Norman Lake 2019 - 2021
BC Lake Stewardship and Monitoring Program
Summary Report

The BC Lake Stewardship Society (BCLSS) and the Ministry of Environment and Climate Change Strategy (ENV) partner with local volunteers and stewardship groups to characterize lake water quality through the *BC Lake Stewardship and Monitoring Program* (BCLSMP). The BCLSMP's focus is on understanding water clarity, temperature, oxygen, and nutrients as these provide a basic understanding of lake processes and influence biological productivity. Concerns about productivity are common, specifically because high productivity can affect recreation and drinking water due to harmful algal blooms and can also impact aquatic organisms, such as fish. For more information about the BCLSMP please visit www.gov.bc.ca/lakestewardshipmonitoring.

Photo 1. Photo of Norman Lake (Source: provided by volunteers)

Background

Norman Lake is located approximately 41 km southwest of Prince George, BC, within the traditional territory of the Nazko First Nation and Lheidli T'enneh First Nations, and the Omineca Administrative Region. The lake is at an elevation of 840 m (a.s.l) and has a uniform morphology consisting of one large basin, a surface area of 505 ha, a maximum depth of 23.8 m, and a shoreline perimeter of 14.1 km (FIDQ, 2020) (**Figure 1**). The main inflow and outflow for Norman Lake is Dahl Creek, flowing in at the west end and out at the east end. Chuk Creek is a secondary inlet found in the southeastern end of the lake.

Norman Lake is a recreational lake that supports populations of burbot, lake whitefish, mountain whitefish, largescale sucker, long-nose sucker, peamouth chub, and redside shiners (FIDQ, 2020). There are about 140 cabins located along the north shore, although the residential footprint at the watershed scale is less than 1%. The total watershed area is 168.7 km^2 and includes a mix of low flat lands and hilly uplands. The dominant land use is harvested, or disturbed, areas (50%) (**Figure 2**), followed by forested areas (46%). The remaining 4% consists of waterbodies (3.8%), wetlands (0.1%) and developed/residential areas (0.1%).

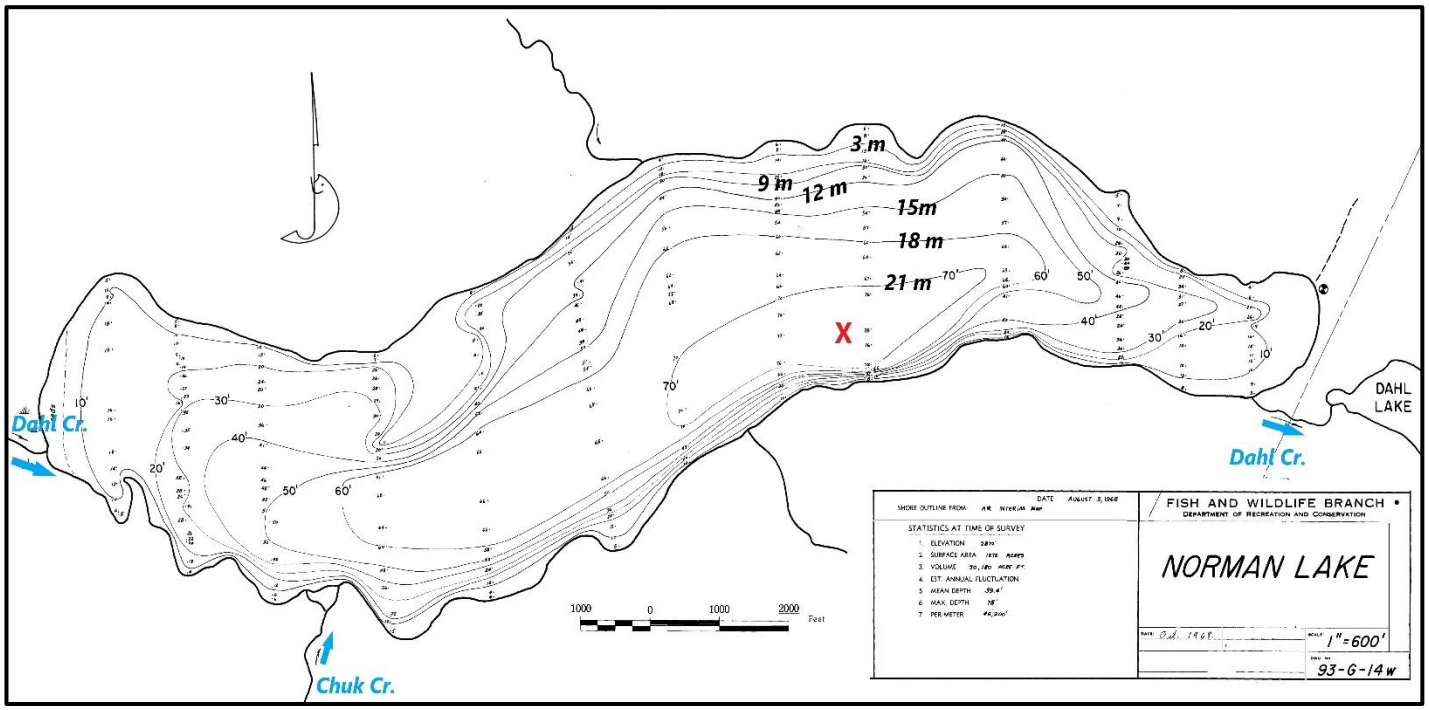

Figure 1. Bathymetric Map of Norman Lake, including sampling station location identified by the **red x**.

Monitoring Approach

Norman Lake monitoring was conducted at a Level 3 BCLSMP study level from June of 2019 to September of 2021 after concerned residents noted a potential change in the lake water quality following several wildfire events in the region. A Level 3 BCLSMP study is typically conducted at the deepest lake location, and includes monitoring of dissolved oxygen, temperature, water clarity, algal productivity, and nutrient levels (e.g., phosphorus). Information on these parameters is collected at least twelve times during the open water season for three years to characterize the temporal variability typical of lake systems and can help to identify issues such as summer oxygen depletion, internal nutrient loading, and times of high algal productivity.

Water quality information was collected from Norman Lake Deep Station (Environmental Monitoring Systems (EMS) ID: E206654) during total of 14 sampling events. Four sampling events occurred in 2019 and ten sampling events occurred in 2021 (**Table 1**). This does not meet the minimum data requirement of 12 sampling events per year for BCLSMP. No sampling was conducted in 2020 because of the COVID-19 pandemic.

Water samples were collected for chemical analyses at three depths (1 m below surface, mid-depth, and 1 m above sediment bottom) from the Deep Station during each sampling event and submitted to laboratory for analysis of phosphorus (all three depths) and chlorophyll-a (shallow samples only). In 2019, temperature and dissolved oxygen were recorded at three sampling depths (1 m below surface, mid-depth and 1 m above sediment bottom), and in 2021 full temperature and dissolved oxygen profiles were collected (i.e., data collected at 1 m depth intervals throughout the water column). Secchi disc depth was also recorded during most sampling visits in 2019 and 2021. Water quality information under the BCLSMP was collected between June and August in 2019 and May and September in 2021.

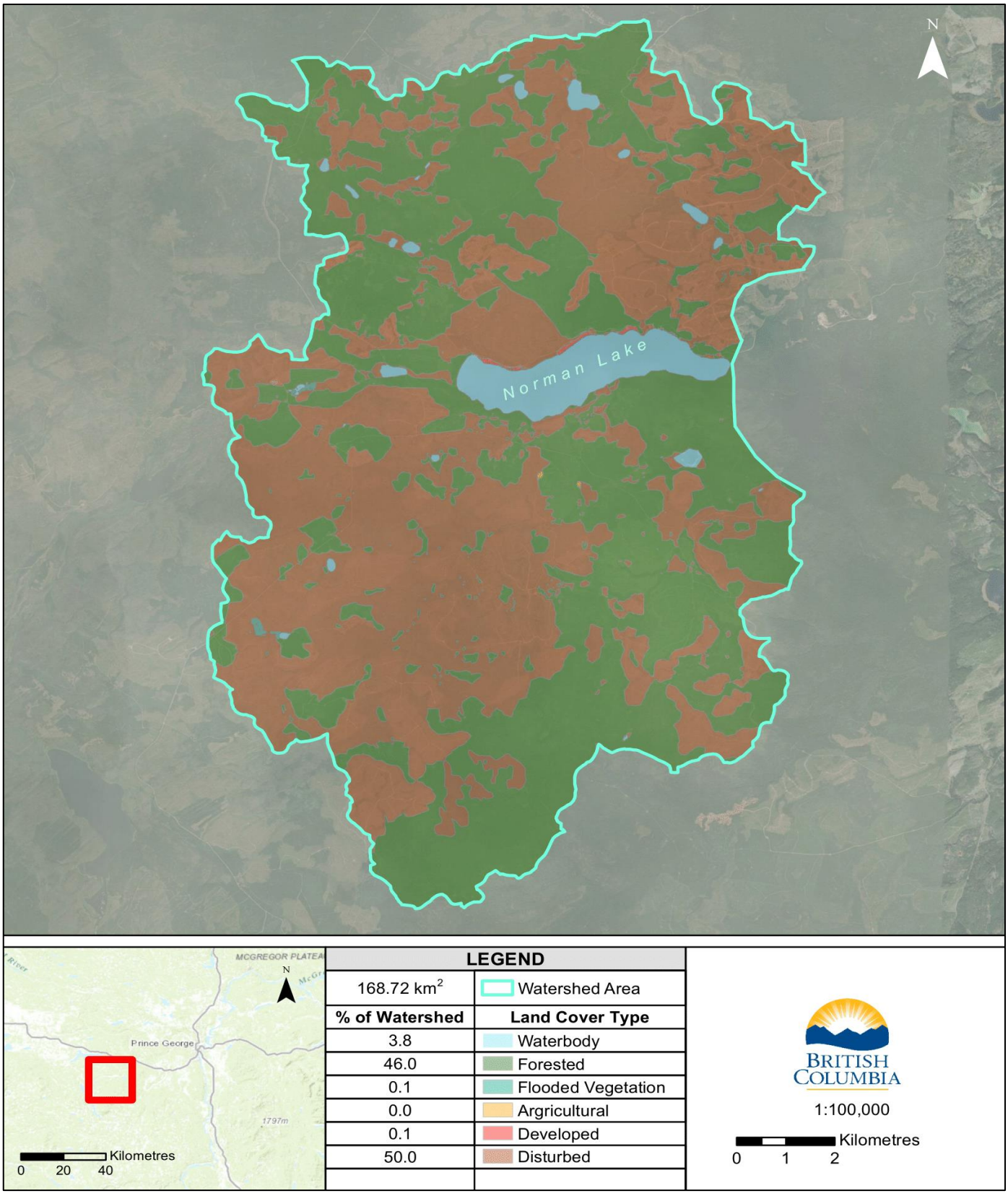

Figure 2: Map showing Norman Lake watershed and associated land uses.

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen (DO) strongly influence physical, chemical, and biological processes in lakes. Annual temperature and oxygen patterns vary depending on local climate, lake shape, prevailing wind direction and lake depth (BCLSS, 2022). Water is most dense and therefore heavier at 4°C and less dense (i.e., lighter) at both colder and warmer temperatures. During the summer, lakes more than 6 m deep usually experience a layering effect called stratification, with the warmer, less dense water sitting on top of the cooler and heavier water. Stratification keeps bottom cool water isolated from top warmer water which traps nutrients released from bottom sediments until the layers mix in the fall. This mixing is also called lake overturn and can occur one to multiple times per year. During the mixing process, the bottom waters get recharged with oxygen, and nutrients are brought up to the surface.

Temperature and DO data collected at the Norman Lake Deep Station in 2019 and 2021 indicate stable summer stratification (**Figure 3**). The 2019 sampling started late in June and did not capture the spring mixed conditions, which occurred between May and mid-June in 2021. The fall overturn was not captured during either of the sampling years, although **Figure 3** shows that the lake appears to have started mixing the last week of August in 2019 and not until the second week of September in 2021. From mid-June to September distinct layers of warm and cold water formed in Norman Lake in 2019 and 2021, with peak surface temperatures ranging from 22 - 24°C in July. The lake remained stratified throughout the summer months without any apparent intermittent mixing events.

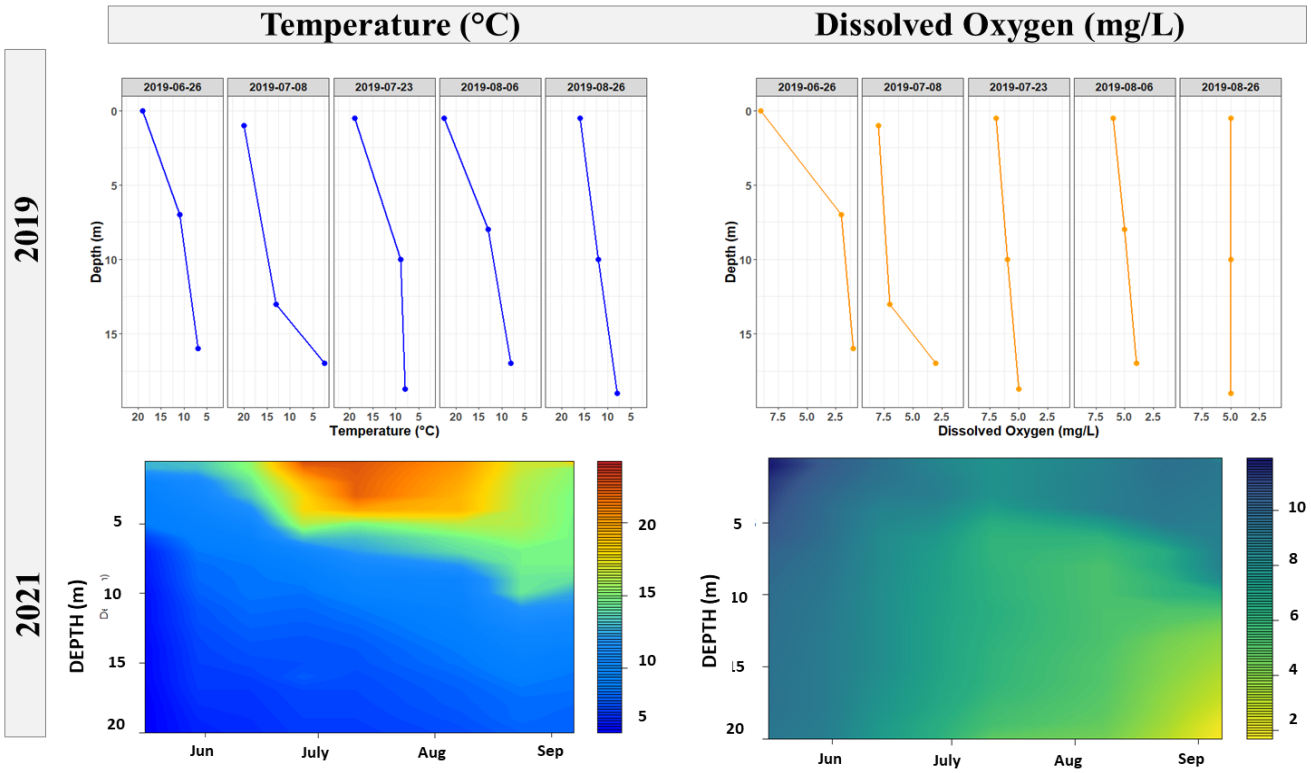

Figure 3: Temperature and DO results at the Norman Lake Deep Station in 2019 and 2021. The coloured contours display patterns of warming/cooling and increasing/decreasing concentrations of DO.

The DO levels in Norman Lake were influenced by the seasonal temperature stratification (**Figure 3**). The highest DO (~12 mg/L) was observed when the lake was mixed in May in 2021. The top 5 m of the lake remained mostly above 6-8 mg/L throughout the sampling period. Values dropped to less than 4 mg/L below 13 m depth in mid-August and remained so into September.

Both temperature and DO results show that most of the water column at Norman Lake Deep Station was suitable

habitat for fish during the sampling period. Many fish species, especially salmonids, show signs of stress at temperatures greater than 18°C and DO concentrations less than 4 mg/L (Truelson, 1997). During the time that the top 5 m in Norman Lake were greater than 18°C, the area between 5 m and 13 m depth had sufficient levels of DO for the more sensitive fish species.

Water Clarity and Algal Biomass

Water clarity is an indicator of algae, suspended sediments, and other particles in the water. It is measured using a Secchi disc to see how far light can penetrate through the water column. Chlorophyll-a is a common pigment found in almost all plants. It captures light energy and drives the process of photosynthesis. In open water areas of lakes, it occurs in free-floating microscopic algae (phytoplankton), which are important parts of the lake food-web. Chlorophyll-a in lake water is an indicator of the algal biomass present in the water. In highly productive systems, algal biomass can become excessive, causing aesthetic concerns, and impacting water quality.

Secchi depth (m) and chlorophyll-a (µg/L) were measured at the Norman Lake Deep Station in 2019 and 2021 **(Figure 4).** The average Secchi depth in Norman Lake in both 2019 and 2021 was 1.7 m. The maximum, or deepest, Secchi depths occurred in early August of both years (Aug 6, 2019 = 2.10 m; Aug 8, 2021 = 2.35 m), whereas the lowest (most shallow) values were in the spring (Jun 24, 2019 = 1.4 m; May 16, 2021 = 1.15 m). Water clarity is typically greatest following the spring overturn and early algal blooms, but before summer algal growth peaks. Elevated concentrations of chlorophyll-a corresponded with shallower Secchi depth readings in both years, although this was more challenging to compare for 2019 due to the limited number of samples. These data show that poorer water clarity in Norman Lake is likely due in-part to increased algal biomass (**Figure 4**). The clearest water in 2021 corresponded to the lowest chlorophyll-a concentration during the early summer. The maximum values captured for chlorophyll-a (27.2 µg/L) occurred between late August and early September of 2021, which is a common time for late summer algal blooms to occur.

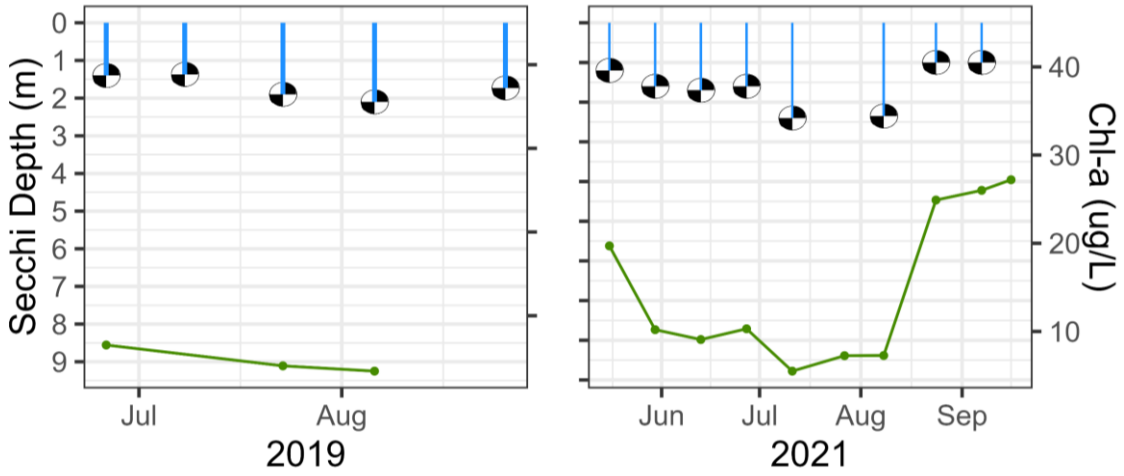

Figure 4. Secchi depth (bars with circles) and chlorophyll-a (green line) measured at the Norman Lake Deep Station.

Phosphorus

Phosphorus is typically the limiting nutrient for most lakes in BC, meaning that phosphorus concentration strongly influences biological production in aquatic environments (BCLSS, 2022). Nitrogen is also an important nutrient in aquatic environments but is generally second to phosphorus as the most limiting nutrient. There are several forms of phosphorus present in lake water. Dissolved phosphorus in the form of ortho-phosphate (PO_4) is the most readily available form of phosphorus for algae and aquatic plants. Total phosphorus (TP), stored in sediments and organic

matter, can be converted to PO_4 in low oxygen conditions. Total dissolved phosphorus (TDP) is another bioavailable form of phosphorus. Monitoring the different forms of phosphorus is helpful towards understanding how much is available for plant growth. Phosphorus (TP, TDP, and Ortho-P) concentrations from the Norman Lake Deep Station collected at the three sampling depths are listed in **Table 1** and shown in **Figure 5**.

Table 1. Minimum, maximum and average phosphorus results from samples collected in 2019 and 2021.

			Phosphorus		
Station	**Depth Sampled (m)**	**Summary Statistics**	**Total Phosphorus (ug/L)**	**Total Dissolved Phosphorus (ug/L)**	**Ortho-Phosphate (ug/L)**
Norman Lake @ Deep Station	Shallow (0-1 m below surface)	Min	9.5	2.0	1.0
		Max	38.9	19.0	4.5
		Average	18.8	8.9	1.4
	Mid (7-11 m below surface)	Min	2.0	2.0	1.0
		Max	85.0	20.6	9.0
		Average	23.7	11.4	4.2
	Deep (17-22 m)	Min	34.1	17.8	9.7
		Max	68.9	48.7	36.8
		Average	51.9	31.4	24.4

Differences in phosphorus concentrations were observed between the deep (17-22 m) samples that were collected close to the sediment surface (lake bottom), versus both the shallow (0-1 m) and mid depth (7-11 m) samples, with the highest concentrations found in the deep samples. In 2021 phosphorus in the deep samples increased slightly through the summer and into the fall, while remaining relatively constant at the shallow and mid depths. The limited dataset makes it hard to interpret whether this pattern occurred in 2019 as well, but historically the increase in phosphorus in the deep waters was more variable and less pronounced.

The historical data from this EMS location shows more variability in the shallow and mid depth phosphorus levels throughout the summer which could be due to mid-season mixing (or partial mixing) events (**Figure 5**). This could be evidence that stratification patterns in Norman Lake are changing. In 2021 BC experienced a record-breaking heat wave that occurred across the province starting in June, which would have contributed to more intense lake stratification. It is important to note, however, that the average concentration of all three forms of phosphorus throughout the water column has not substantially increased since 1998-1997. The average total phosphorus concentration during the ice-off season from 1998-1997 was 24.06 µg/L (range of 7-66 µg/L), and the average from 2019 and 2021 was 26.15 µg/L (range of <1.0-85 µg/L).

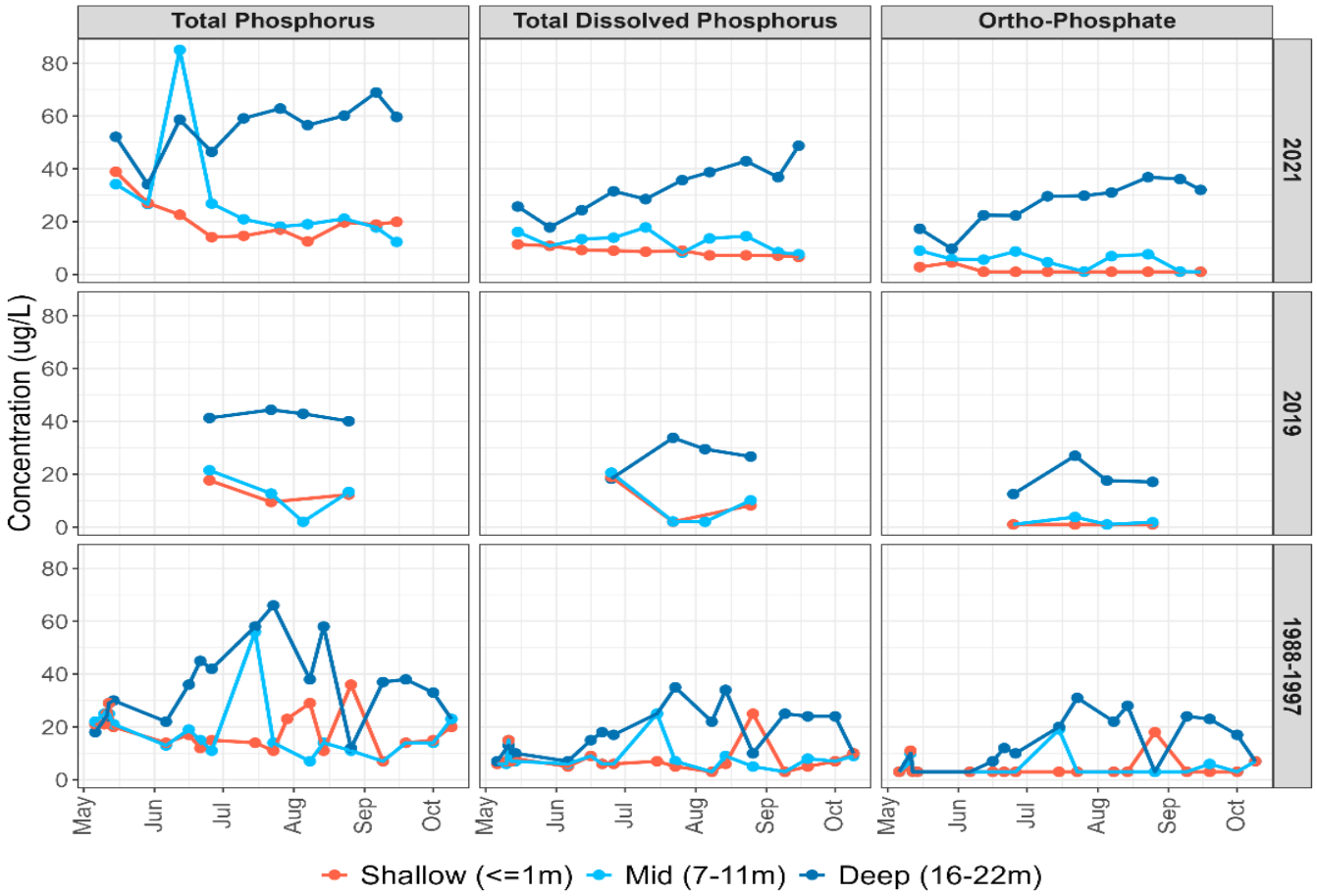

Figure 5. Norman Lake 2019, 2021 and historic 2019-2021 total phosphorus (TP), total dissolved phosphorus (TDP), ortho-phosphate (PO4) results.

Trophic Status

Trophic status describes the level of biological productivity within a waterbody and is measured by using Secchi depth, chlorophyll-a, and total phosphorus concentrations (Nordin, 1985). Low productivity lakes are called *oligotrophic* and tend to have clear water and sufficient oxygen for aquatic life throughout the year. Lakes with moderate productivity are called *mesotrophic*. *Eutrophic* lakes have high productivity and often have high densities of aquatic plants and/or algae. Algal blooms may occur in these lakes frequently, reducing recreational opportunities and potentially impacting aquatic habitat.

The results show that Norman Lake ranges from moderately productive to highly productive depending on the year and the trophic indicator (**Table 3**). Water clarity in both 2019 and 2021 were within the range of a eutrophic lake. The total phosphorus concentrations during spring were historically in the upper mesotrophic ranges, but within the eutrophic range in 2021. The average summer chlorophyll-a levels again indicated that Norman Lake was highly eutrophic in 2021, but has been within the mesotrophic ranges historically and potentially in 2019, however, with few data points in that year it is difficult to make strong conclusions.

Table 3. Norman Lake trophic indicator results (as per Nordin, 1985).

Parameters	Trophic Categories			Norman Lake		
	Oligotrophic	Mesotrophic	Eutrophic	1988-1997	2019	2021
Chlorophyll *a* (µg/L)[1]	0 - 2	2 - 7	>7	4	5	15
Secchi Depth (m)[1]	>6.0	3.0 - 6.0	<3.0	-	1.7	1.7
Total Phosphorus (µg/L)[2]	1 - 10	10 - 30	>30	24	*	36
[1]Summer average, [2]Spring mixed conditions, *Spring mixed values not available.						

Summary

The key results of this study show that Norman Lake is stratified between June and mid-September. During this time suitable fish habitat remained available in the middle depths of the lake, although 2021 data shows that available habitat may start to become limited late in the summer and early fall if stratification and warm water temperatures persist. Key parameters (i.e., chlorophyll-a, water clarity, and phosphorus concentration) suggest that Norman Lake is a moderately productive system that is either becoming more productive (eutrophic) or is prone to experiencing highly productive years under certain climatic conditions, such as an exceptionally hot summer. Years when the lake surface is warmer for longer (i.e., earlier in the spring and/or later in the fall) will result in more intense (longer and stronger) lake stratification and higher productivity. Increases in productivity will make Norman Lake more susceptible to occasional algal blooms and poorer water clarity.

Going Forward

There is strong evidence that climate change is exacerbating existing issues in lakes that are already experiencing problems. One climate change impact already observed in many northern hemisphere lakes is earlier onset and longer periods of stratification, which may make internal nutrient loading more problematic (Woolway et al., 2020). If there is volunteer interest and capacity, continued monitoring at a less intense BCLSMP study level (e.g., Level 1: regular temperature and Secchi depth measurements at Norman Lake Deep Station from spring to fall overturn) would be beneficial to help understand variability in Norman Lake productivity. These data are important for long-term lake condition records and will provide early warning signs of deterioration in water quality. It is also recommended that monitoring include ice on and off dates. A follow up Level 3 study can be conducted again in 5-10 years to track potential changes in lake water quality.

Tips for Keeping Norman Lake Healthy:

See link under Monitoring Resources on: www.gov.bc.ca/lakestewardshipmonitoring
BCLSS's LakeKeepers Manual: https://www.bclss.org/programs#lake-keepers-manual

Who to Contact for More Information

The Ministry of Environment and Climate Change Strategy	**The BC Lake Stewardship Society**
Email: volunteerlakes@gov.bc.ca Website: www.gov.bc.ca/lakestewardshipmonitoring	Email: info@bclss.org Website: www.bclss.org

Norman Lake data presented in this report can be accessed here: https://arcg.is/1G9LG40

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Land Use Map by: Kim Klaczek (ENV)

References

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