Bednesti Lake 2018 – 2021 + 1998 - 2010
BC Lake Stewardship and Monitoring Program
Summary Report

BCLSS

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.

Background

Bednesti Lake is in the Omineca-Peace region near Hwy 16, 50 km west of Prince George, within the Traditional Territory of the Lheidli T'enneh First Nation. The lake is roughly 5 km long, has a maximum width of 1 km and a maximum depth of 20.7 m (**Figure 1**). Its surface area is 261 hectares, and it has a shoreline perimeter of 14.7 kilometers. The main inflow into Bednesti Lake is Kellogg Creek, located at the southwest end of the lake. There are also a few tributaries on the north and south side of the lake that drain into Bednesti Lake. All the tributaries, including Kellog Creek have current or deactivated road crossings. Bednesti lake drains out at the southwest end into Berman Lake and into Tachintelachick Creek, which eventually flows into the Nechako River.

Photo 1*:* Photo of Bednesti Lake (provided by volunteer sampler Ayner Kersey).

Bednesti Lake has a watershed area of 81.6 km^2, which includes flat drier plateaus and wetter lowlands, that include treed and non-treed bogs and wetlands (**Figure 2**). The Bednesti watershed is relatively un-disturbed by direct human land use activities with approximately 75% of the total area considered "natural" forested or unforested lands. Of the remaining 25%, 16% is classed as disturbed which is largely associated with harvested area south of Bednesti Lake, 7.5% is waterbodies and <1% is developed land. Bednesti Lake has approximately 103 lakeshore residences, all of which are zoned for full time living, and one restaurant/motel/camping facility. A 139-hectare Ecological Reserve also borders the Bednesti Lake watershed. The Bednesti Ecological Reserve was established in 1978 to "preserve a representative wetland community and disjunct tamarack stands on the Interior Plateau" (BC Parks website).

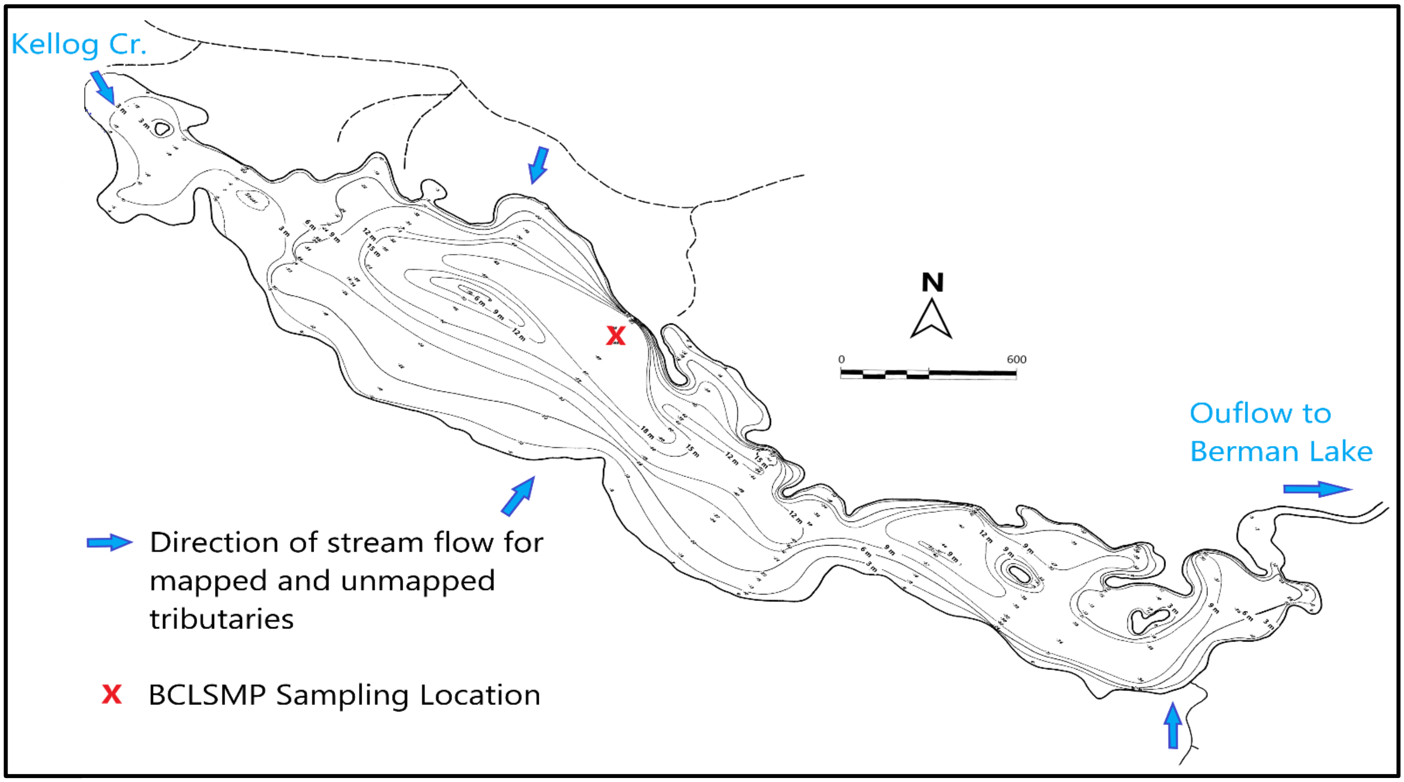

Figure 1. Bathymetric Map of Bednesti Lake, including sampling station location and inflow/outflow streams.

Monitoring Approach

The Bednesti Lake monitoring program began in 1998 as a partnership between the Ministry of Environment and the Bednesti Volunteer Lake Water Testing Group, although periodic water quality sampling has occurred in Bednesti since 1978. The sampling program was initiated due to concerns by residents around potential impacts to the lake from land use practices (i.e., silviculture herbicides), ongoing development within the watershed and lake riparian area, declining fish stocks, especially lake trout (*Salvelinus namaycush*) (Jacklin 2011, Pers. Comm.), observations of increasing frequency and duration of algal blooms, and dense aquatic plant growth, especially Canadian pondweed (*Elodea canadensis*). Canadian pondweed was first reported in Bednesti Lake in 1968, and more recently it has been identified as a problem in the lake's west end.

Water quality information was collected from Bednesti Lake Central Deep Station (Environmental Monitoring Systems (EMS) ID: E231760) for nine years over three Level 3 monitoring programs occurring from 1998-2000, 2007-2010 and 2018-2021. From 1998 to 2000 29 sampling events occurred, 34 occurred between 2007 and 2010, and 29 occurred between 2018 and 2021. No sampling was conducted in 2009 or 2020.

Water samples were collected for chemical analyses at three depths (1 m below surface, mid-depth, and 1 m above sediment bottom) from the Central 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 and 2021 full temperature and dissolved oxygen profiles were collected (i.e., data collected at 1 m depth intervals throughout the water column). During all the other sampling years temperature and dissolved oxygen were recorded just at the three sampling depths. Secchi disc depth was also recorded during most sampling visits from 1998 to 2021. Water quality information under the three BCLSMPs was collected between the either April, May or June and October or November during all sampling years.

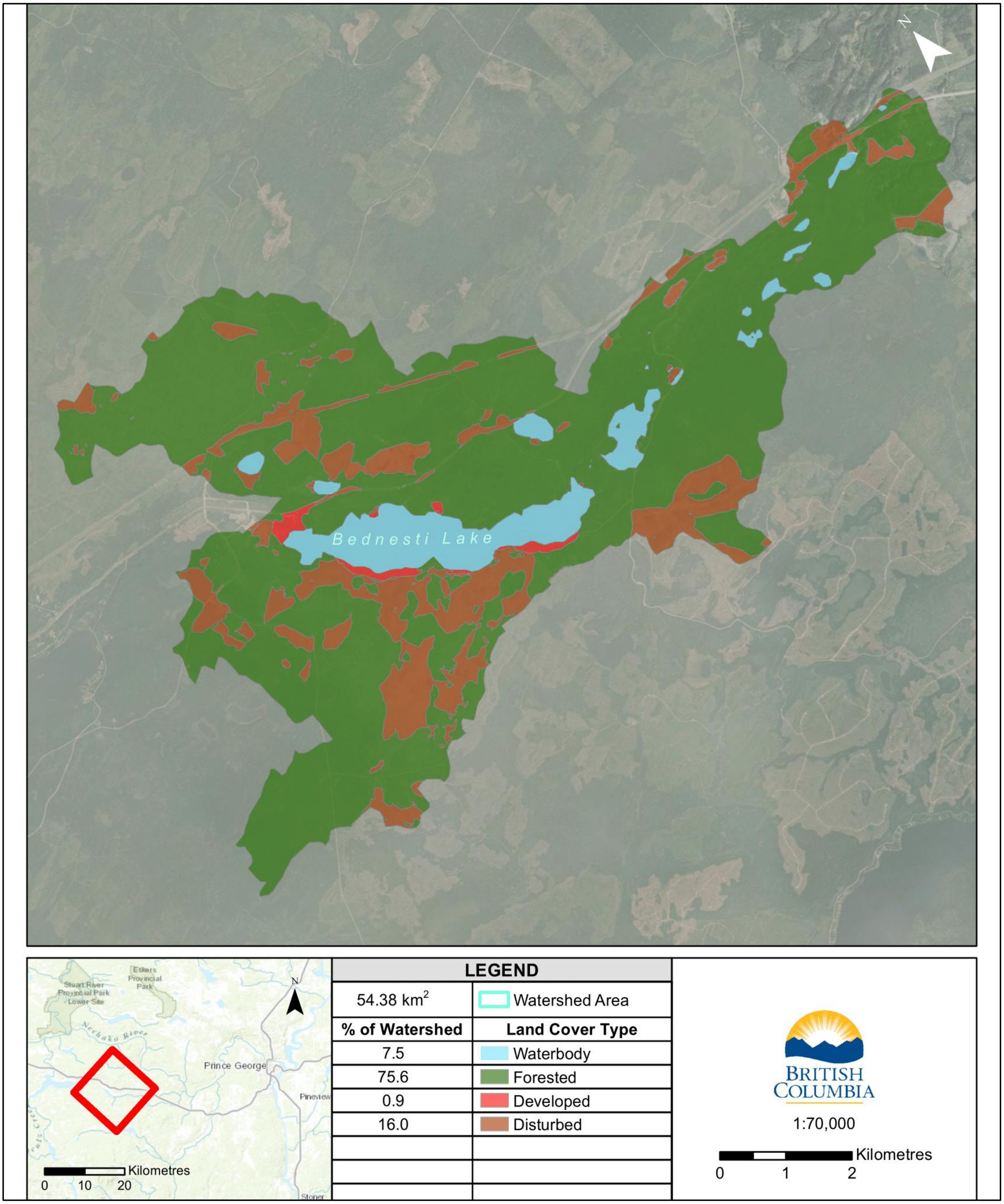

Figure 2: Map showing Bednesti Lake watershed and associated land uses.

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 4ºC 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 Bednesti Lake Central Deep Station in 2019 and 2021 indicate stable summer stratification (**Figure 3**). Sampling during both years started in early June and did capture the spring mixed conditions, which occurred around mid-June both years. The fall overturn occurred in mid-late September. In 2019 fall sampling was not continuous, but data from the final sampling event in mid-October show that the lake was fully mixed at that time (**Figure 3**). Therefore, from mid-June to late September distinct layers of warm and cold water formed in Bednesti Lake in 2019 and 2021, with peak surface temperatures occurring in July (20.8ºC in 2019 and 22.3ºC in 2021). The lake remained stratified throughout the summer months without any apparent intermittent mixing events.

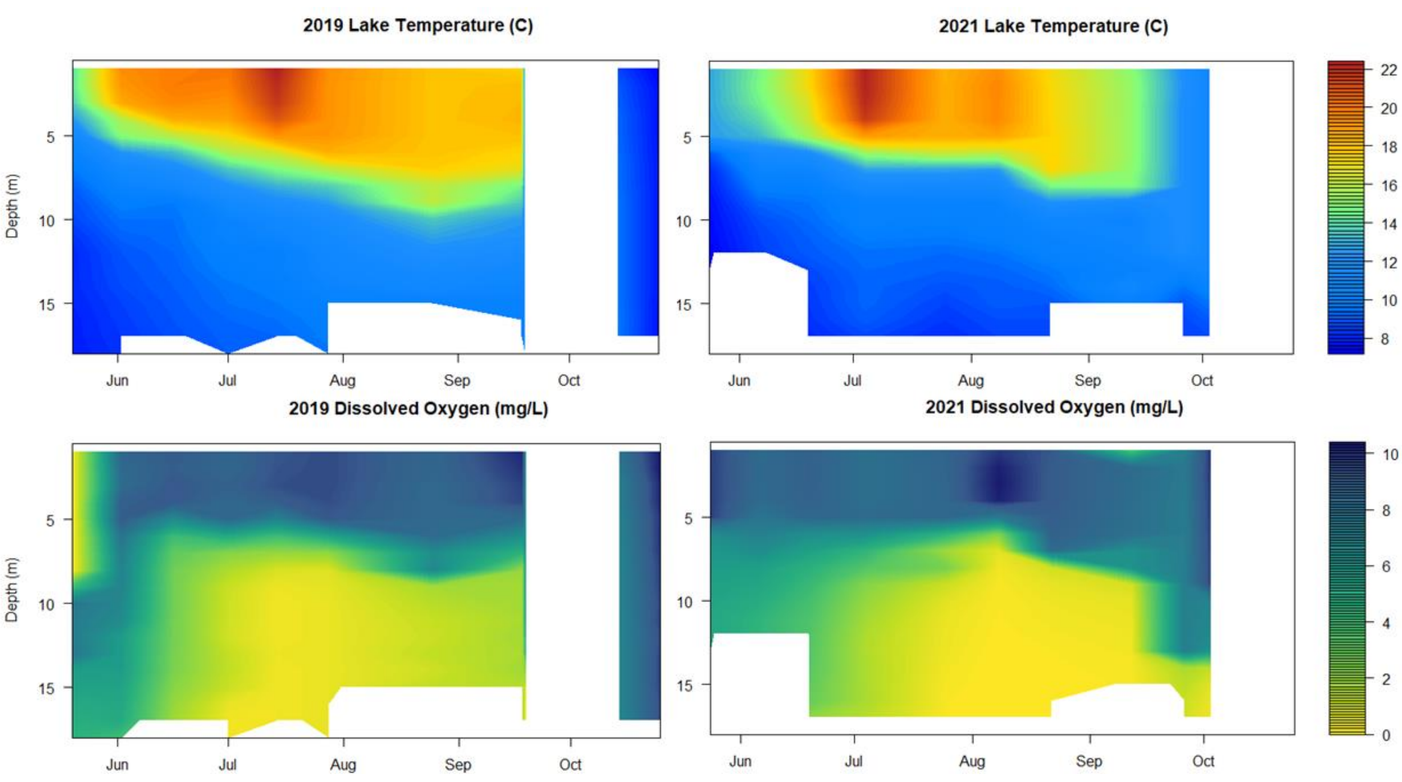

Figure 3*:* Temperature and dissolved oxygen profiles collected at 1 m intervals at the Central Deep station in 2019 and 2021. The coloured contours display patterns of warming/cooling and increasing/decreasing concentrations of dissolved oxygen. White space on the graph means that no data was collected for that data and/or depth.

The DO levels in Bednesti Lake were influenced by the seasonal temperature stratification (**Figure 3**). The highest DO levels (~11-12 mg/L) were observed in the fall when the lake was mixed. The top 5 m of the lake remained above 6-8 mg/L throughout the ice-off period in 2019 and 2021, but values dropped to less than 4 mg/L below 8 m depth in July and remained so into September.

Both temperature and DO results show that during the summer months fish habitat in Bednesti Lake may become limited for some fish species. Many fish species, especially salmonids, show signs of stress at temperatures greater than 18ºC and DO concentrations less than 4 mg/L (Truelson and Bio, 1994). During the time that the top 5 m in Bednesti Lake were greater than 18ºC, there were only a few meters of the water column that had sufficient levels of DO for the more sensitive fish species.

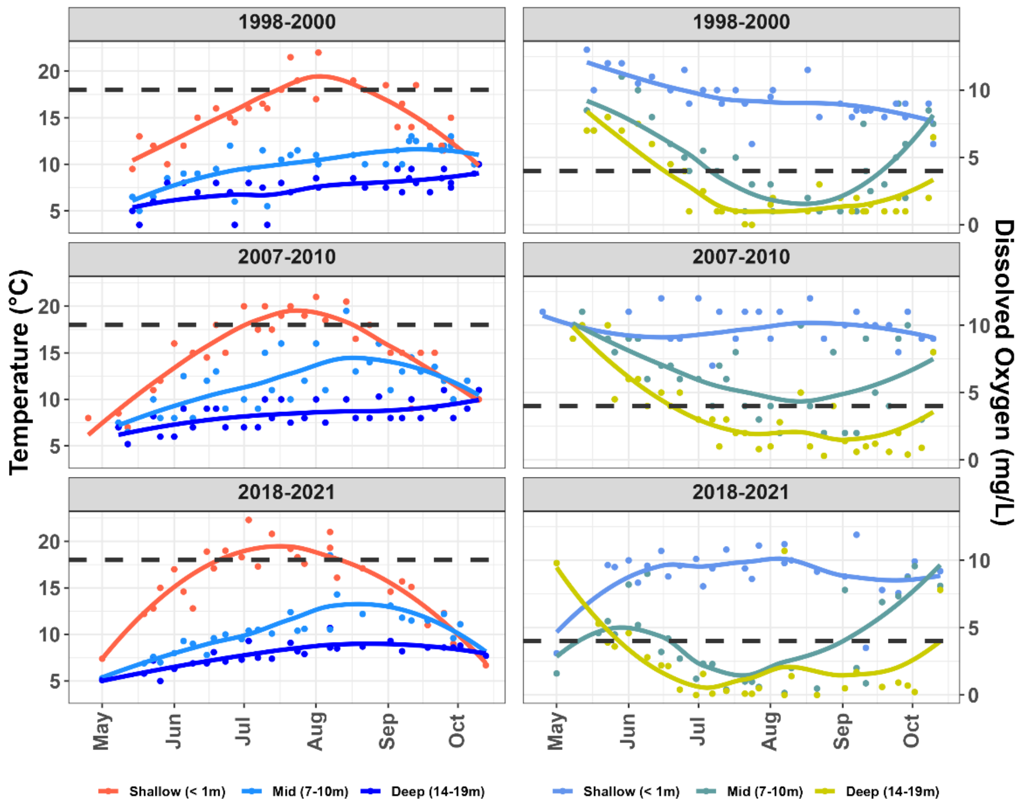

Figure 4: Temperature and DO results taken at three sampling depths at Bednesti Lake Central Deep Station during each of the three level 3 sampling periods. The dashed grey lines represent 18ºC and 4 mg/L to show potential depth zones in the lake that may be unsuitable for more sensitive fish species.

Historical temperature and DO data were collected at the three sampling depths during the level 3 programs from 1998-2000 and 2007-2010. This data shows that a similar stratification pattern also occurred between 1998 and 2000, but between 2007 and 2010 the DO at the mid depth (7-10 m) of the lake remained above 4 mg/L and below 18ºC (**Figure 4**).

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.

In Bednesti Lake, Secchi depth and chlorophyll-a were measured at the Central Deep station during the 1998-2000, 2007-2010 and 2018-2021 sampling time periods (**Figure 5**). The average Secchi depths in Bednesti Lake were 3.8 m from 1998 to 2010, 3.5 m from 2007 to 2010, and 2.4 m from 2018 to 2021. Water clarity is typically greatest following the spring overturn and early algal blooms, but before summer algal growth peaks. In Bednesti Lake water clarity did not fluctuate greatly throughout the sampling periods, but there were increases in clarity observed following the spring overturn as well as during the fall mixed conditions.

Elevated concentrations of chlorophyll-a weakly corresponded with the shallower Secchi depth readings, which suggests that poorer water clarity was due in-part to spring and summer algae blooms, but also that water clarity is not entirely related to algal density in Bednesti Lake. The average chlorophyll-a concentrations in Bednesti Lake were

2.6 μg/L from 1998 to 2010, 3.0 μg/L from 2007 to 2010, and 4.3 μg/L from 2018 to 2021. The highest maximum values occurred in 1998 (7.5 μg/L), 2010 (6.5 μg/L), 2018 (10.2 μg/L), 2019 (9.1 μg/L) and 2021 (7.5 μg/L). These peak values were in mid-late summer months for 1998, and 2019, but early in the spring in 2010 and later in the fall in 2018 and 2021 (**Figure 5**). This suggests that Bednesti Lake is more likely to experience periods of high algal density, or even potential blooms, during the middle of summer or close to the fall overturn. Although algal taxonomy data were not collected, the biomass patterns indicate that the algal community likely follows succession patterns typical of northern temperate lakes; where early spring algal biomass peak is dominated by large-bodied diatoms that prefer cold temperatures while taking advantage of nutrients mixed into the water column during spring overturn, and summer populations tend to be dominated by smaller-bodied green algae and cyanobacteria.

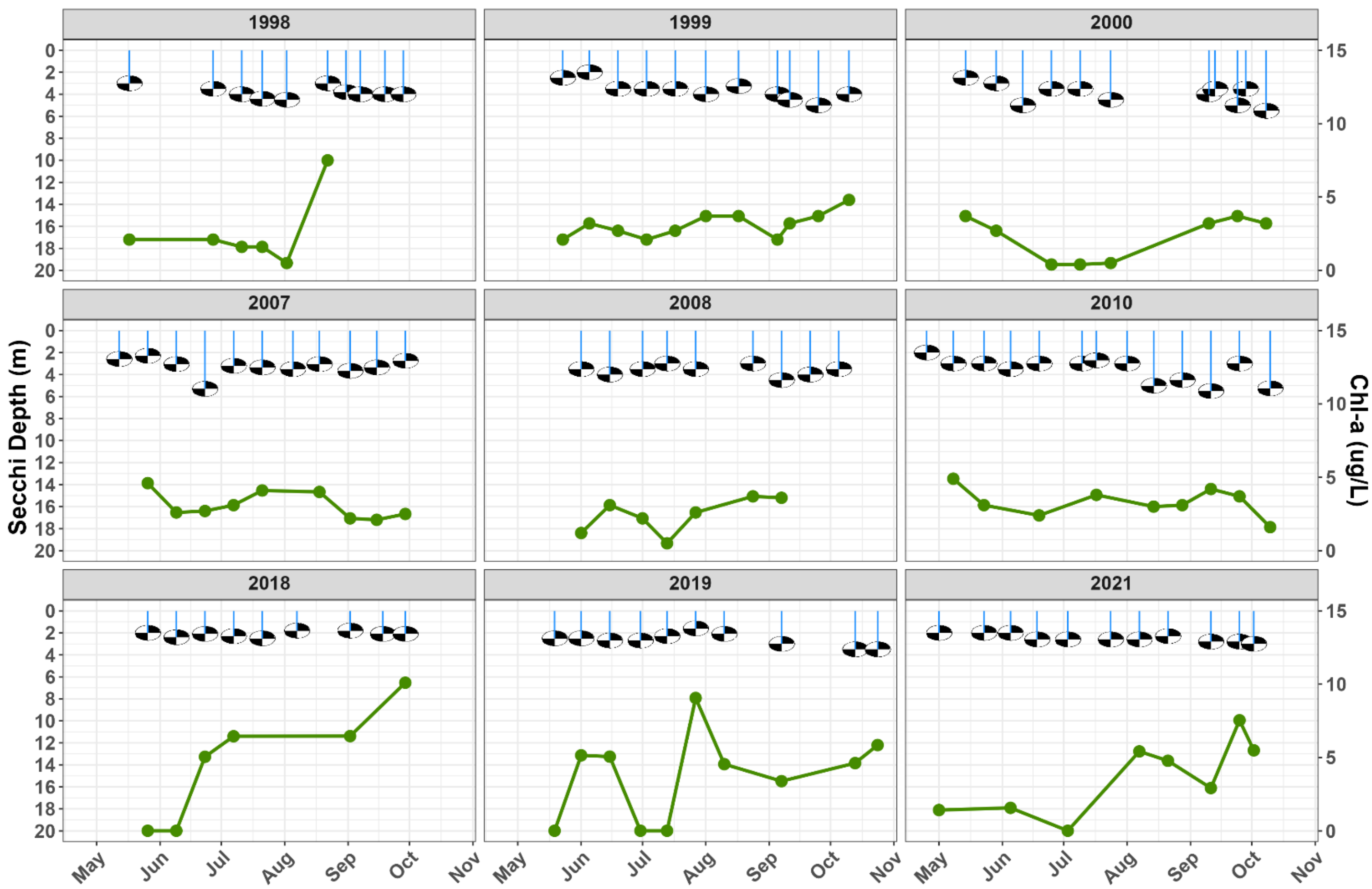

Figure 5. Secchi depth (bars with circles) and chlorophyll-a (green line) measured at the Bednesti Lake Central Deep Station during all three BCLMSP Level 3 Sampling Programs.

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 Bednesti Lake Central Deep Station collected at the three sampling depths are listed in **Table 1** and shown in **Figure 6**.

Table 1. Minimum, maximum and average phosphorus results from samples collected in 2018, 2019 and 2021.

			Phosphorus		
Station	**Depth Sampled (m)**	**Summary Statistics**	**Total Phosphorus (ug/L)**	**Total Dissolved Phosphorus (ug/L)**	**Ortho-Phosphate (ug/L)**
Bednesti Lake @ Central Deep Station	Shallow (0-1 m below surface)	Min	6.2	3.8	1.0
		Max	41.8	14.4	5.5
		Average	18.7	6.74	1.56
	Mid (7-10 m below surface)	Min	5.8	2.7	1.0
		Max	29.3	10.8	5.9
		Average	16.6	6.36	1.8
	Deep (14-19 m)	Min	5.8	2.0	1.0
		Max	193	159	141
		Average	44.3	28.4	23.0

Differences in phosphorus concentrations were observed between the deep (14-19 m) samples that were collected close to the sediment surface (lake bottom), versus both the shallow (0-1 m) and mid depth (7-10 m) samples, with the highest concentrations found in the deep samples. In all sampling years phosphorus levels in the deep samples began to dramatically increase around the middle of August and peaked sometime in September when the lake was mixing, while remaining relatively constant at the shallow and mid depths (**Figure 6**). This pattern occurred during every year sampled although there was variability in the magnitude of the phosphorus concentration peaks. The average concentrations for phosphorus 14-19 m below surface in Bednesti Lake was consistently 2-3 times higher than the concentrations in the top 10 m. This provides strong evidence that Bednesti Lake exhibits internal nutrient loading when the lake is thermally stratified. When looking at the data across all the sampling years it also appears as if the phosphorus inputs from the bottom sediments may be increasing in concentrations and occurring over a longer time. These results suggest that it is very likely that internal nutrient loading in Bednesti Lake is contributing to the increase algal and plant productivity (i.e., chlorophyll-a concentrations) and the subsequent decreased water clarity (i.e., Secchi depth).

It is important to note, however, that the average concentration of all three forms of phosphorus throughout the water column has not substantially increased across the three level 3 sampling programs (**Table 2**). The average total phosphorus concentration during the ice-off season at all three sampling depths was 30.02 µg/L (range of 10-160 µg/L) from 1998-2000, 17.64 µg/L (range of 2-137 µg/L) from 2007-2010, and 26.55 µg/L (range of 5.8-193 µg/L) from 2018-2021.

Table 1: Summary of DEEP layer phosphorus data for Bednesti Lake. Samples are grouped by the level 3 sampling programs (i.e., 1998-2000; 2007-2010; 2018-2021). Data is summarized by the minimum, maximum, and mean (average) values calculated from samples collected during the specified time frame (between sampled from and sampled to).

Total Phosphorus (ug/L)						
Depth Zone	**Min**	**Max**	**Mean**	**Number of Samples**	**Sampled From**	**Sampled To**
Deep	11	160	43.56	27	1998-06-28	2000-09-24
	4	137	30.07	27	2007-05-13	2010-10-11
	5.8	193	44.29	26	2018-05-25	2021-10-03

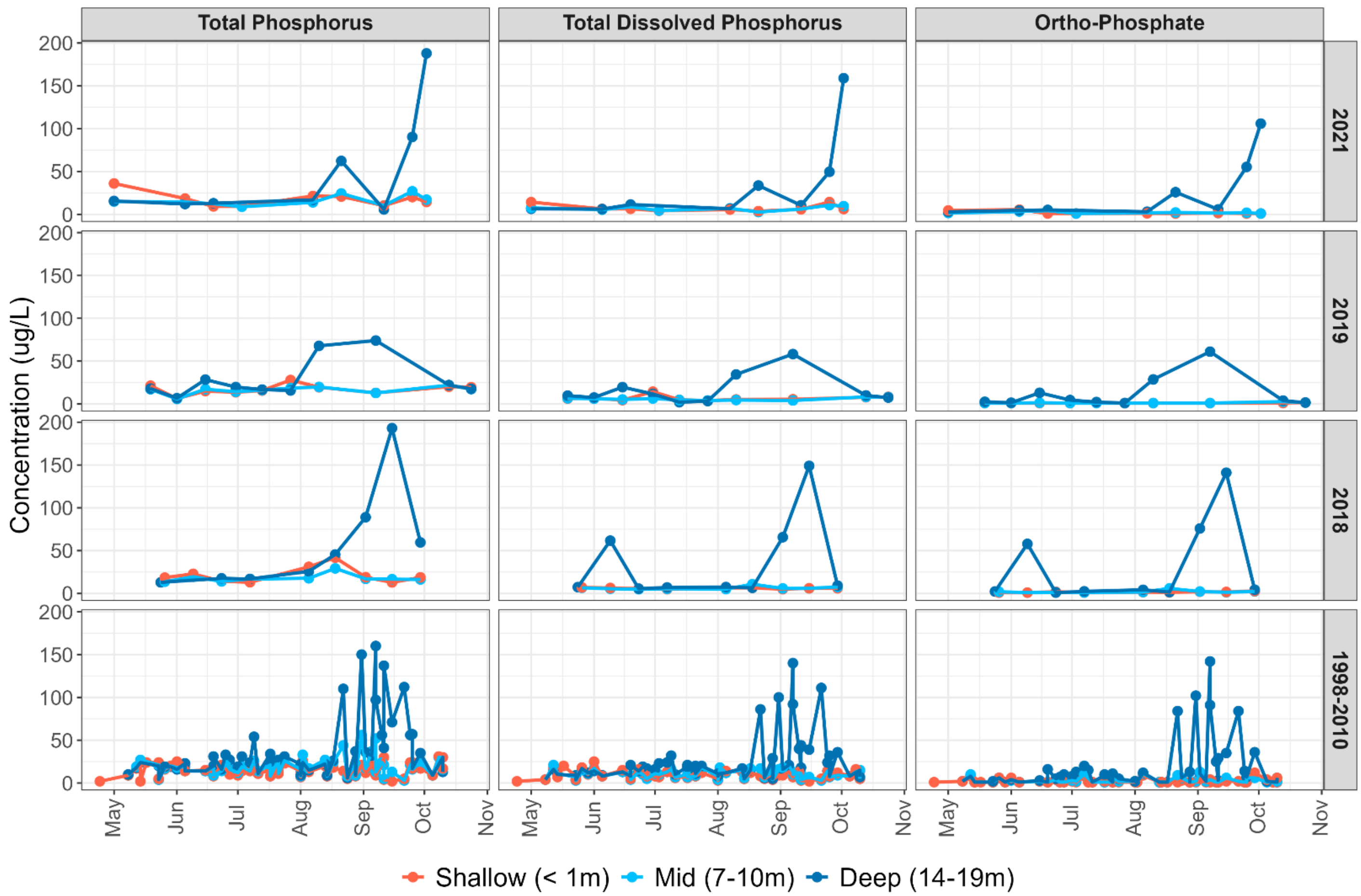

Figure 6. Bednesti Lake 2018, 2019, 2021 and historic 1998-2010 total phosphorus (TP), total dissolved phosphorus (TDP), ortho-phosphate (PO4) results. The historic data was not averaged and includes ALL sampling results between 1998-2010.

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 average concentrations for all the parameters are listed in **Table 3** and indicate that Bednesti Lake is **mesotrophic** (i.e., moderately productive), and has been so since 1998. Cumming (2000) reported that the lake core taken from the deepest point of Bednesti Lake showed that the lake has been mesotrophic as far back as 1915, when organic matter deposition in the lake began to increase. However, the more recent increasing chlorophyll-a concentration and decreasing Secchi depth from the 2018 to 2021 period supports observations made by lake residents regarding declining water clarity and increasing aquatic plant and algal growth.

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

Parameters	**Trophic Categories**			**Bednesti Lake**		
	Oligotrophic	Mesotrophic	Eutrophic	1998-2000	2007-2010	2018-2021
Chlorophyll *a* (μg/L)[1]	0 - 2	2 - 7	>7	2.50	2.58	4.12
Secchi Depth (m)[1]	>6.0	3.0 - 6.0	<3.0	3.71	3.51	2.34
Total Phosphorus (μg/L)[2]	1 - 10	10 - 30	>30	22.4	10.79	18.69

[1]Growing season average (June - September), [2]Spring mixed conditions (April - May)

Summary

The key results of this study show that Bednesti Lake stratifies soon after the ice melts in the spring and remains stratified into mid-September most years, but as late as October in some years. During this time suitable fish habitat remained available in the top 5-10 m of the lake except for 2-4 weeks in July and/or August when the surface temperatures were too warm and DO levels below 5 m were too low for the more sensitive fish species. DO in Bednesti Lake dropped to less than 4 mg/L below 5 m depth relatively rapidly (i.e., within ~1 month) once the lake was stratified, and it appears that the bottom layer of the lake remained below 4 mg/L through the fall overturn (**Figure 3 & 4**), although it was mixed fully during the spring overturn. 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, which will further reduce available fish habitat and result in higher productivity from internal nutrient loading. The concentrations of key parameters (i.e., chlorophyll-a, water clarity, and phosphorus) suggest that Bednesti Lake is a moderately productive system, and has been so since 1998, but is prone to experiencing higher productivity during years with certain climatic conditions, such as an exceptionally hot summer and/or with atmospheric nutrient inputs from wildfires. The years will the highest productivity were 2021, 2018, 2010, 2008 and 1998 (**Figure 5 & 6**). There were a lot of forest fires in the region in 2010 and 2018, and in 2021 the province experienced a record-breaking heat wave during the months of June and July. These events would have contributed to higher productivity in Bednesti Lake.

Going Forward

In 2021 Environmental Dynamics Inc. was contracted to write a report looking at water quality trends in Bednesti and Berman Lake. This report compared the results from the Bednesti volunteer monitoring program to similar monitoring programs on other lakes in the region and found a similar pattern of gradual productivity increases across the region. As the climate in the region continues to change it is expected that lake productivity will also increase. 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 Bednesti Lake Central Deep Station from spring to fall overturn) would be beneficial to help understand variability in productivity. If possible, continuing to collect full temperature and dissolved oxygen profiles (i.e., what was done in 2019 and 2021) would greatly increase the ability to monitor lake stratification patterns and the potential for internal loading of phosphorus into the lake. 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 Bednesti 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

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

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