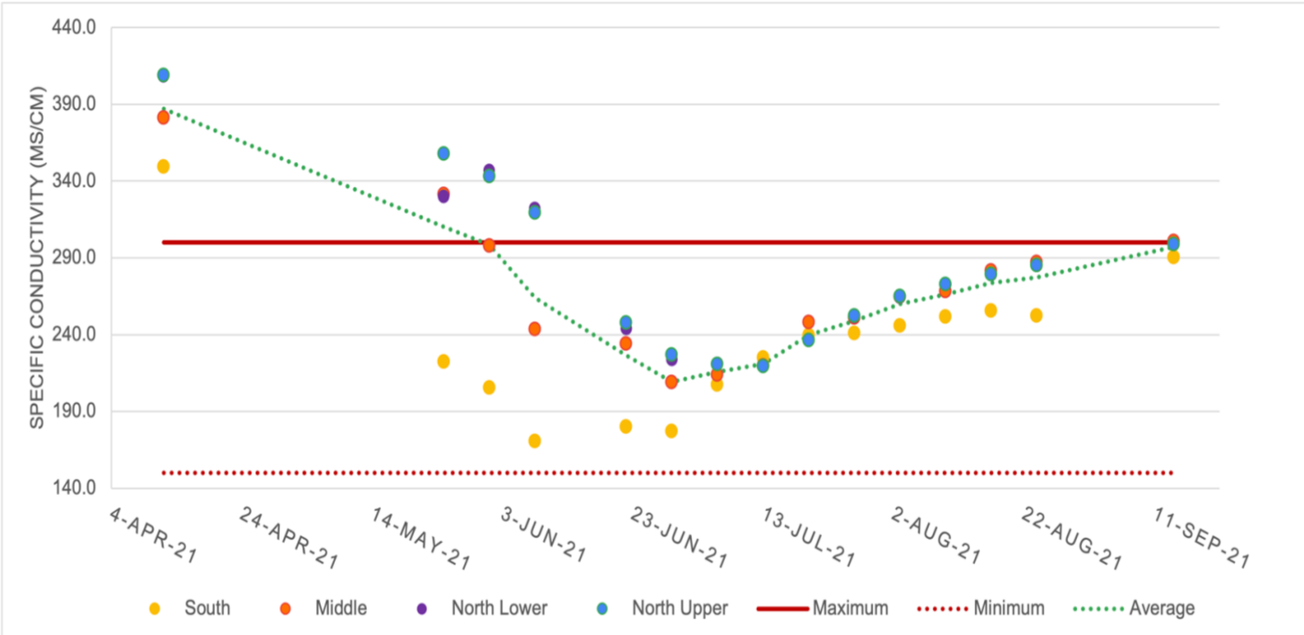

Figure 12a: Lake Windermere Specific conductivity (µS/cm) measurements 2021. Recommended maximum and minimum values and average conductivity across all sample sites.

2.6 Phosphorus

Overview

Phosphorus (P) is a nutrient essential for life. Phosphorus 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 algal growth and overproduction of bacteria, which can affect other forms of aquatic life and human health by toxic algal blooms.

Water stewardship assistant and citizen scientist collecting water samples on lake Windermere.

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

Phosphorus is naturally derived from soil erosion and biological recycling within the lake. For example, natural sources of Phosphorus include nutrient cycling when plants and animals die and decompose and soil mineral transport. Two primary human-caused inputs of Phosphorus into waterways in North America include agricultural runoff and wastewater. Within the Lake Windermere watershed, possible anthropogenic sources of Phosphorus in the tributaries and the lake include agricultural runoff, golf course and resort fertilizer runoff, waterfront lawn & garden fertilizer runoff, and municipal stormwater runoff containing detergents and other phosphate-bearing chemicals, or leaky shoreline septic systems.

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

Results

2021 saw an increase in results for Total and Dissolved P levels compared to 2020. The highest recorded value for Total P in 2020 was 14.60 µg/L at the South sample site on June 23rd, compared to the highest recorded value for Total P in 2021, which was 29.70 µg/L at the Middle sample site on June 22nd. The lowest value in 2020 was 5.30 µg/L on August 25th at the Middle sample site, and the lowest value in 2021 was 5.60 µg/L on September 14th at the Middle sample site (Figure 7a). Out of the total P samples taken in 2021, 39% exceeded the MOE recommendation of 10 µg/L. The middle and North upper sample sites had 50% of their samples exceeding the MOE maximum. The average total P exceeded the MOE Maximum for 50% of the sample days during May-July. The month of June had the highest average Total P, recorded at 15.78 µg/L.

It is expected that Total Phosphorous be higher when Turbidity is highest. This relationship may have been present during the 2021 Sampling Season, given that Total Phosphorous was highest on June 22nd and Turbidity was highest two weeks prior on June 8th, which is the same time frame observed in the 2020 data. However, this may also indicate that the sources of phosphorous to the Lake Windermere system fluctuated throughout the season. It is difficult to point to the source of phosphorous as it occurs both naturally and through human inputs. It is essential to continue to watch this trend for future management strategies.

At the Middle sample site, the highest ever-recorded value of Total P by the LWA was 67 µg/L on August 20th, 2013. This record was more than six times the recommended limit and prompted the LWA to increase monitoring for phosphorous. Since then, 31 out of 149 samples (21%) have exceeded Total P, nine of which occurred in 2021 (Figure 7b).

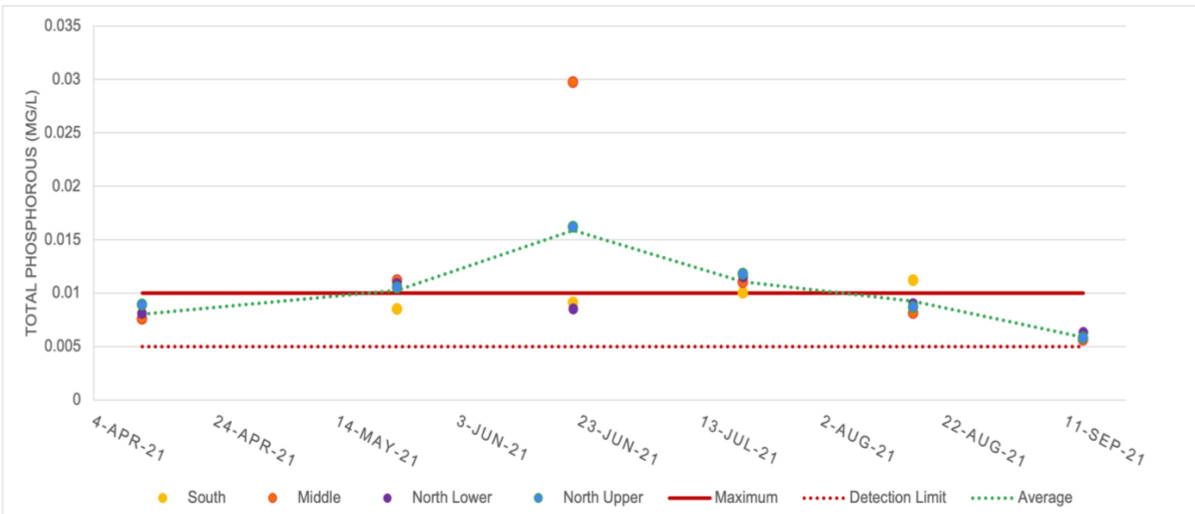

Figure 13a: Monthly Total Phosphorus and Monthly Average Total Phosphorous, collected from Lake Windermere between April 12th and September 14th, 2021.

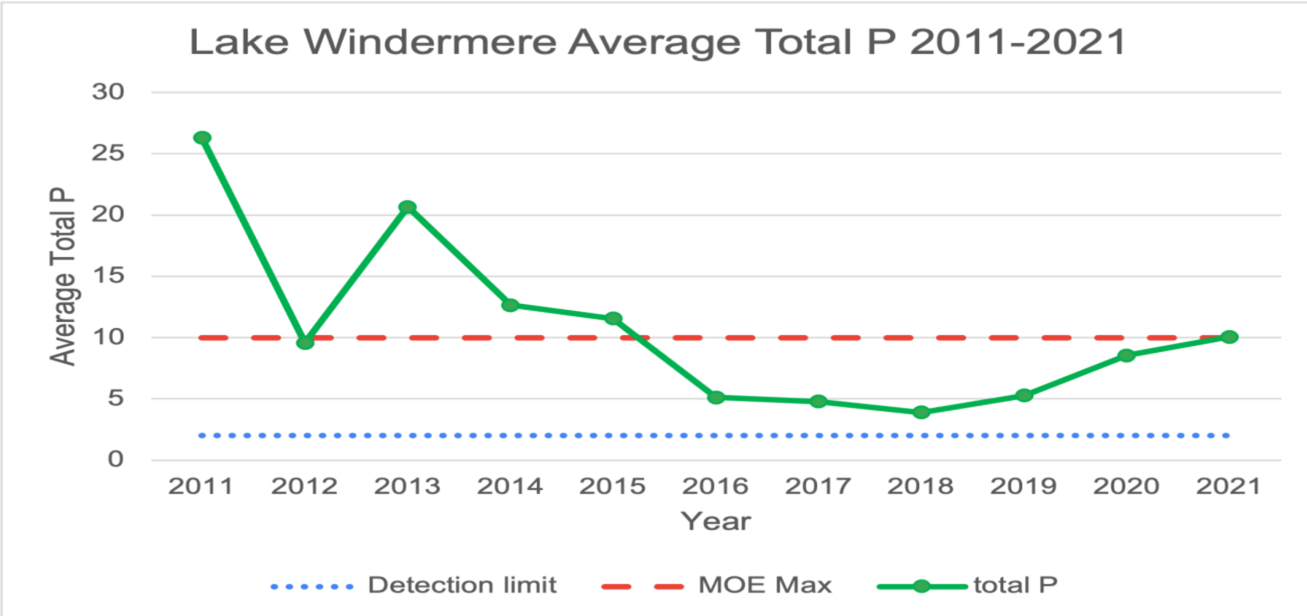

Figure 7b: Lake Windermere Average Annual Total Phosphorous data, 2011-2021.

2.7 Secchi Depth

Overview

Secchi depth is related to water clarity and is a measure of how deep light can penetrate the water column. Changes in water clarity, similar to turbidity, can be a result 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). Therefore, Secchi is a measurement of how deep the photosynthetic zone goes into the water column.

Lake Windermere water monitoring Secchi depth.

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 are no objectives 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 2021 across all sample sites was **1.**82m (Figure 8a), which was 1.83m less than the average 2020 depth. However, the average depth in 2020 was not calculated as accurately as 2021 because it included the Secchi depth measurements that were the same as the total depth. Therefore, an accurate analysis of the changes in clarity between the two seasons cannot be calculated. Secchi depth was the lowest from June 3rd to June 23rd. In 2020 the lowest average Secchi depth readings were recorded between June 9th and 23rd. This is indicative of the timing for our spring freshet when the snow melts.

The 2021 lowest average readings correspond with an increase in turbidity at the same time. However, there was a spike in average turbidity on July 6th which did not correspond with a decrease in average Secchi depth. (Figure 8b). Secchi depths were lower in the South sample site, because this site is shallower than the other sites, as well as the site that's closet to the tributary from Columbia Lake.

Comparing Secchi depth to Total depth creates a more accurate picture of how clear the water column is (Figure 8b). If the Secchi depth is the same as total depth, it means we can see to the bottom of the lake. The Secchi depth was the same as the total depth for 60% of the data in 2021 (Figure 8c). The North site which is the deepest site had the greatest most Secchi depth readings that were less than the total depth. The middle site had the least amount of Secchi depth readings that were less than total depth. On June 8th both the South site and the North Site recorded the largest variance between Secchi depth and the maximum depth. Which also correlates to the date when the average Secchi depth was the lowest, and when the turbidity was the highest (Figure 8b).

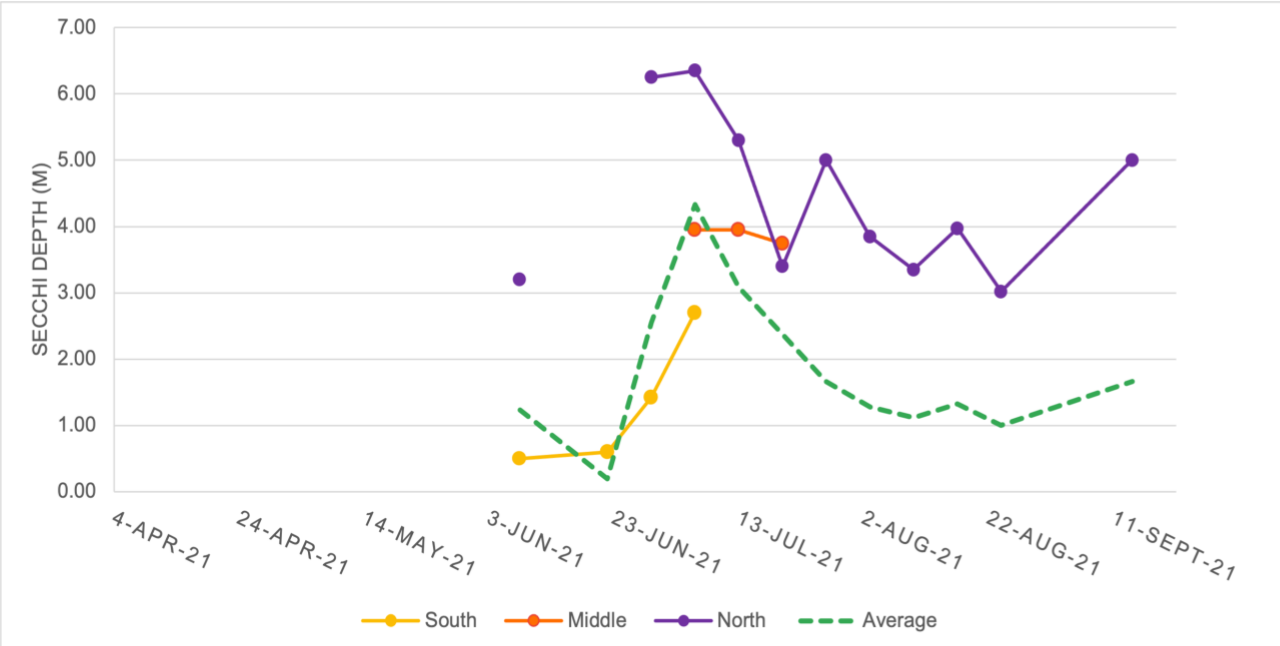

Figure 8a: Lake Windermere Secchi depth (metres) measured weekly for the sampling period April 12th to September 14, 2021. Secchi depths the same depth as the water column were not included.

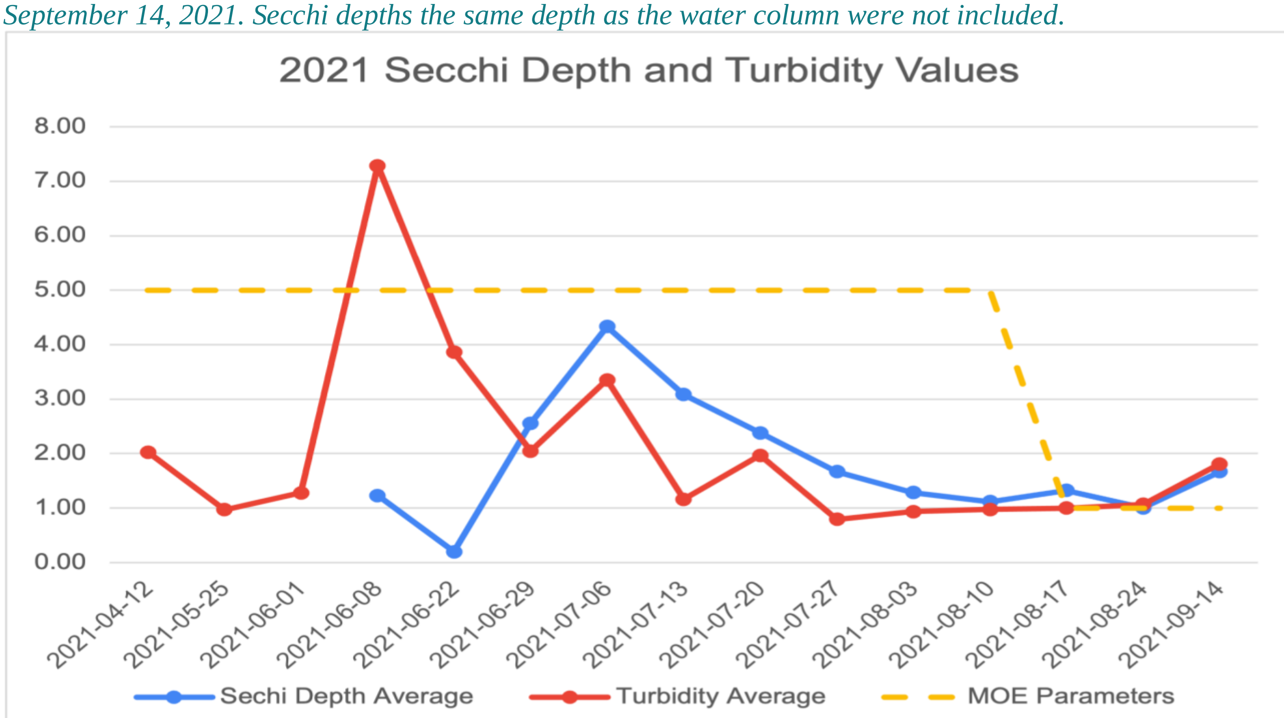

Figure 8b: Lake Windermere Average Secchi Depth and Average Turbidity Depth, 2021.

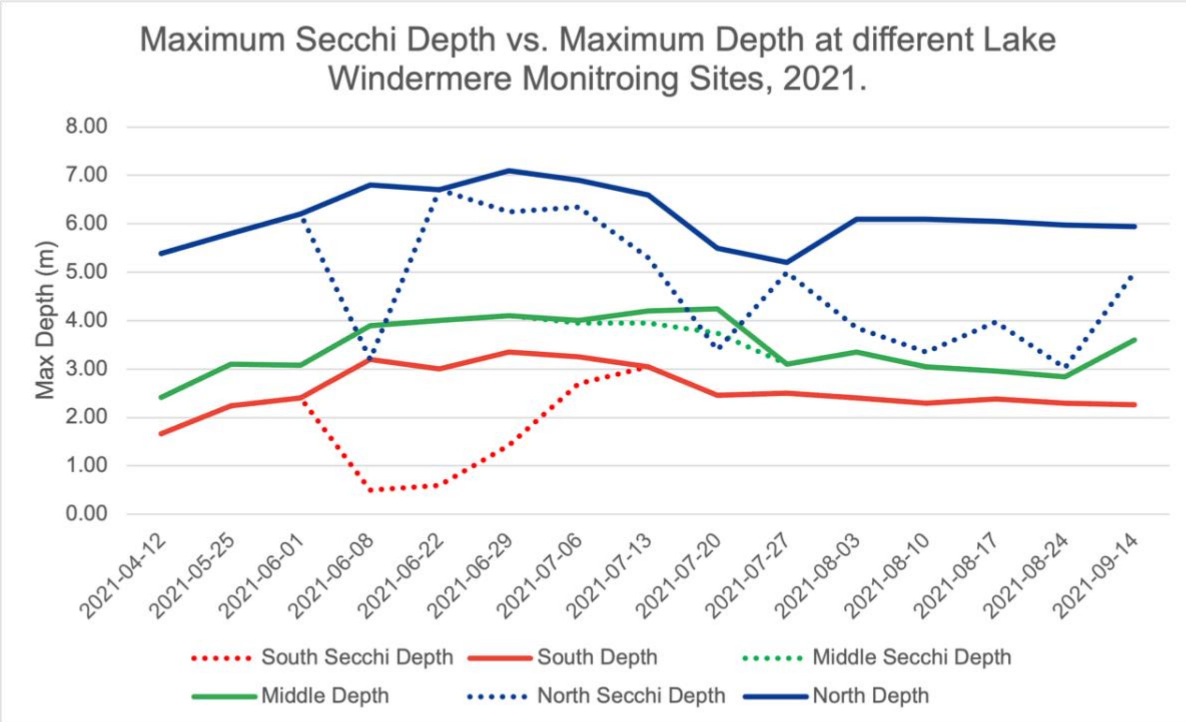

Figure 8c: Lake Windermere Maximum Secchi Depth and Maximum Total Lake Depth in 2021.

2.8 - Total Depth

Overview

Lake Windermere is a widening of the central Columbia River channel, which makes it different from typical lakes around Southern BC. The main difference is that it is very shallow, on average, between 3-4m depth in mid-summer. It also has a high-water exchange rate (flushing) which allows water to flow through more quickly than an average lake, giving it a better capacity to carry sediments and nutrients downstream because of this faster flow.

Water Stewardship Assistant and Citizen Science Volunteer Monitoring Total Depth.

The average water depth is recorded for all three sample sites throughout the lake, but this is not very representative of Lake Windermere. This lack of representation 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 the deepest point in the lake, measuring on average between 6-7m in depth.

The water will separate into layers in deeper lakes, with cooler, denser water falling to the bottom. The process of water becoming separated into lighter and denser layers is called "thermal stratification." Lake Windermere does not stratify, meaning there is no significant difference between the North Upper and North Lower water quality samples.

Depth can be an essential consideration for aquatic life, recreational boaters, and drinking water users. Shallow water poses more risks to boaters because they 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 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 2021 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 more pronounced than in previous years due to a high snowpack winter and increased precipitation throughout the spring season.

The 2021 season saw a gradual incline in depth between June to July and a sharp decline in depth between the middle of July to the end of July (Figure 9a). This variability was likely caused by abnormal weather patterns such as increased precipitation in June and high temperatures at the end of June, causing flooding into the lake.

The deepest recorded value was 7.1m and was measured on June 29th at the North sample site. This can be compared to the deepest value in 2020, also measured at the North sample site, which was 7.2m on June 30th (Figure 9a). The highest recorded value at this site since monitoring began in 2006 has been 7.3m, recorded in July 2012 and June 2013.

The season of 2021 saw some of the steepest rates of decline in water level recorded in recent years (Figure 9b). Other years such as 2014 and 2017, saw seep rates of decline. However, the difference is that they often continued to decline, whereas 2021 is one of the only years to have a minor increase in depth between August and September. The average annual depth decreased by 0.2m since 2013, with an increase in 2017 with a slight increasing trend in 2021. The year with the lowest average depth was 2016, and the highest annual depth was recorded in 2013 (Figure 9c).

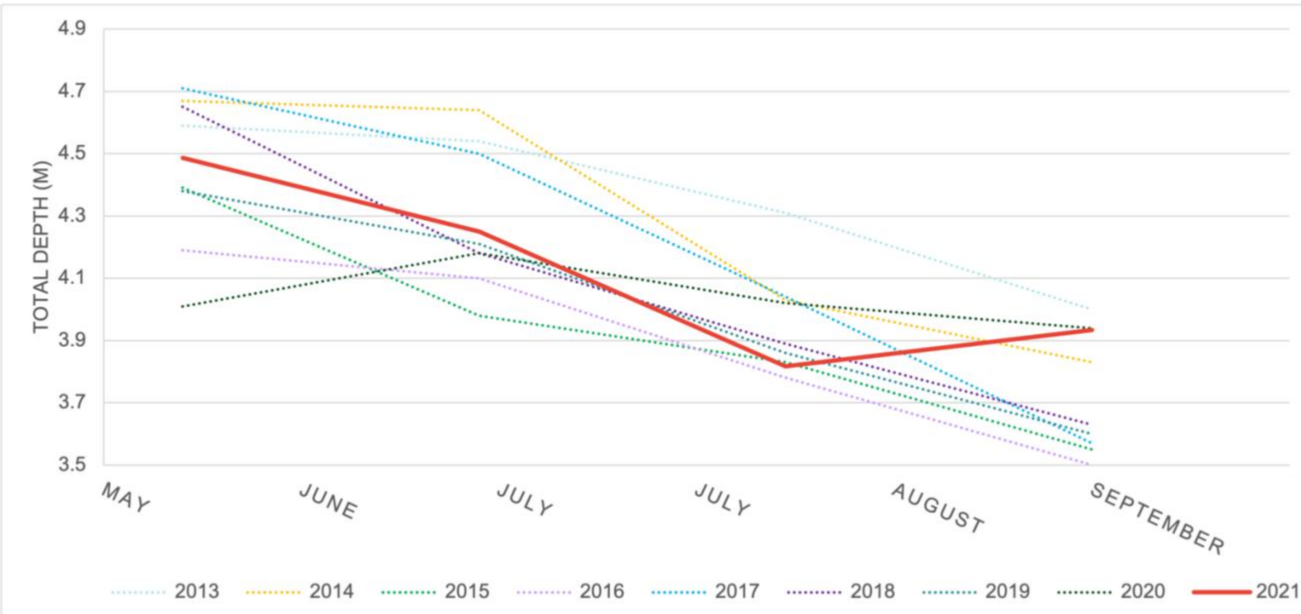

Figure 9a: Lake Windermere Total Depth (m) of different survey sites and depth-averaged across all sites, measured between April 12th and September 14th.

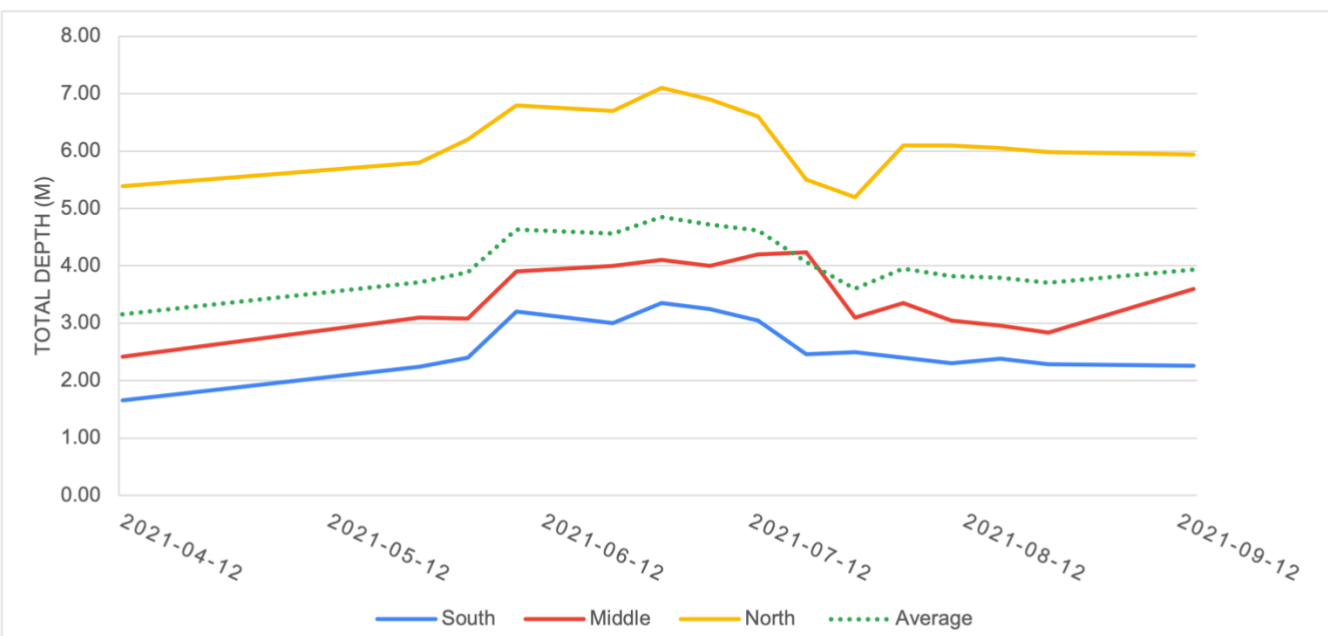

Figure 9b: Lake Windermere Average Depth measured between June-September 2013-and 2021.

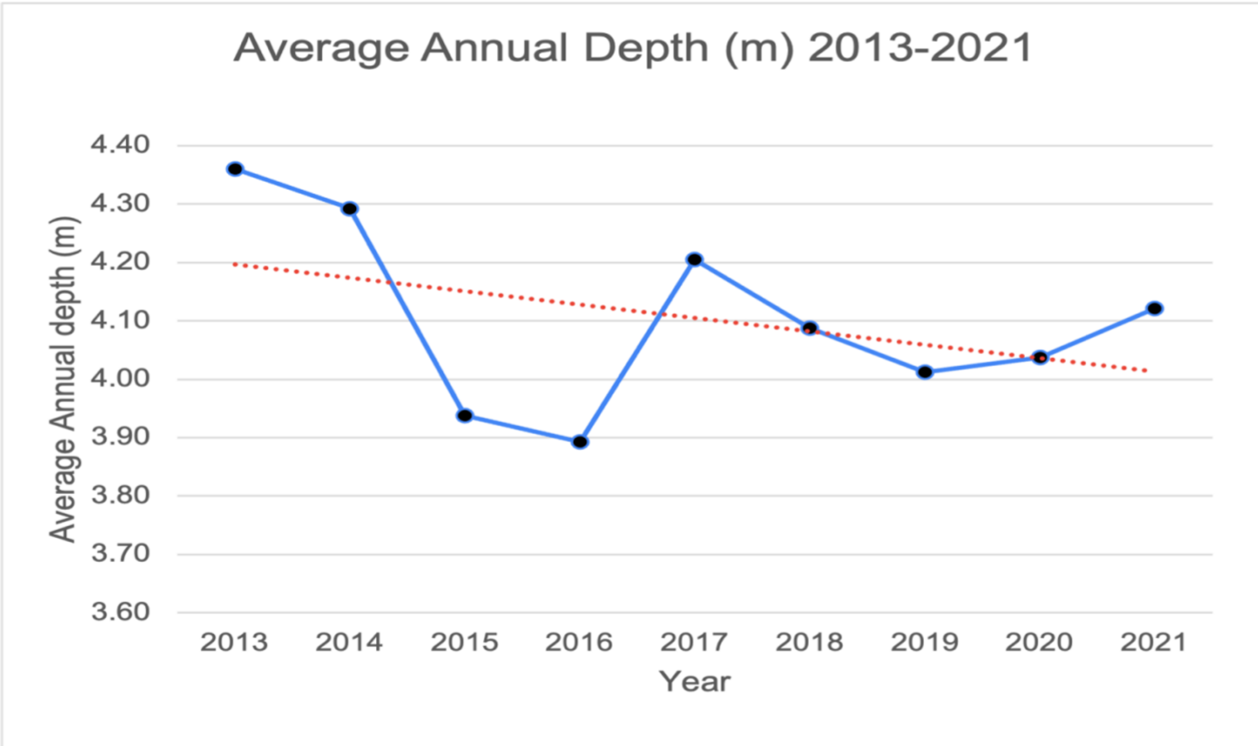

Figure 9c: Average Annual Depth Comparing Data from 2013-2021.

3. Aquatic Plant Survey, Invasive Mussel, and Veliger Sampling

The following is an excerpt from the 2021 **Lake Windermere Aquatic Invasive Plant Species Inventory Report,** Prepared for the Lake Windermere Ambassadors by Rachel Darvill, BSc., MSc., R.P. Bio, Golden Eye Ecological Services, November 2021.

3.1 Overview

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 algal blooms and by trapping sediments that would be disturbed by motorized boats and wave action. Without rooted aquatic plants to help hold sediment in place, increased Turbidity can degrade 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.

Water Stewardship Assistant checking substrate samplers for invasive muscles.

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 2013, they 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 the two main borders of the province and its high recreational use further increase this risk of introduction. Invasive species out-compete most other native species if allowed to establish. This increase in competition often results in a loss of biodiversity and native species, which can negatively affect water quality and fish and 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. In 2020, LWA installed six substrate samplers along the east side of Lake Windermere that were monitored monthly from May to September for zebra and quagga mussels.

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 past years.

Shoreline sampling occurred at six pre-established survey stations, the same stations surveyed in previous years of survey effort. The pre-established survey stations were chosen (pre-selected in 2015) because those sites posed a higher risk of invasion than other shoreline locations. High-risk sites include locations known to have higher amounts of trailered boat traffic (boats coming in from other areas that could be affected by aquatic invasive species), public boat launches, or boat marinas with multiple boat docking slips.

3.2 Results

The 2021 survey marked the twelfth year of invasive species sampling and included twelve lake-bottom (offshore) sampling locations and one shoreline-sampling location, 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. As with previous years of survey efforts, dense areas or beds of Indigenous aquatic plants were observed, and some stations lacked abundant and diverse aquatic plant communities.

While not a part of this study, during an aerial survey conducted on April 8th, 2019 (during an annual bird survey by the principal consultant), photographs of Lake Windermere were taken, indicating that motorboats could be influencing the Indigenous plant communities of Lake Windermere (Figures 2 and 3).

Informal observations were made regarding more buoys on the water compared to previous years of survey effort. There was a lack of freshwater mussels seen on the lake bottom and the rake compared to previous years of survey effort. More freshwater sponges were pulled up with the rake compared to previous years. There are a variety of other biological ecological indicators that might be used to evaluate changes in the lake ecosystem. The lack of freshwater mussels is concerning because Lake Windermere is an ideal habitat for them, and they are known indicators of good water quality. Therefore, it is recommended to complete a regular annual survey that would include freshwater muscles as an indicator of lake health. Sponges are also a sensitive species and therefore are also an indicator of good water quality which could be included in the study.

3.3 Discussion and Recommendations

Aerial photograph taken on April 8, 2019, showing effects of motorboats on aquatic vegetation on benthic surface at Lake Windermere.

No aquatic invasive plants have been found in Lake Windermere, although the distribution and abundance of plants in the lake may be changing, as seen in aerial photographs. Several abiotic factors affect aquatic plants, including substrate anoxia, temperature, and inorganic carbon availability (Bornette & Puijalon, 2011). The different types of nutrients in Lake Windermere may also influence the growth and species type of aquatic plants (Tootoonchi & Gettys, 2019). It is recommended to determine how and where aquatic plant species abundance and diversity change over time in Lake Windermere. For example, an aerial/drone photography survey could be conducted at a specific time of the year (August), which could provide a way of evaluating change in specific areas over time.

A decline in the amount of aquatic vegetation can lead to a cascade of adverse environmental impacts since plant decreases affect the ecological functions aquatic plants provide (see Introduction section) (Sagerman et al., 2020). The physical forces from boats (i.e., wash, turbulence, propeller action with cutting effects, sight, and sound disturbance) have negatively affected lake ecosystems elsewhere. They can harm the health of Indigenous aquatic plants in a freshwater ecosystem (Liddle & Scorgie, 1980). Motorboats and the wash (or wake) have caused considerable erosion of plant roots in other lake ecosystems (Liddle & Scorgie, 1980), and studies have shown that motorboats have dramatically reduced plant biomass primarily through direct cutting (propellor) and scouring of the substrate (Asplund, 2000). Mooring can also significantly impact the abundance of freshwater aquatic vegetation (Sagerman et al., 2020). It is beyond the scope of this study to determine how the abundance of freshwater aquatic vegetation may have changed in Lake Windermere. If changes in aquatic plant abundance and distribution can be determined, it may also be helpful to have additional information contributing to these changes (e.g., conduct annual counts on the number of boats, anchoring buoys and moorage slips on Lake Windermere).

Aerial photograph taken on April 8, 2019, showing effects on aquatic vegetation at Lake Windermere

A lack of freshwater mussels was noted throughout the survey in 2021. In previous years of survey efforts, freshwater mussels were often observed and pulled up on rake tosses designed for plants. Freshwater mussels are amongst the most imperilled organisms globally (Lydeard et al., 2004; Metcalfe-Smith & Cudmore-Vokey, 2004; Strayer et al., 2004), with only four to seven species known to occur in BC (Gelling, 2008; Nedeau, 2009). Fifty-five percent of North America's mussels have gone extinct or are imperilled, compared to only 7% of the continent's bird and mammal species (Master, 1990). This significant decline is strongly associated with habitat destruction and the additional degradation associated with anthropogenic influences such as dams, sedimentation (that can come from motorboats), and introduction of nonindigenous aquatic bivalve mollusks and pollution (Williams et al., 1993).

It is suggested to adhere to the MFLNRORD recommendation for development applications to help protect the abundant freshwater mussel population in Lake Windermere (that very little is known about). A freshwater mussel inventory is recommended to be conducted on Lake Windermere to gather baseline information on their abundance and diversity and to learn what specific areas may be more important than others in terms of the habitat value for freshwater mussels.

Several rake pull samples revealed a green freshwater sponge during the aquatic plant surveys an animal species likely known as *Spongilla lacustris*. These animal species are fascinating and deserve more attention. "Sponges are important for maintaining ecosystem function and integrity of marine and freshwater benthic communities worldwide" (Bell et al., 2015). "Little information is available for most species [of freshwater sponge], and more data is needed on the impacts of anthropogenic-related pressures" (Bell et al., 2015). It is recommended that an investigation be conducted to survey the abundance and distribution of freshwater sponges at Lake Windermere and assess how this species may be affected by anthropogenic-related activities.

It was observed that there are several hard-stemmed bulrush Deep Marsh communities on the edges of Lake Windermere, e.g., the sites of Rushmere Community Docks and the End of Ruault Road. This ecological community is blue-listed in BC, meaning it is at-risk in the province. None of the hard-stemmed bulrush Deep Marsh communities in Lake Windermere have been recorded in BC's Conservation Data Centre database. It is recommended that these locations be identified and entered the provincial database and the regional Official Community Plan for Lake Windermere.

4. Waterbirds

4.1 Overview

In 2018, LWA conducted their first Waterbird Survey, complete with a report highlighting the findings. This project was taken 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 significant for large flocks of migratory birds, such as American coots (Fulica americana) and 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 2020 and 2021 to continue learning about bird populations on Lake Windermere.

4.2 Results

During the Survey on October 7th, 2,677 individuals were recorded from a total of 4 different species. Of these sightings, the Surf Scoter and Red-necked Grebe, Horned Grebe, Eared Grebe, Western Grebe, and California Gulls have been designated species at risk. Out of all the individual sightings, 166 of them, which is %6 of all individuals, are Species at Risk. There is a strong recommendation for management strategies to accommodate human use and bird conservation for Lake Windermere.

4.3 Recommendations and Discussion

- 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
- 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. Fish Survey

5.1 Overview

There are many knowledge gaps related to the native fish and mussel populations on Lake Windermere. In 2021 the Lake Windermere Ambassadors hired Lotic Environmental to conduct a larger-scale study that reproduced work previously done while utilizing improved methods.

The 2021 Fish Survey is still being analyzed and published on the Lake Windermere Ambassador Website in a separate report.

2021 Lake Windermere Fish Survey, Lotic Environmental.

6. Swim Beach Water Quality

6.1 Overview

Escherichia coli (*E. coli*) is a type of fecal coliform bacteria found in the intestines of most healthy warm-blooded animals. Most *E. coli* are harmless, though some can produce toxins that can cause illness in people. *E. coli* in water can be an indicator of sewage or animal waste contamination, Other coliform bacteria are commonly found in soil or vegetation and are part of the natural microbial flora.

The count of *E. coli* colonies per 100mL of water is a common way to measure how many of this species of bacteria is present in the water; however, it is essential to know that this value represents a total count of all *E. coli* colonies, which means it does not necessarily contain the strains which produce toxins harmful to humans. A higher *E. coli* count simply increases the probability that the water could contain a toxin-producing strain.

An *E. coli* assessment determines whether swim beach water quality meets recognized health standards. The LWA has an ongoing agreement with the Interior Health Authority (IHA) to collect public beach water samples; the IHA laboratory analyzes samples for E. coli bacteria, compliance with Health Canada Guidelines. 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

6.2 Results

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

- James Chabot Provincial Park 27.4 *E. coli*/100 mL
- Kinsmen Beach 12.3 *E. coli*/100 mL
- Windermere Beach 4.5 *E. coli*/100 mL

The highest single sample in 2020 was 40 E. coli /100mL, recorded on June 7th at the Central site of Kinsmen Beach. While this is still a low value, the cause for the increase remains unknown.

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

7. Tributary inflow - Windermere and Abel Creek

7.1 Overview

Besides the central Columbia River channel, Windermere Creek is the primary source of inflow into Lake Windermere. This tributary stream drains an area of approximately 90 km and provides essential fish spawning habitat (NHC, 2013). At the same time, 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.

Water Stewardship Assistants monitoring Windermere Creek’s Water Quality and Quantity.

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 the fieldwork undertaken by local volunteers and non-profit organizations. LWA has continued monitoring Windermere Creek and now also monitors Abel Creek as a continuation of this project.

Water chemistry follows similar protocols and uses the same equipment as 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 measurement method 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 of how to flow volumes change seasonally within a given stream area. During equipment comparisons between LWA and Shuswap Indian Band in October 2020, there was a significant discrepancy between the flow/velocity measurements using a velocity head rod vs. the flow meter method. In 2018, the LWA obtained four HOBO U20-L Water Level Loggers.

Lake Windermere Ambassador Staff and Volunteers doing CABIN invertebrate sampling in Windermere Creek.

These loggers measure water temperature and pressure to provide a reading on flow measurements to complement surface velocity measurements. 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 at the LWA Office.

7.1 Results

The sampling results from the 2021 Creek Surveys are provided in a supplementary report.

8. Acknowledgements

The 2021 Lake Windermere community-based water quality-monitoring project was made possible thanks to generous funding support from:

- District of Invermere
- Columbia Basin Trust
- Columbia Valley Community Foundation
- Columbia Valley Local Conservation Fund
- Real Estate Foundation of BC
- BC Community Gaming Grants
- Regional District of East Kootenay
- Toby Creek Nordic Ski Club
- Eco Canada
- BC Parks
- BC Hydro
- Community Donations

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- Danny Smart
- Water Rangers Kit

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- 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

Water sampling took place within a four-hour timeframe on Tuesday mornings, from May to September 2021. 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 with the 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, Disolved oxygen and conductivity were read using a YSI ProDSS meter. pH is read using a Eutech Waterproof pH Test 10. Turbidity was read using a Hach 2100QPortable Turbidimeter calibrated to 10 NTU.

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 approximately 1m below the surface. The Lower water sample depth depended on the total depth of the water column: If the total depth was less than 5m then the Lower water sample was collected 1m above the lake bottom, but if the total depth was greater than 5m then the water sample was collected at 4m (due to the maximum length of the YSI. The Middle and South sites were sampled at 1m below the surface only. All water samples were collected using a horizontal VanDorn sampler.

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)

Water birds

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 (3site), James Chabot (3 sites), and Kinsmen (3sites)). 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 Excel, 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=