Okanagan Lake Collaborative Monitoring Agreement
2024 Summary Report

Prepared for:
Okanagan Basin Water Board
City of Kelowna
Regional District of Central Okanagan
District of Summerland
BC Ministry of Environment and Parks

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Executive Summary

Since 2011, a collaborative program, now run by the Okanagan Basin Water Board, has monitored Okanagan Lake's water quality monthly from March to September, aiming to assess compliance with water quality objectives and identify trends in nutrient and biological data. The 2024 report summarizes findings from this long-term monitoring, including physical, chemical, and biological parameters, and places them within the context of the program's history.

Summary of 2024:

- Diminished watershed resiliency, stemming from climate change's increased extreme weather variation, is evident in the Okanagan's exceptionally hot and dry conditions observed in 2023 and 2024.
- While Okanagan Lake overall shows signs of human impact, the Armstrong Arm exhibits significantly greater degradation due to a combination of factors including agriculture, logging, septic systems, and wildfire, with more frequent exceedances of water quality standards compared to other locations where weather is a more dominant factor.
- Water clarity was near normal with no year-over-year trends during the past 10 years.
- Surface water temperatures were record high at all sites during 2024
- Low dissolved oxygen remains a perennial concern in the deep water of the Armstrong Arm
- Nitrogen concentrations (total and inorganic) were stable or declining during the past 5 years despite the decades long-increasing trends
- Total phosphorus in Okanagan Lake, influenced by sediment and showing a long-term increasing trend since the mid-2000s, fluctuated with wet and dry years across all sites, while dissolved phosphorus remained stable or decreased at most locations, except for an increase in the Armstrong Arm.
- Chlorophyll-a concentrations declined throughout the lake during the past 5 years.
- Despite meeting chlorophyll-a objectives in 2024, Okanagan Lake exhibited a concerning increase in phytoplankton abundance, particularly cyanobacteria, leading to exceedances of biovolume and taxonomic objectives, especially in the Armstrong Arm, and continuing a long-term increasing trend at Kelowna and Armstrong Arm.

Ongoing concerns:

- Chronically low Secchi depth in the Armstrong Arm
- Increasing nitrate in hypolimnion of Okanagan Lake since 1970s
- Increasing total phosphorus at all sites except Summerland since early 2000s
- High densities of potentially toxic cyanobacteria in Armstrong Arm during 2018-2024
- Role of Climate Change in water quality changes in Okanagan Lake
- Phosphorus loading to the Armstrong Arm and north basin of Okanagan Lake from the White Rock Lake and McDougall Creek wildfires

Positive changes:

- Stable or decreasing nitrogen in Okanagan Lake during past 5 years
- Declining chlorophyll-a concentrations

Water Quality Objectives, 2011-2024 Values, and Trends for Okanagan Lake

Table 1: Okanagan Lake water quality objectives

Parameter (Nordin, 2005)	**Summerland**	**Kelowna**	**Ok Centre**	**Armstrong Arm**
Secchi Depth (growing season average: Apr-Sep)	>7m	>6m	>6m	>5m
Dissolved Oxygen (minimum in bottom waters)	-	-	-	>5 mg/L
TP (mg/L as P) (maximum at spring overturn)	<0.007	<0.008	<0.008	<0.01
Chlorophyll-a (µg/L) (maximum seasonal average)	<4.5	<4.5	<4	<5
TN (mg/L as N) (maximum at spring overturn)	<0.230	<0.230	<0.230	<0.250
N:P Ratio (spring weighted ratio)	>25:1	>25:1	>25:1	>25:1
Algae Taxonomy (% heterocystous cyanobacteria)	<5%	<5%	<5%	<5%
Algae Biomass (µL/L) (growing season average)	<0.75	<0.75	<0.75	<0.75
Zooplankton Biomass (µg/L) (growing season average)	>50	>50	>50	>50
Zooplankton Taxonomy (% cladocerans)	>5%	>5%	>5%	>5%

Table 2: Attainment of Okanagan Lake water quality objectives compared to growing season averages during 2024

Objective	Summerland	Kelowna	Ok Centre	Armstrong Arm
Secchi Depth	7.6	7.3	7.4	4.4
Dissolved Oxygen	8.50	8.60	8.70	1.10
TP (mg/L) 0:10m:	0.005	0.006	0.008	0.0
20-45m:	0.005	0.005	0.006	0.0
Chlorophyll-a (µg/L)	1.2	1.5	1.8	1.4
TN (mg/L) 0-10m:	0.218	0.223	0.205	0.216
20-45m:	0.243	0.239	0.222	0.288
N:P Ratio 0-10m:	56:1	46:1	38:1	16:1
20-45m:	48:1	45:1	39:1	18:1
Algae Taxonomy (% heterocystous cyanobacteria)	4.0%	6.4%	5.2%	25.6%
Algae Biovolume (µL/L)	0.846	1.106	1.149	1.576
Zooplankton Biomass (µg/L)	8.3	11.2	9.3	12.5
Zooplankton Taxonomy (% cladocerans)	11.1%	1.0%	12.2%	3.3%

Legend:

Achieved objective	Achieve objective in some but not all samples	Did not achieve objective

Table 3: Summary of trends compared to attainment of water quality objectives in Okanagan Lake during 2011-2024

Objective	Summerland	Kelowna	Ok Centre	Armstrong Arm
Secchi Depth	-	-	-	-
Dissolved Oxygen	-	-	-	-
TP (mg/L) 0:10m:	↑	↑	↑	↑
Chlorophyll-a (µg/L)	↓	↓	↓	↓
TN (mg/L) 0-10m:	-	-	-	↓
N:P Ratio 0-10m:	↓	↓	↓	↓
Algae Taxonomy (% heterocystous cyanobacteria)	↑	↑	-	-
Algae Biovolume (µL/L)	↑	↑	↑	-
Zooplankton Biomass (µg/L)	-	-	↓	↓
Zooplankton Taxonomy (% cladocerans)	-	-	-	-

Legend:

Achieved objective	Achieve objective in some but not all samples	Did not achieve objective

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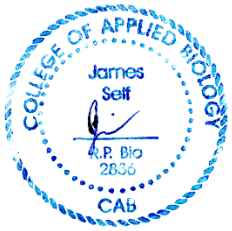

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Definitions

The following terms are defined as they are used in this report.

Term	Definition
Algae bloom	A superabundant growth of algae that may result in surface scum depending on type of algae that is blooming
Anoxic	Devoid of oxygen
Bioavailable	Available for use by plants or animals
Chlorophyll-a	Primary photosynthetic pigment in algae; used as a measure of photosynthetic activity
Cyanobacteria	Bacteria-like algae having cyanochrome as the main photosynthetic pigment
Diatoms	Algae that have hard, silica-based "shells" frustules
Fall overturn	Surface waters cool and sink, until a fall storm mixes the water column
Eutrophic	Nutrient-rich, biologically productive water body
Hypoxic	Very low dissolved oxygen
Macronutrient	The major constituents of cells: nitrogen, phosphorus, carbon, sulphate, H
Micronutrient	Small amounts are required for growth; Si, Mn, Fe, Co, Zn, Cu, Mo etc.
Microflora	The sum of algae, bacteria, fungi, *Actinomycetes,* etc., in water or biofilms
Monomictic	"One Mixing": describes lakes that are thermally stratified in summer and mixed in winter
Nutrient limitation	A nutrient will limit or control the potential growth of organisms e.g. P or N
Phytoplankton	Algae that float, drift or swim in water columns of reservoirs and lakes
Plankton	Those organisms that float or swim in water
Riparian	The interface between land and a stream or lake
Secchi depth	Depth where a 20 cm Secchi disk can be seen; measures water transparency
Thermocline	The lake zone of greatest change in water temperature with depth (> 1°C/m); it separates the surface water (epilimnion) from the cold hypolimnion below
Zooplankton	Minute animals that graze algae, bacteria and detritus in water bodies

Term	Definition
AFDM	Ash-free dry mass
Chl-a	Chlorophyll-a units µg/L
DO	Dissolved oxygen units mg/L
N	Nitrogen units mg/L as N
Ortho-P	Orthophosphate ≈ SRP monomeric inorganic phosphorus units mg/L as N
P	Phosphorus units mg/L as P
DIN	Dissolved inorganic nitrogen = ammonia + nitrate + nitrite units mg/L as N
TDN	Total dissolved nitrogen = ammonia + nitrate + nitrite + dissolved organic N units mg/L as N
TDP/DP	Total dissolved phosphorus units mg/L as P
TN	Total nitrogen: organic + dissolved units mg/L as N
TP	Total phosphorus: organic + dissolved units mg/L as P

Lake Classification by Trophic Status Indicators (Nordin, 1985)

Trophic Status	chlorophyll-a ug/L	Total P ug/L	Total N ug/L	Secchi disc m	Phytoplankton density (cells/mL)	Phytoplankton biomass (mg/m^3)
Oligotrophic	0 – 2	1 – 10	<100	> 6	<1000	0-500
Mesotrophic	2 – 5	10 – 20	100 – 500	3 – 6	1000-5000	500-2000
Eutrophic	>5	> 20	500-1000	< 3	>5000	>2000

Nutrient Balance Definitions for Microflora (Dissolved Inorganic N : Dissolved Inorganic P) (Nordin,1985)

Phosphorus Limitation	Co-Limitation of N and P	Nitrogen Limitation
>15 : 1	<15 : 1 – 5 : 1	5 : 1 or less

1.0 Introduction

1.1 Overview

The British Columbia Ministry of Environment and Parks (ENV) in partnership with the City of Kelowna, the Regional District of Central Okanagan, and the District of Summerland began a seasonal sampling program of Okanagan Lake in 2011 to increase the temporal resolution of water quality data being gathered. This program was performed collaboratively between ENV staff, Okanagan Nation Alliance (ONA; 2011), and Larratt Aquatic Consulting (2012-2024). The current program is overseen by the Okanagan Basin Water Board (OBWB). Okanagan Lake was sampled monthly from March to September from 2011-2024 at four key sites (Figure 1, Table 4).

Table 4: GPS coordinates of sampling sites

Site Name	EMS ID	Latitude	Longitude
Summerland	0500454	49.600550°	-119.628030°
Kelowna	0500236	49.861350°	-119.513420°
Ok Centre	0500730	50.089900°	-119.478270°
Armstrong Arm	0500239	50.315450°	-119.357180°

Note: EMS = Environmental Monitoring System and serves as ENV's database of water quality

Sampling focused on three broad subjects at each site: physical parameters, water chemistry, and biological activity.

Physical parameters including temperature profiles were taken at each site on each date to build a composite image of conditions in Okanagan Lake over time (Figure 4). Secchi depth, a measure of water clarity, was also recorded for each site.

In addition, dissolved oxygen profiles were taken and a range of parameters were chemically analyzed from samples taken in the epilimnion (1-5-10 m composite) and the hypolimnion (20-32-45 m composite). Chemistry focused on the major nutrients in their various forms. Chemistry results were analyzed by ALS Environmental throughout this study.

Biological sampling included generic parameters such as chlorophyll-a concentration and biomass, as well as detailed taxonomic classification of phytoplankton (algae) and zooplankton.

The 2024 data were added to the existing 2011 – 2023 database upon which all the analyses in this report were performed. Water quality objectives were based upon Nordin (2005) (Appendix 1).

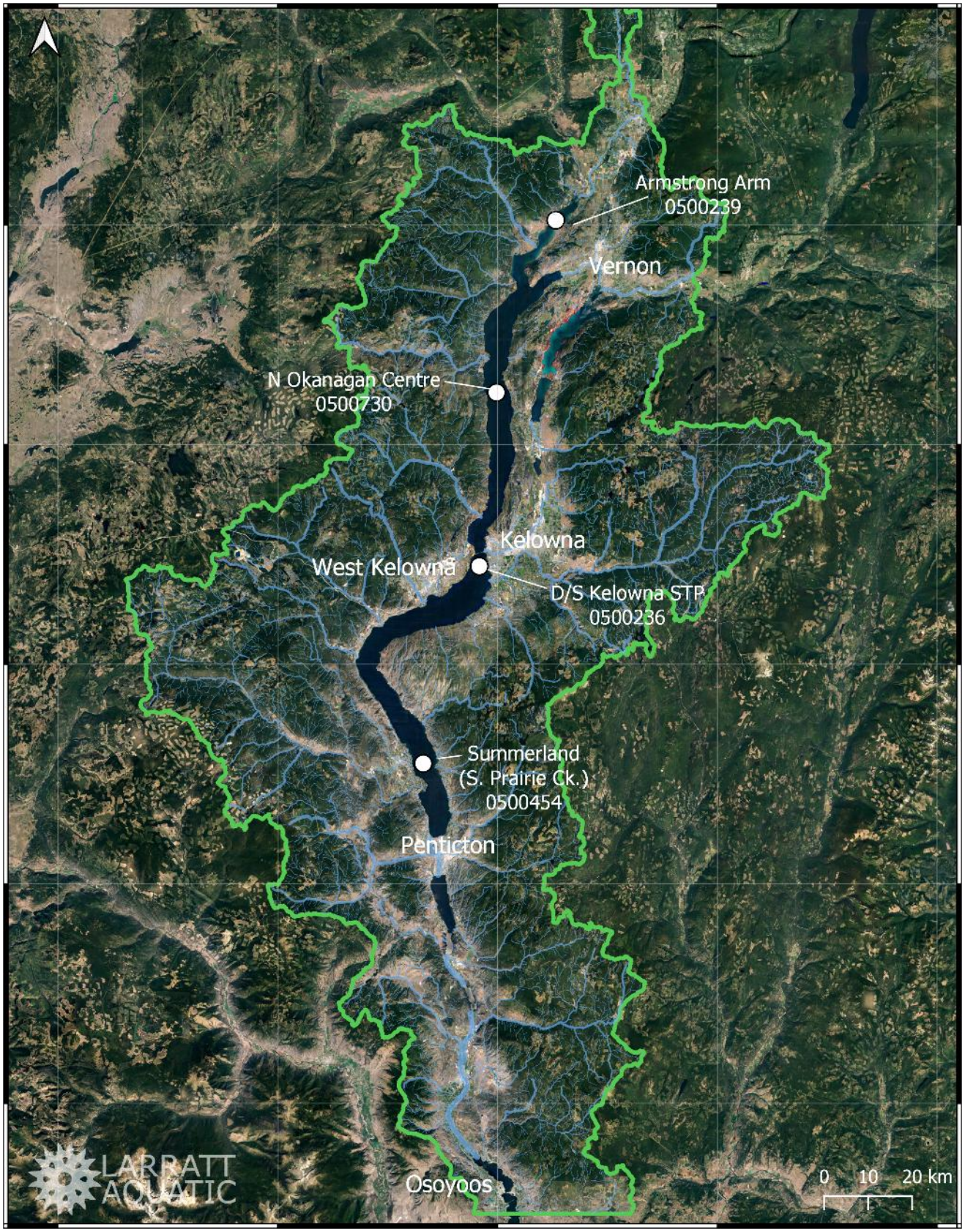


Figure 1: Okanagan Basin Watershed with four sampling locations identified

1.2 Weather and Climate Conditions in 2024

The weather during any given year will have a major impact on physical conditions, water chemistry, and biological activity in Okanagan Lake during that and subsequent years. The weather during 2024 was hotter and drier than usual for the Okanagan climate (Figure 2). Freshet was very muted. The water level of Okanagan Lake was held near normal despite the very hot and dry conditions because of very low outflows in the Okanagan River (Figure 3). Fortunately, there were no major fires in the Okanagan during 2024 despite the hot dry summer. This type of extreme weather is expected to become more frequent and more intense because of Climate Change.

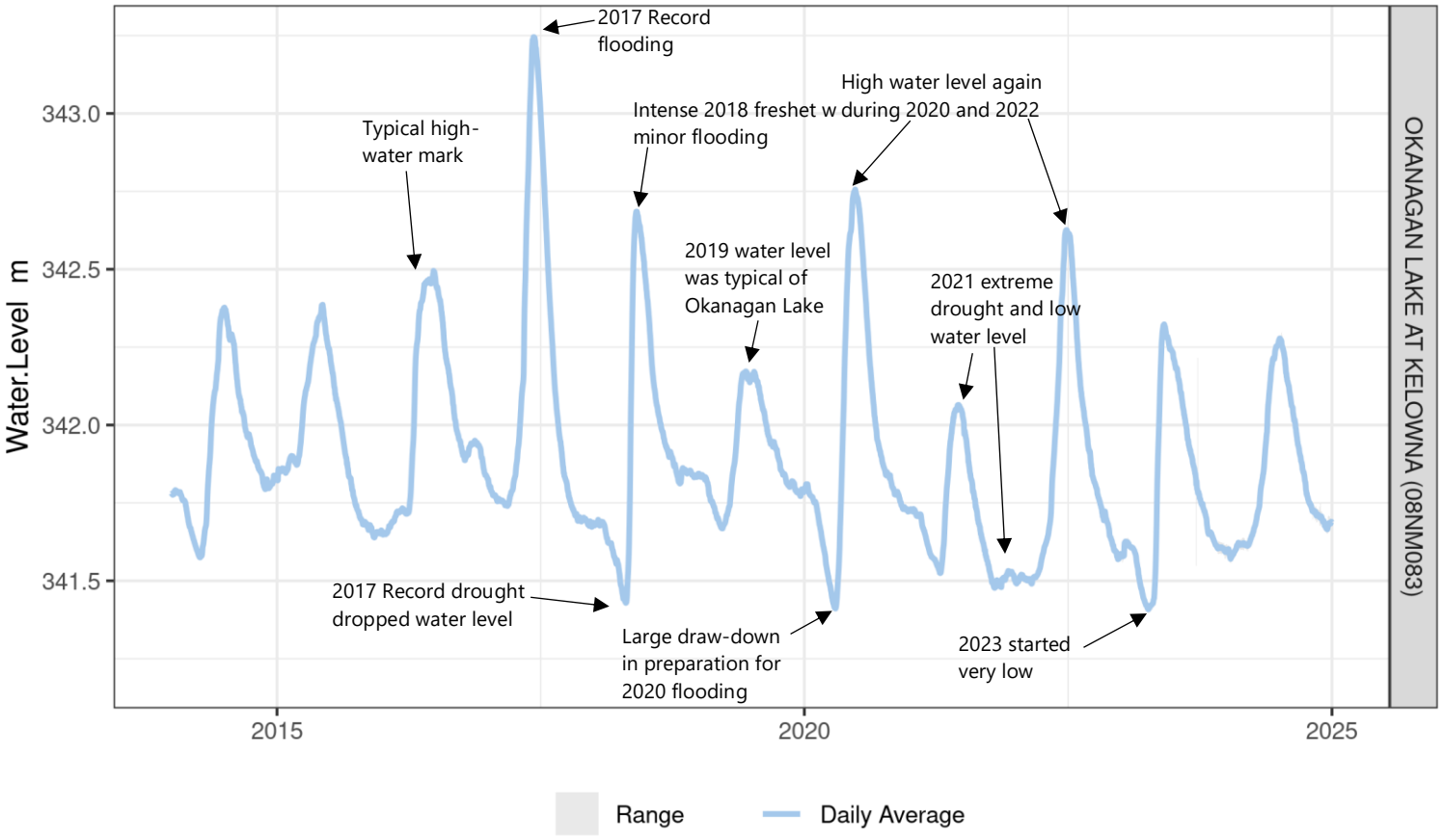


Figure 2: Water level in Okanagan Lake at Kelowna from 2014-2024
Source: (Water Office, 2025)

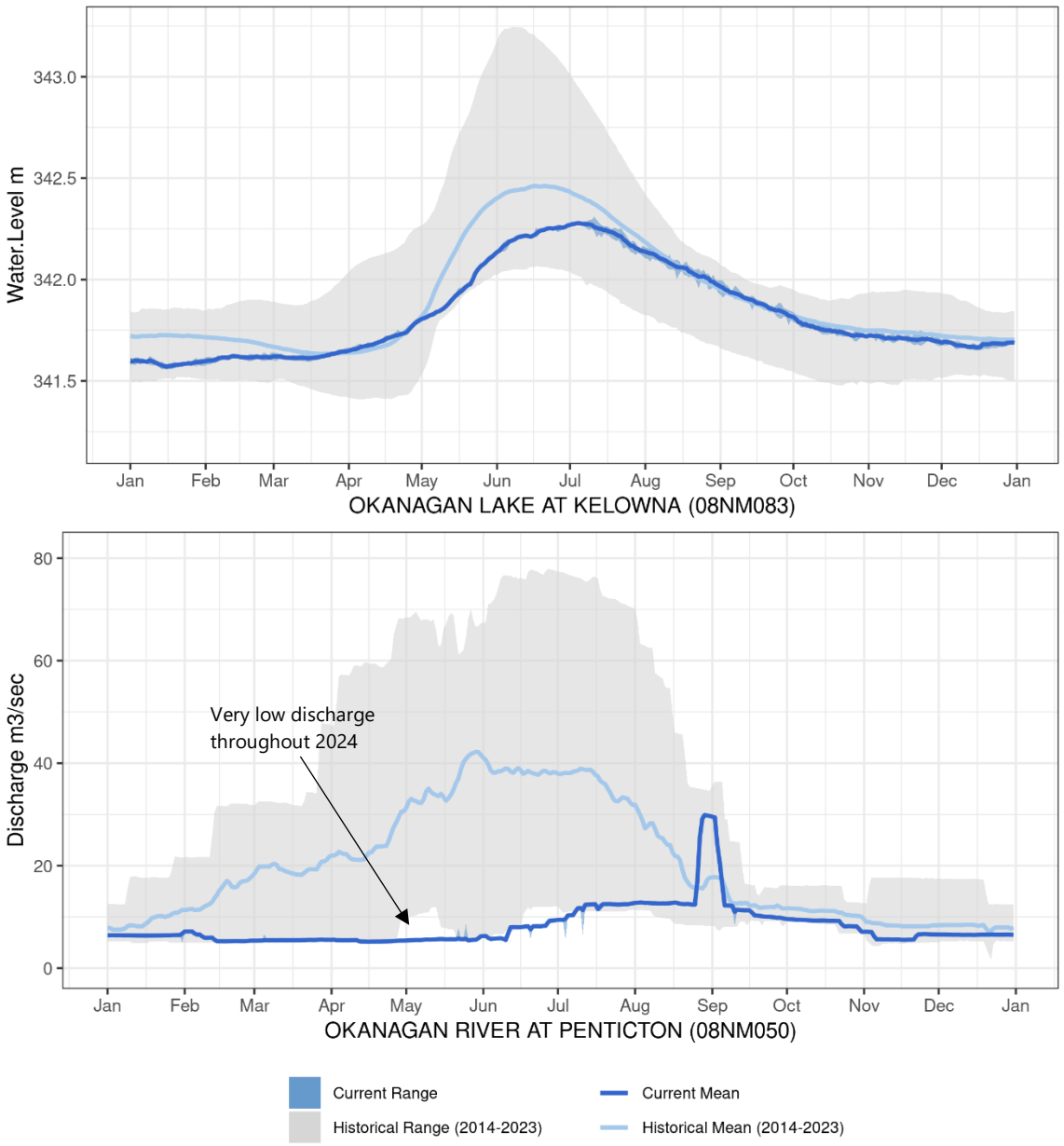


Figure 3: Daily average water level in Okanagan Lake and discharge at Penticton during 2024 compared to previous 10 years

Source: (Water Office, 2025)

2.0 Results & Discussion

2.1 Physical

2.1.1 Temperature

Okanagan Lake is a deep monomictic lake. From May to November each year, the surface water (epilimnion) is thermally isolated from the deep water (hypolimnion) by a thermocline. The sun warms the epilimnion to over 20 °C each summer while water below 20 m changes temperature by less than 4 °C annually (Figure 4).

The three main basin sites (Summerland, Kelowna, and OK Centre) exhibit similar thermal behavior while the northern Armstrong Arm site is shallower and reaches a higher surface temperature each summer (Figure 4). Thermal stratification in Okanagan Lake breaks down each November and the water column freely circulates through the winter. There were no statistically significant trends in the 2011–2024 temperature data either annually, seasonally (Mann-Kendall trend tests).

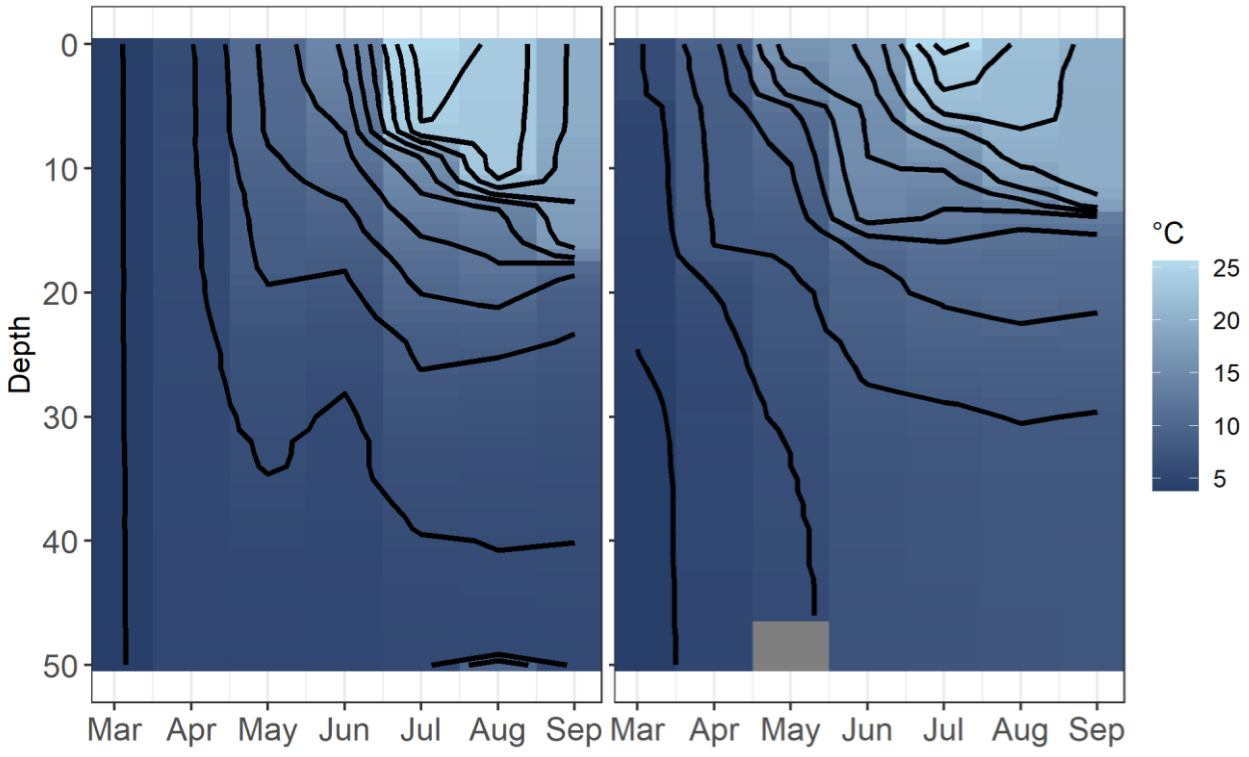


Figure 4: Temperature profiles for Okanagan Lake at Summerland (left) and Armstrong Arm (right), 2024

Notes: Lines represent contours of same temperature or dissolved oxygen within the water column through time. Samples not collected during March 2020 at Armstrong Arm because of ice-cover

Surface water temperatures of Okanagan Lake at all four sites close to average throughout the before transitioning to above average during the late spring into fall months (Figure 5). July surface water temperatures were the warmest at each site for the 2011-2024 dataset (Figure 5).

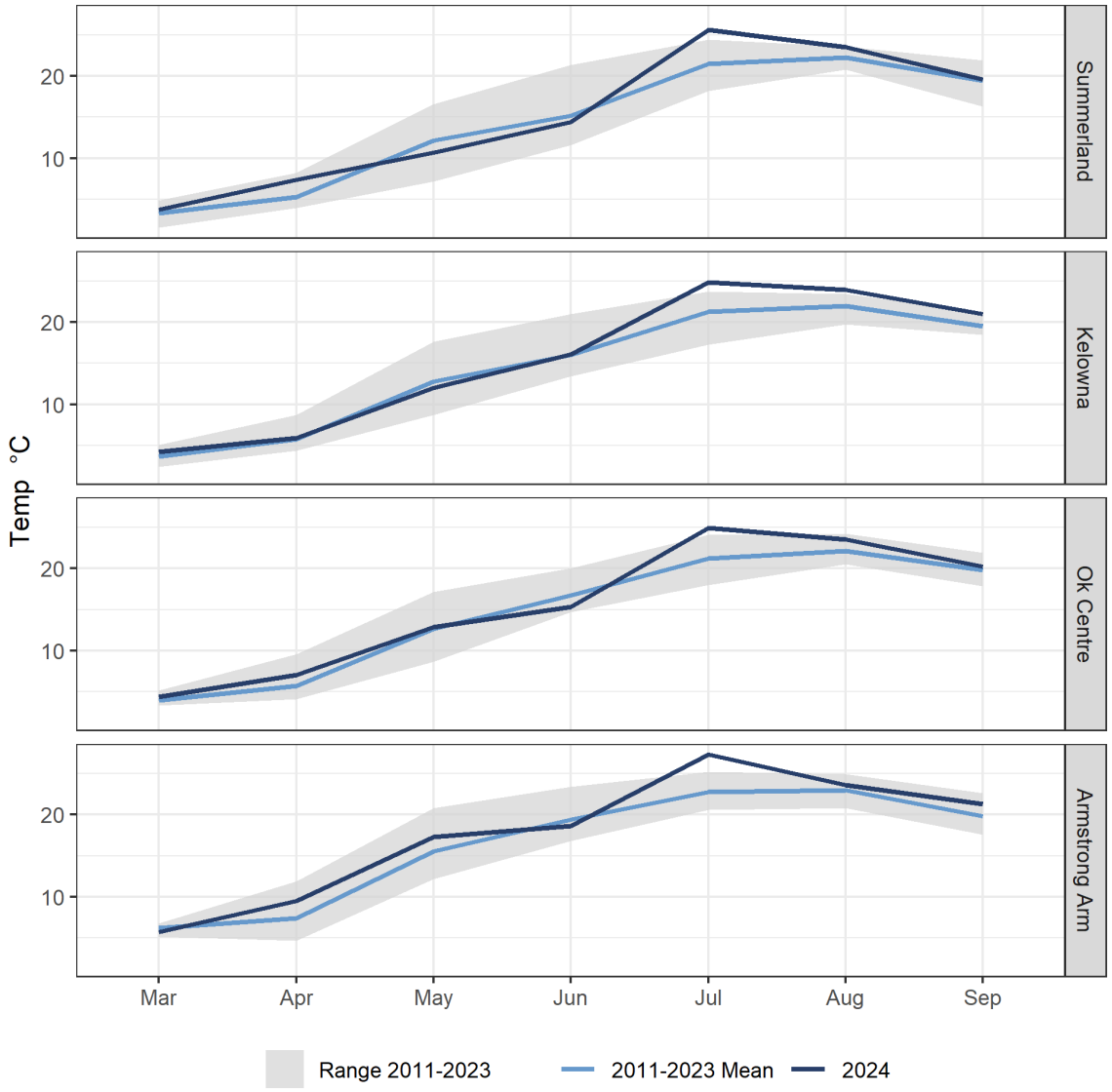


Figure 5: Temperature at Okanagan Lake sampling sites during 2023 compared to 2011-2022

2.1.2 Water Clarity and Secchi Depth

Water clarity, as measured by Secchi depth, ranged from a minimum of only 2.0 m at Armstrong Arm in April to a maximum of 14.1 m at Okanagan Centre in March during 2024 (Table 5). Secchi depth annual averages were near the 2011-2023 average during 2024 (Figure 6, Figure 7). All sites failed to meet their respective objectives during 2023 (Table 5). The overall average for Okanagan Lake historically has been near 6.5 m and averaged 6.7 ± 2.4 m in 2024 (Andrusak et al., 2006; Nordin, 2005). Extensive watershed damage from recent large wildfires also contributes fine sediment and nutrients to Okanagan Lake that directly and indirectly impair water clarity.

Secchi depth followed a consistent pattern each year. Maximum Secchi depths occurred in the late winter when biological activity was the lowest. During increased spring algal growth and freshet, the Secchi depth dropped dramatically to the lowest of the year at all sites. As nutrients were used up, algae concentrations diminished, and water clarity increased through the summer and into the fall (Figure 6).

The Secchi depth in the Armstrong Arm was much lower than at the other sites in Okanagan Lake during all years. This is clearly illustrated in Figure 7. Secchi depth was stable from 2011-2024 and there were no statistically significant year-over-year trends in the Secchi depth data from 2011-2024 but there was a significant drop from the 1980s to the 2010s when the historical data was considered (Mann-Kendall tests, Figure 7). This long-term trend is related to a period of high water-clarity in the years following the installation of nutrient removal systems at wastewater treatment plants; the current lower water clarity likely relates to the cumulative effects of increased population and human activities within the Okanagan watershed over the past 30 years.

Table 5: Growing Season (Apr-Sep) Secchi depth in meters at Okanagan Lake sampling sites, 2024

Site	Objective	Average	Std Dev	Max	Min
Summerland	>7.0	7.6	2.1	10.0	5.3
Kelowna	>6.0	7.3	2.3	9.7	4.3
Ok Centre	>6.0	7.4	2.3	9.9	4.1
Armstrong Arm	>5.0	4.4	1.8	6.2	2.0

Note: Objective refers to growing season average (Apr-Sep); Coloured shading indicates status of objective during that year with green meaning met objective and red meaning failed to meet objective

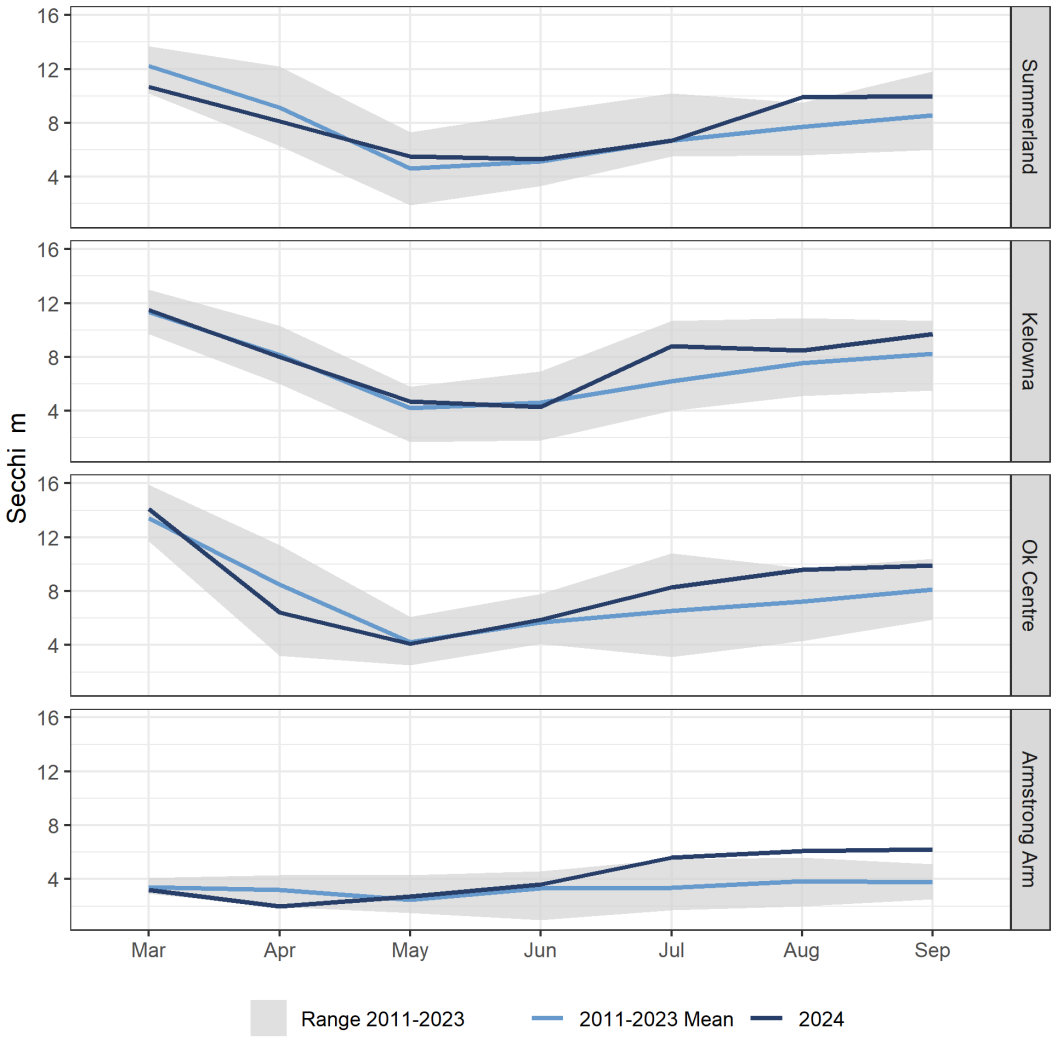


Figure 6: Secchi depth at Okanagan Lake sampling sites during 2024 compared to 2011-2023

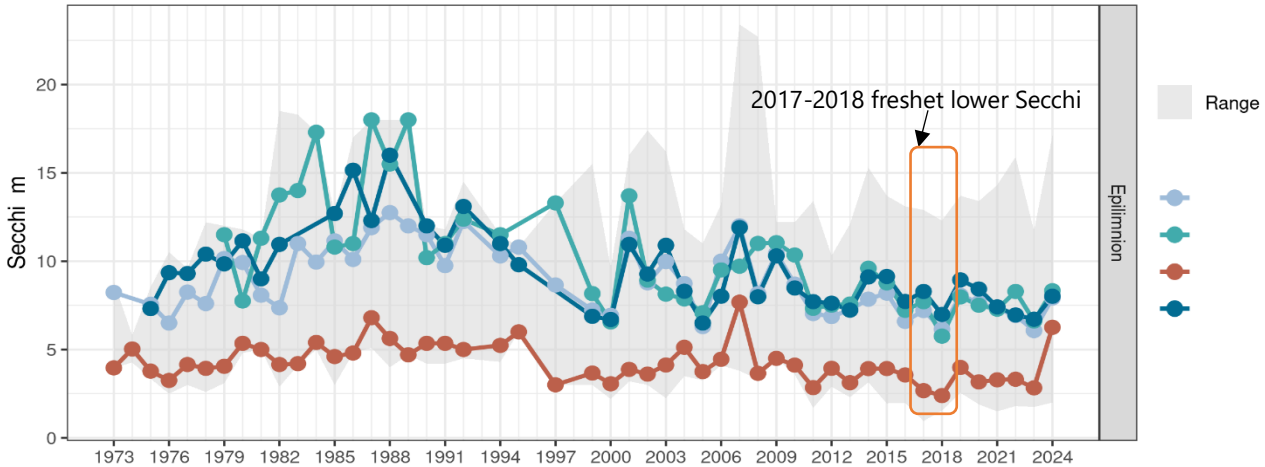


Figure 7: Annual average secchi depth in Okanagan Lake from 1973-2024

2.2 Chemistry

Chemistry sampling focused on dissolved oxygen, nitrogen and phosphorus (the most important aquatic nutrients), and silica, a key micronutrient. Increasing nutrient trends frequently result from human activities such as wastewater effluent disposal, riparian degradation, agriculture, fertilizer use, storm water, etc. These human-caused impacts are gradual and are easiest to detect as year-over-year trends.

2.2.1 Dissolved Oxygen

Dissolved oxygen (DO) is essential for all aquatic animals. Low DO will stress fish and possibly preclude them from certain portions of the water column. Hypoxic conditions occur when DO is very low (<2 mg/L) and this has a profound impact on water chemistry through the mobilization of nutrients and metals from the sediment. The three major basin sites (Summerland, Kelowna, and OK Centre) exhibit similar thermal and high dissolved oxygen behavior while the northern Armstrong Arm site is shallower and behaves differently. The later reaches a higher surface temperature and experiences a reduction in dissolved oxygen in the deep water each summer (Figure 8). The reduction in dissolved oxygen is caused by decomposition of organic material in the sediment and deep water and can lead to internal nutrient loading if oxygen becomes depleted. The Armstrong Arm is the only site with a dissolved oxygen objective (>5 mg/L in bottom water), a threshold that it fails to meet every year. By September 2024, the low dissolved oxygen zone (depth below red line in Figure 8) had a minimum concentration of only 1.6 mg/L and was approximately 10 m thick above the lake bottom.

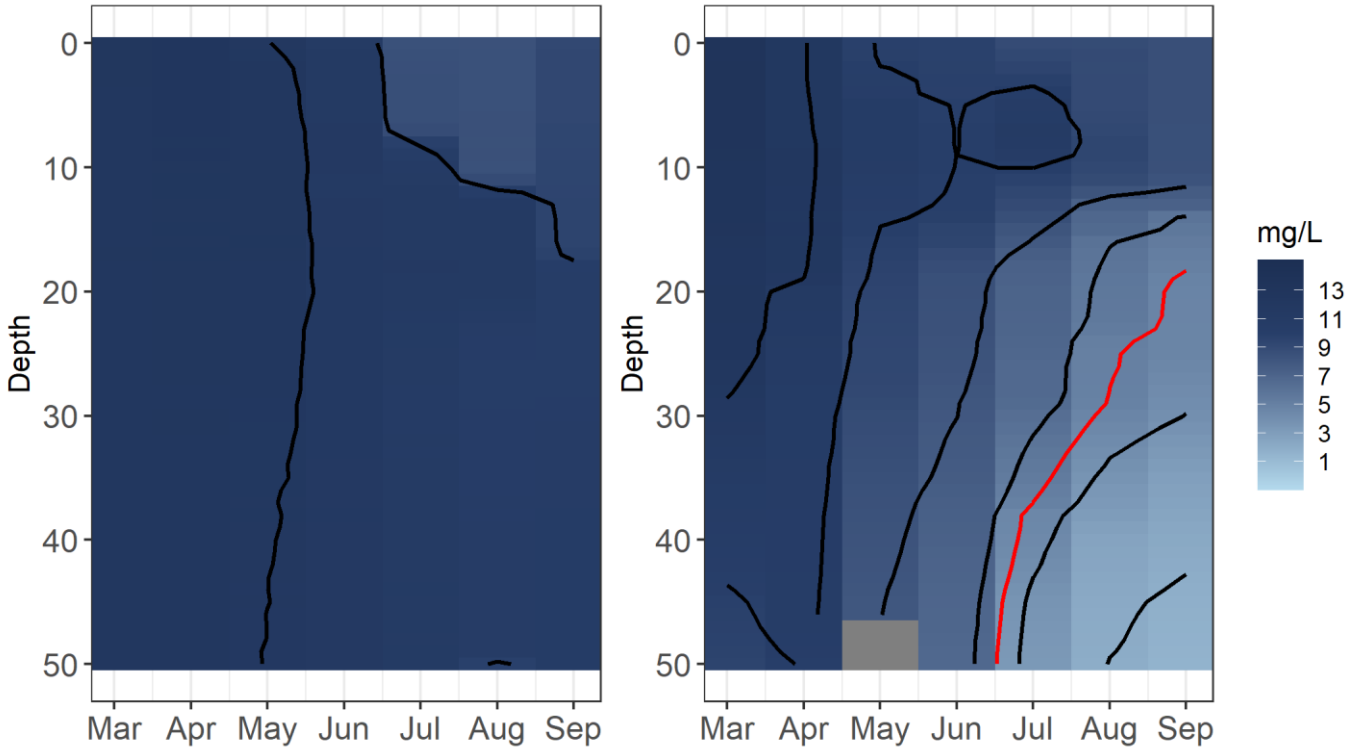


Figure 8: Dissolved oxygen profiles for Okanagan Lake at Summerland (left) and Armstrong Arm (right) during 2024

Dissolved oxygen profile illustrates high dissolved oxygen concentrations at Summerland and characteristic oxygen depletion in deep waters of the Armstrong Arm. Lines represent contours of same dissolved oxygen within the water column through time. Note: The red line on dissolved oxygen plot represents Water Quality Objective; all water below this line does not meet the objective.

2.2.2 Silica

Diatoms, a major group of algae in Okanagan Lake, use silica (measured as dissolved silica) as a structural building block for their cell walls. While no objectives for silica concentrations in Okanagan Lake have been set, monitoring continues as silica is a key micronutrient for this important group of algae. Silica was higher during 2017-2018, likely an effect of the flooding and intense freshets during those years, but when looking at the long-term data, there was an increasing trend from the 1970s to 2000 followed by a period of stability since 2000 (Table 6, Figure 9).

Table 6: Silica concentration in mg/L at Okanagan Lake sampling sites, 2024

Site	Average	Std Dev	Max	Min
Armstrong Arm	7.37	1.27	10.40	5.85
Kelowna	6.72	0.50	7.57	5.94
Ok Centre	6.72	0.47	7.22	5.79
Summerland	6.68	0.33	7.03	6.00

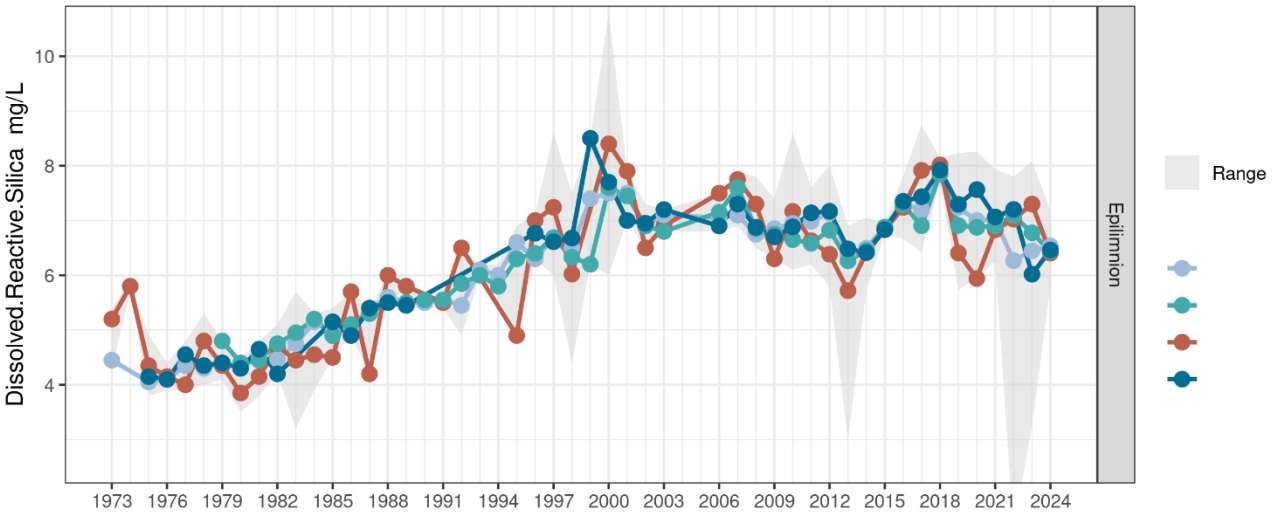


Figure 9: Annual average silica concentration in Okanagan Lake at each sampling site by year with trends highlighted, 1973-2024

2.2.3 Nitrogen and Phosphorus

Nitrogen and phosphorus are the most important nutrients in most aquatic environments. Nutrient limitation occurs when an essential element (most commonly nitrogen and/or phosphorus) is in relatively short supply. Algae production is limited by the availability of that nutrient despite potential abundance of other nutrients. In the Okanagan, phosphorus is the main limiting nutrient while dissolved inorganic nitrogen also limits productivity during the summer. Their concentrations are directly linked to the amount and type of algae that the lake produces (Nordin, 2005).

Nitrogen

Total nitrogen (TN) averaged 0.215 ± 0.029 mg/L as N in the epilimnion of Okanagan Lake during 2024. The objective for Okanagan Lake was set as a spring value (March sample date[1]) of 0.230 mg/L for the main basins and 0.250 mg/L for the Armstrong Arm. The objective was exceeded at Summerland, Kelowna, and Okanagan Centre during 2024 as it has in most years (Table 7). TN, previously identified as increasing, appears to have stabilized in the main basins while TN showed a declining trend in the Armstrong Arm from 2017-2024 (Mann-Kendall, p≤0.001; Table 7). Average TN values were comparable to those found in the literature for Okanagan Lake (0.17-0.23 mg/L as N; Andrusak et al.,2000).

[1] The Armstrong Arm sample is typically collected in early April because of ice-cover in that part of the lake

Table 7: Total nitrogen in mg/L as N concentration at Okanagan Lake sampling sites, 2023

Summerland	<10m	0.230	-		0.033	0.258	0.17
	>20m		-		0.018	0.259	0.216
Kelowna	<10m	0.230	-		0.036	0.264	0.177
	>20m		-		0.027	0.266	0.204
Ok Centre	<10m	0.230	-		0.025	0.234	0.164
	>20m		-		0.012	0.24	0.206
Armstrong	<10m	0.250	↓*		0.028	0.265	0.185
Arm	>20m		↓*		0.047	0.346	0.208

Note: Red shaded cells indicate that the Spring value exceeded the objective while green indicates that the value met the objective. Statistical significance of general trends derived from all data for a site may disappear when depths are split apart due to smaller sample size | * = Trend from 2017-2024

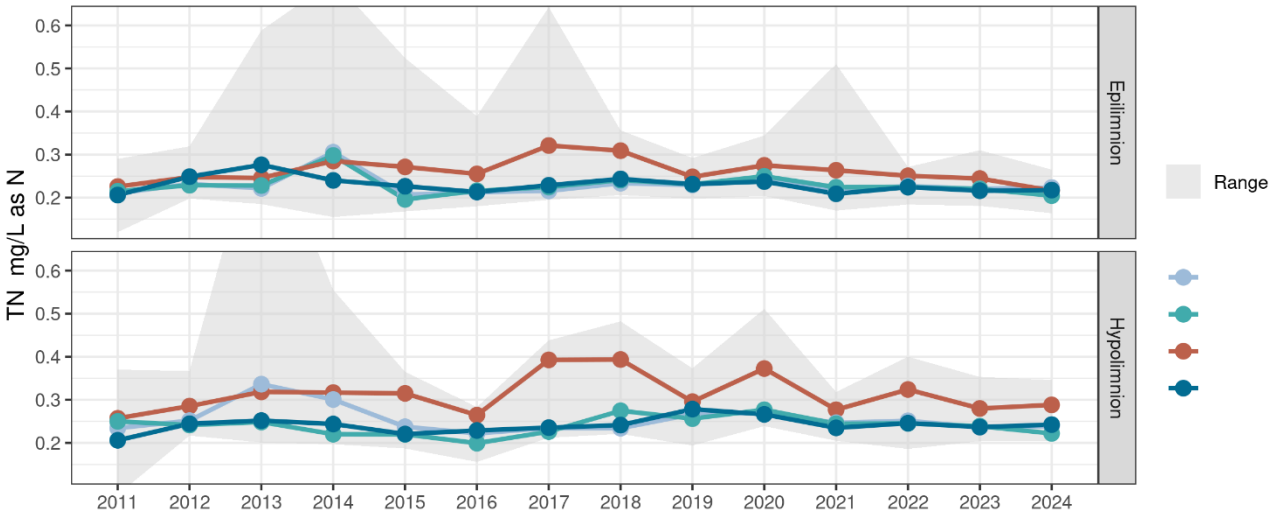


Figure 10: Annual average total nitrogen in Okanagan Lake, 2011-2024

Hypolimnetic nitrate increased at all sites from 2011 until 2019 followed by stable concentrations in the Armstrong Arm since 2019 and declining concentrations throughout the rest of the lake (Mann-Kendall, $p<0.001$ for Summerland + Kelowna + Okanagan Centre 2019 - 2024; Figure 11). Analysis of the entire Okanagan Lake water chemistry database indicates that this trend has been ongoing for decades (1973-2024 dataset; Mann-Kendall, $p<0.001$; Figure 11). This suggests a connection to human activities in the region because the trend has continued through several wet-dry climate cycles. There is also recent research noting that changes in nitrate concentration are a marker of climate change (Mas-Pla & Menció, 2019; Stuart et al., 2011). Layered on top of this trend are short-term variations depending on a given year's weather. The current declining trend is likely related to recovery after the 2017-2018 flooding and several consecutive drought years reducing groundwater returns to Okanagan Lake.

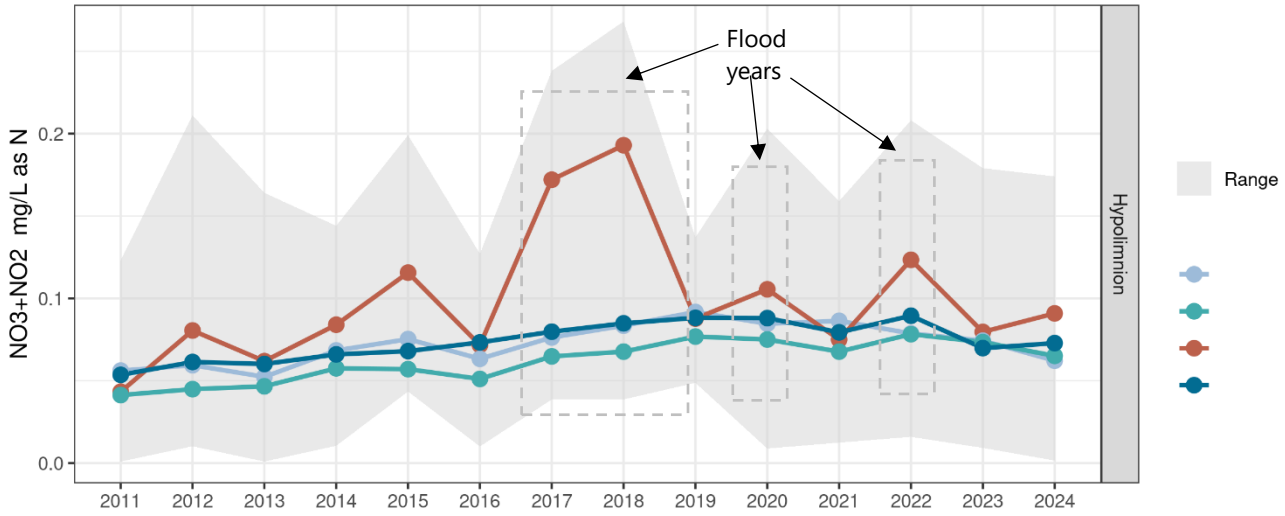


Figure 11: Annual average nitrite (NO_2) + nitrate (NO_3) in mg/L as N in the deep water of Okanagan Lake, 2011-2024

Nitrate is rapidly consumed by algae in the epilimnion each spring and thermal stratification prevents replenishment from the deeper water during the summer (Figure 11). Nitrate increased dramatically each summer in the hypolimnion of the Armstrong Arm because of chemistry associated with the low-DO conditions (Figure 12). For example, nitrate increased from <0.0032 mg/L as N in the epilimnion to 0.174 mg/L as N in the hypolimnion by Sept 2024.

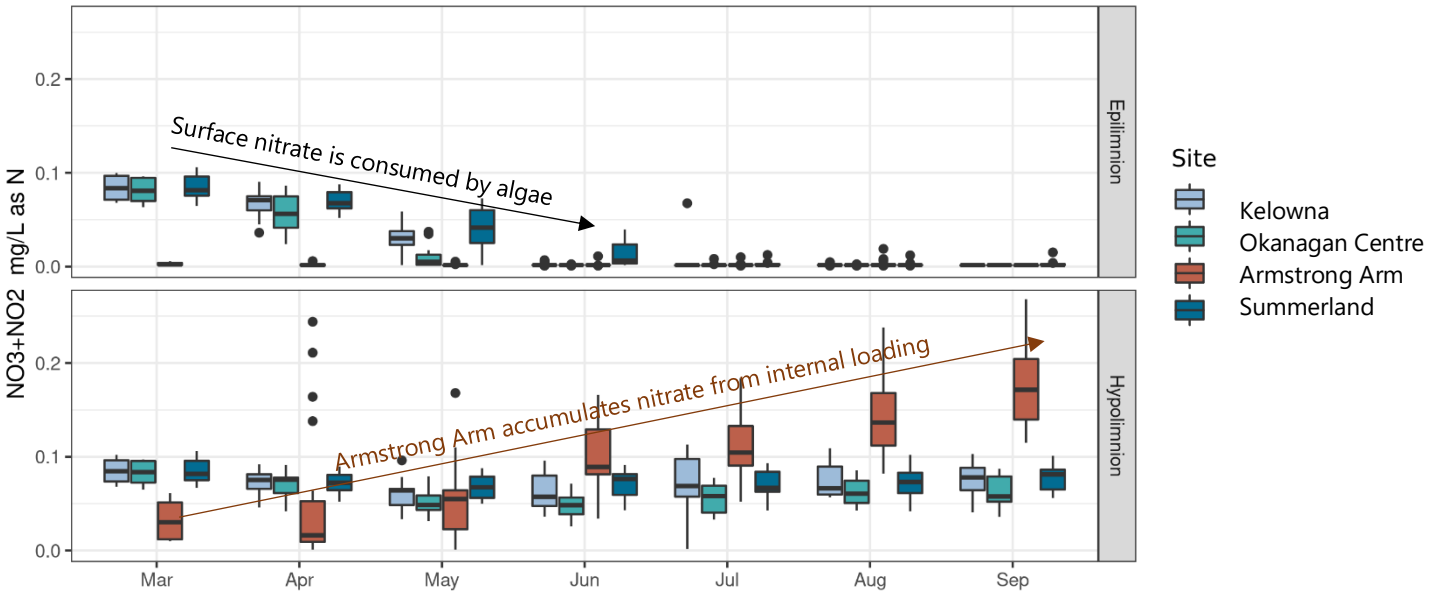


Figure 12: Nitrate + nitrite in Okanagan Lake month illustrating seasonal patterns, 2011-2024

Phosphorus

Total phosphorus (TP) measures all forms of phosphorus including those that may not be bioavailable. Total phosphorus averaged 0.009 ± 0.009 mg/L as P across Okanagan Lake during 2024 (Table 8). The TP objective for Okanagan Lake applies to the maximum phosphorus concentration at the spring overturn (Nordin, 2005; taken as March[2]). The objectives range from 0.007 mg/L in the south basin to 0.010 mg/L in the Armstrong Arm.

The TP objective was exceeded in the epilimnion and hypolimnion of Armstrong Arm in 2024, as it was in most years from 2011-2024 (Table 8). Increasing trends in TP occurred at all sites from 2011-2024 (Mann-Kendall, p≤0.04; Table 8, Figure 13). This trend was driven, in part, by large increases in TP during wet years such as 2012-2013 and 2017-2018, 2020, and 2022. The trend was also more pronounced in the Armstrong Arm and north basin compared to the central or south basins. TP includes phosphorus associated with suspended sediment carried into the lake and it increases in Okanagan Lake during wet years and decreases during dry years (Figure 13).

Table 8: Total phosphorus (mg/L as P) at Okanagan Lake sampling sites during 2024

Site	Depth	Objective	Trend	Avg	SD	Max	Min
Summerland	<10m	0.007	-	0.005	0.001	0.006	0.004
	>20m		↑	0.005	0.001	0.006	0.004
Kelowna	<10m	0.008	-	0.006	0.002	0.010	0.004
	>20m		↑	0.005	0.001	0.006	0.004
Ok Centre	<10m	0.008	↑	0.008	0.006	0.020	0.003
	>20m		↑	0.006	0.000	0.006	0.005
Armstrong	<10m	0.010	↑	0.012	0.008	0.029	0.007
Arm	>20m		↑	0.025	0.014	0.049	0.012

Note: Red shaded cells indicate that spring overturn value exceeded the objective while green shaded cells met the objective during 2022. Trends are based upon 2011-2023 data only

[2] The Armstrong Arm spring sample is typically collected in early April because of ice-cover in March

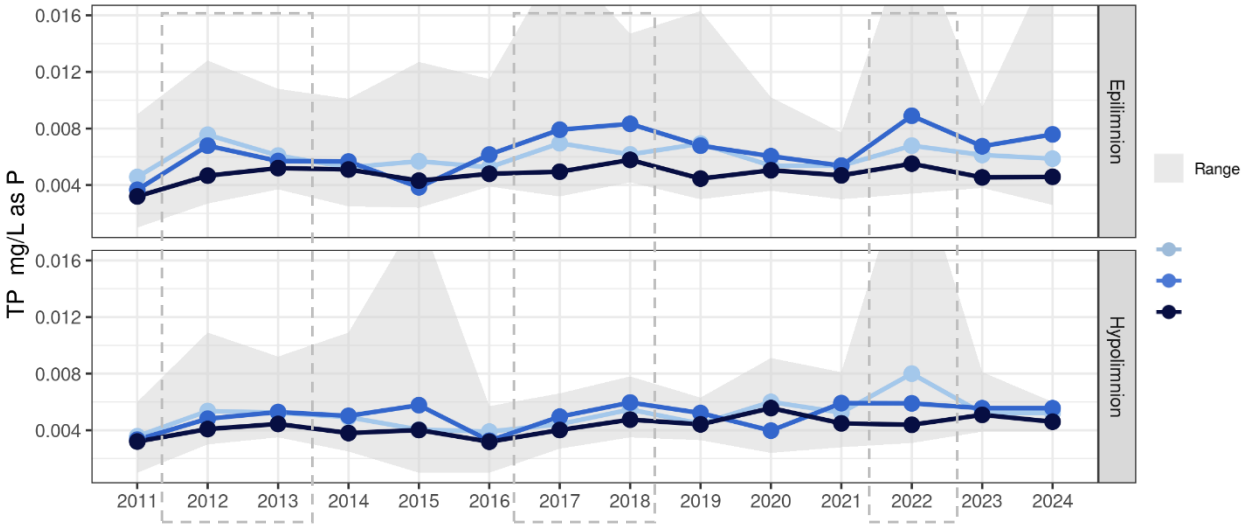


Figure 13: Annual average total phosphorus in Okanagan Lake at the three major basin sampling sites by year from 2011-2024

Notes: Grey boxes indicate wet years

TP experienced minor seasonal variation with a slight increase during freshet in some years at Summerland, Kelowna, and Okanagan Centre while there was dramatic variation in the Armstrong Arm over the course of each growing season. TP increased in the hypolimnion during the summer, possibly from phosphorus released from the sediment under low-oxygen conditions while algae productivity reduced surface concentrations over the growing season (Figure 14).

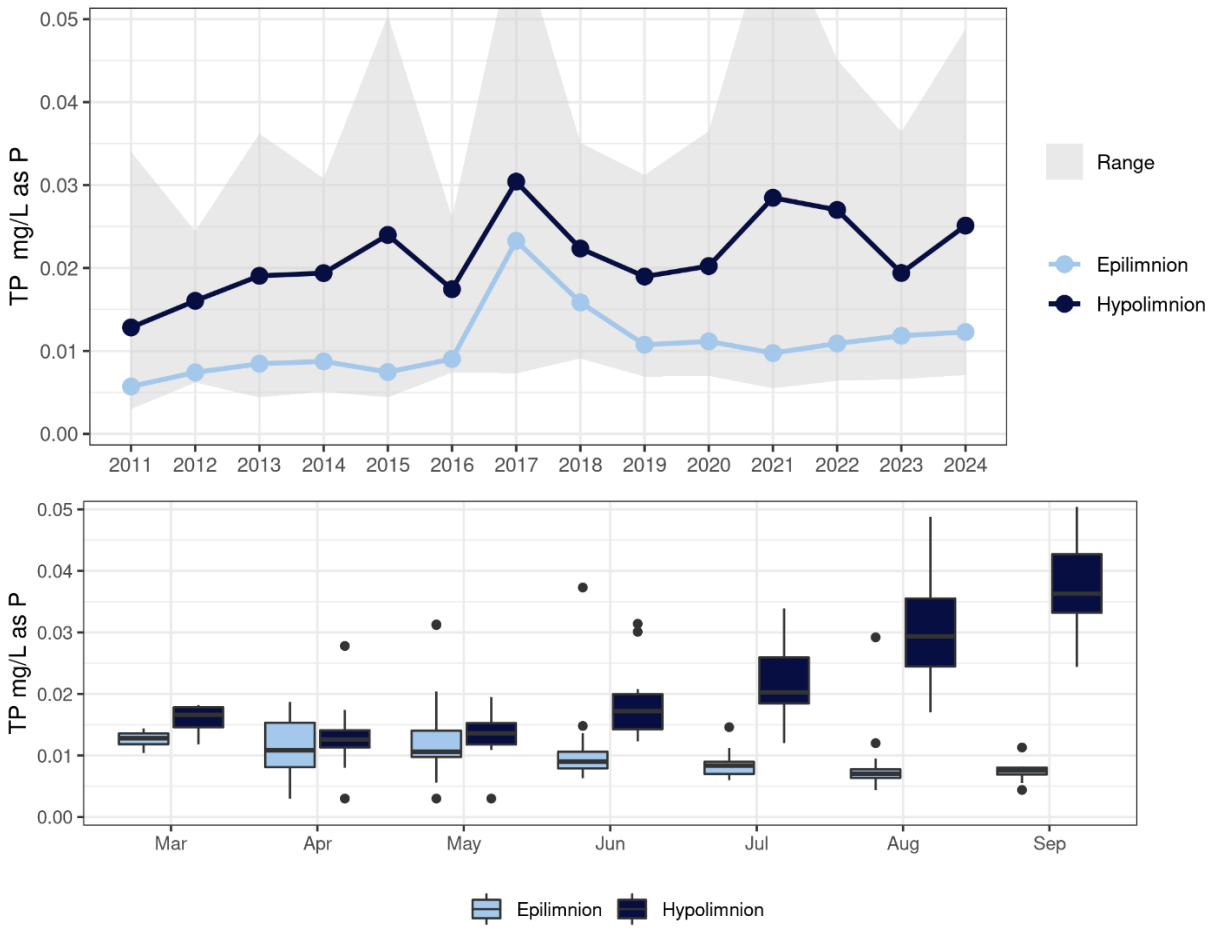


Figure 14: Total phosphorus in the Armstrong Arm, 2011-2024
Note: small reduction in eplimnetic TP over the growing season but it does not drop below detection as nitrate does

Dissolved phosphorus (TDP) measures the more bioavailable forms of phosphorus and is a good indicator of potential impacts to biota. TDP in the epilimnion and the hypolimnion of the Armstrong Arm increased (Mann-Kendall for 2011-2024 in the hypolimnion, $p \leq 0.02$). TDP was stable at Summerland, Kelowna, and Okanagan Centre over the past 10 years (2015-2024). Despite the stable long-term trend, TDP was noticeably higher in the Okanagan Centre epilimnion samples immediately following the White Rock Lake Fire (Sep 2021) and has remained higher since, a potential marker for wildfire impacts (Figure 15). Ortho-phosphate measures only the soluble reactive phosphorus fraction of the TDP and there were no significant trends in ortho-phosphate data at any of the sites from 2011-2024 with 97% of samples from the major basin sample sites having undetectable concentrations during 2024. Anoxic conditions in the Armstrong Arm increase hypolimnetic orthophosphate each summer.

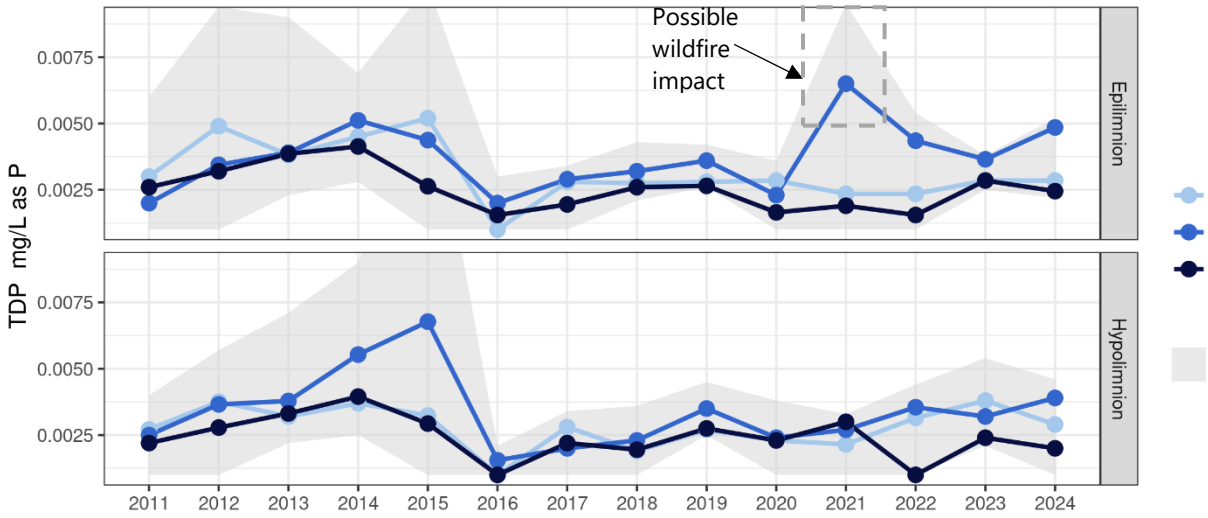


Figure 15: Annual average dissolved phosphorus in Okanagan Lake illustrating declining long-term trend at Okanagan Centre, Kelowna, and Summerland from 2011-2024

N:P Ratio

The ratio of nitrogen to phosphorus is a key factor in determining which types of phytoplankton will proliferate. Many species of cyanobacteria can fix atmospheric nitrogen and are therefore limited primarily by available phosphorus. These algae are more likely to bloom when phosphorus is abundant relative to nitrogen. The Okanagan Lake objective for the spring ratio of total nitrogen to total phosphorus is >25:1 in March samples. The objective was met at Summerland, Kelowna, and Okanagan Centre during 2024 while the Armstrong Arm had higher phosphorus concentrations than the rest of Okanagan Lake and did not meet the objective in 2024 (Figure 13, Table 9). The TN:TP ratio decreased at all sites from 2011-2024 (Mann-Kendall, $p \leq 0.02$) (Figure 13). The declining TN:TP trend is related to corresponding increasing trends in TP in Okanagan Lake (Table 8).

Table 9: Ratio of average TN to average TP during spring at Okanagan Lake sampling locations, 2011-2024

Summerland	<10m	0.258	0.0046		>25:1	↓
	>20m	0.251	0.0052		>25:1	↓
Kelowna	<10m	0.262	0.0057		>25:1	-
	>20m	0.260	0.0058		>25:1	↓
Ok Centre	<10m	0.233	0.0061		>25:1	↓
	>20m	0.232	0.0060		>25:1	↓
Armstrong Arm	<10m	0.185	0.0113		>25:1	↓
	>20m	0.208	0.0116		>25:1	↓

Note: red shaded cells indicate that the value did not meet the objective while green shaded cells met the objective during 2022 | TN and TP columns display annual averages while ratio column is specific to the spring sample date

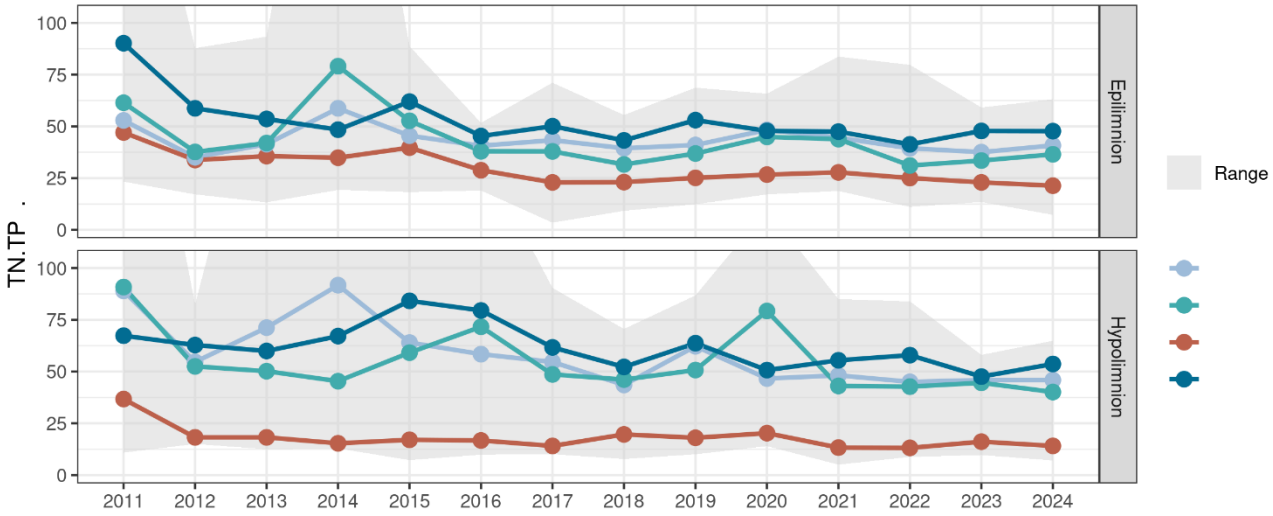


Figure 16: Nitrogen to phosphorus ratio at Okanagan Lake sampling sites 2011-2024

2.3 Biology

2.3.1 Phytoplankton

The Armstrong Arm of Okanagan Lake is shallower and has the potential to produce more phytoplankton and zooplankton than the deep basins of Okanagan Lake regardless of human activity. Phytoplankton and zooplankton samples were taken from all four sites were analyzed during 2024. Biomass analysis and taxonomic identification were performed on the taxonomy samples while chlorophyll-a concentrations were monitored as a productivity metric for phytoplankton abundance.

Chlorophyll-a

Chlorophyll-a (chl-a) is a photosynthetic pigment found in most freshwater algae species. As expected, chl-a followed an inverse trend to Secchi depth (Figure 6, Figure 17). Chl-a was lowest in

the late winter and peaked in April-May during the increased spring algal growth before decreasing through the summer. During 2024, chl-a concentrations met the objectives at all sites (Table 10). Spring chl-a concentrations were moderate with a maximum of 4.5 µg/L at Okanagan Centre (Table 10). Growing season average chl-a concentrations in the Armstrong Arm have declined significantly since 2017 with the three other sites showing similar declining trends since 2021 (sites combined Mann-Kendall, $p<0.001$; Figure 17).

In most years, there was a north to south decreasing trend in the chlorophyll-a data with the Armstrong Arm having the highest and Summerland having lowest average concentrations (Table 10).

Table 10: Growing season average chlorophyll-a in µg/L at Okanagan Lake sampling sites, 2024

Site	Objective	Trend	Average	Std Dev	Max	Min
Summerland	4	↓**	1.204	0.842	2.390	0.454
Kelowna	4.5	↓**	1.535	1.193	3.300	0.481
Ok Centre	4.5	↓**	1.846	1.607	4.450	0.561
Armstrong Arm	5	↓*	1.370	0.632	2.210	0.511

Note: Green shading indicates met objective during 2022 | * = 2017 to 2024 | ** = 2021-2024

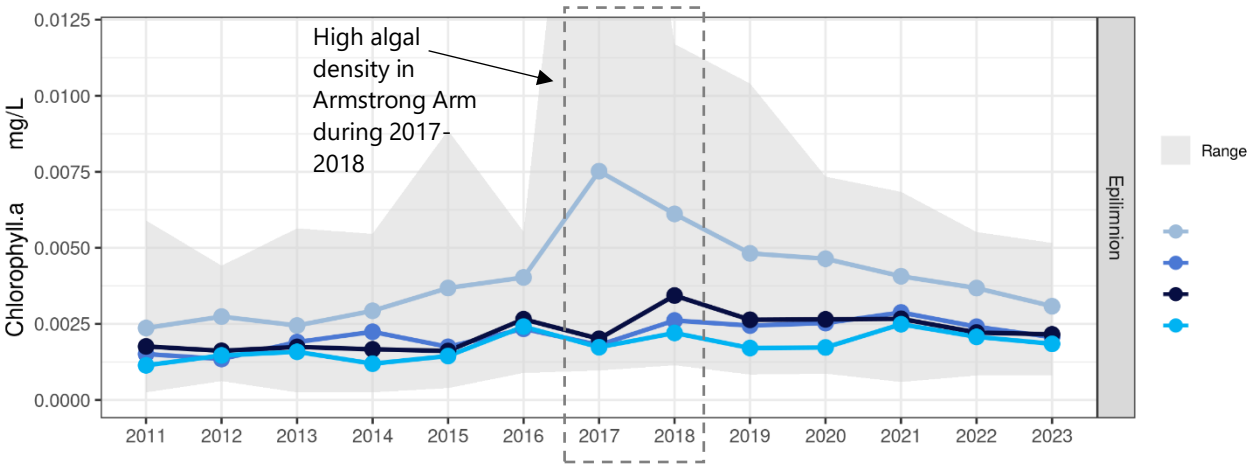


Figure 17: Annual average chlorophyll-a concentration at the four Okanagan Lake sampling sites, 2011-2024

Phytoplankton Biovolume

Phytoplankton biovolume samples were collected as one litre composites from 1-10 m and the biovolumes were determined taxonomically. From 2011-2014, biomass was determined using ash-free dry mass (AFDM). It is not possible to directly compare the results from the two methodologies and only the 2015-2024 results are considered here.

The objective is that the growing season average should be <0.75 µL/L (Table 11). Samples from all sites failed to meet the objective during 2024 because of above average phytoplankton production (Table 11, Figure 18, Figure 19).

Phytoplankton biovolume increased significantly from 2015-2024 at Summerland, Kelowna, and Okanagan Centre (MK tests, p≤0.05). Productivity was lower during 2022 than 2021 but increased again during 2023 and 2024. A one-year lag has been observed between wet years and elevated productivity in Okanagan Lake and this effect helps explain why 2019 and 2021 production was very high despite the much smaller freshets (Figure 18). This is likely related to the higher productivity in 2023 because of the large 2022 freshet. Production in 2025 is therefore expected to be decline after back-to-back drought years. However, extensive watershed damage from wildfires may offset the natural cycle.

Table 11: Phytoplankton biovolume in µL/L at Okanagan Lake sampling sites, 2024

Summerland	<0.75	↑		0.562	1.553	0.273
Kelowna	<0.75	↑	1.106	0.831	2.270	0.179
Ok Centre	<0.75	↑	1.149	1.054	3.012	0.112
Armstrong Arm	<0.75	-	1.576	0.890	3.281	0.663

Notes: Green shading = met objective while red shading = did not meet objective.

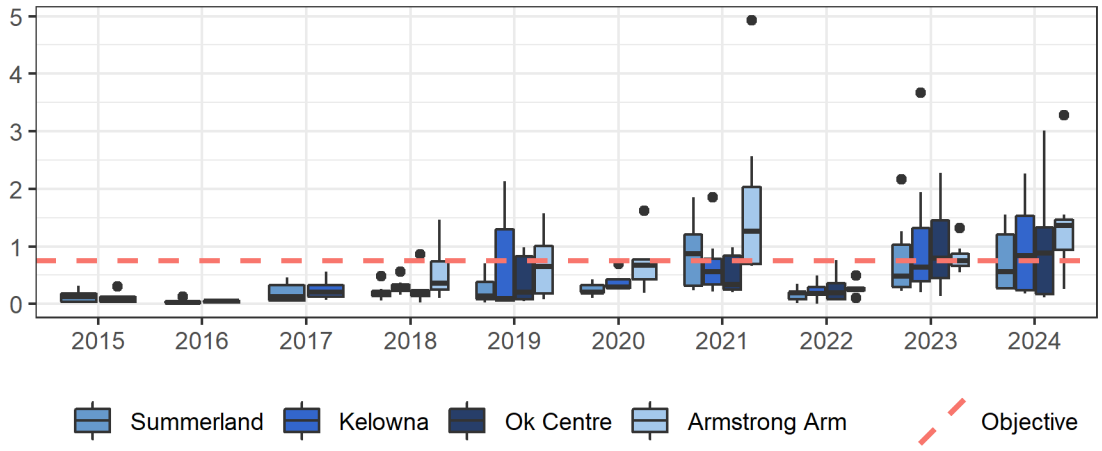


Figure 18: Phytoplankton Biovolume at Summerland and Kelowna, 2015-2024

Phytoplankton Taxonomy

Algae samples were identified to the species level and then grouped into broad algae types for analysis in this report. Diatoms tend to proliferate in the spring and their numbers decrease through the summer. Cyanobacteria were always numerous throughout the growing season in Okanagan Lake, but typically peaked in the late summer (Figure 19, Table 12). Average algae counts were highest at Kelowna but all sites experienced high densities of cyanobacteria during 2024 (Figure 20). Very high heterocystous cyanobacteria densities in the Armstrong Arm may be a marker for nutrients delivered to Okanagan Lake from the areas burned in the White Rock Lake wildfire.

Table 12: Average phytoplankton counts by major algae groups in cells/mL, 2023

	2024 Averages			
Algae Type	Summerland	Kelowna	Okanagan Centre	Armstrong Arm
Diatoms	1052	693	589	626
Greens	68	97	74	309
Yellow-Brown	382	558	679	749
Cyanobacteria	5697	8048	4398	5093
Dinoflagellates	6	6	4	12
Other.Flagellates	349	421	316	534
Total Algae	7554	9824	6061	7323

Figure 19: Taxonomic breakdown of algae by major types during 2024

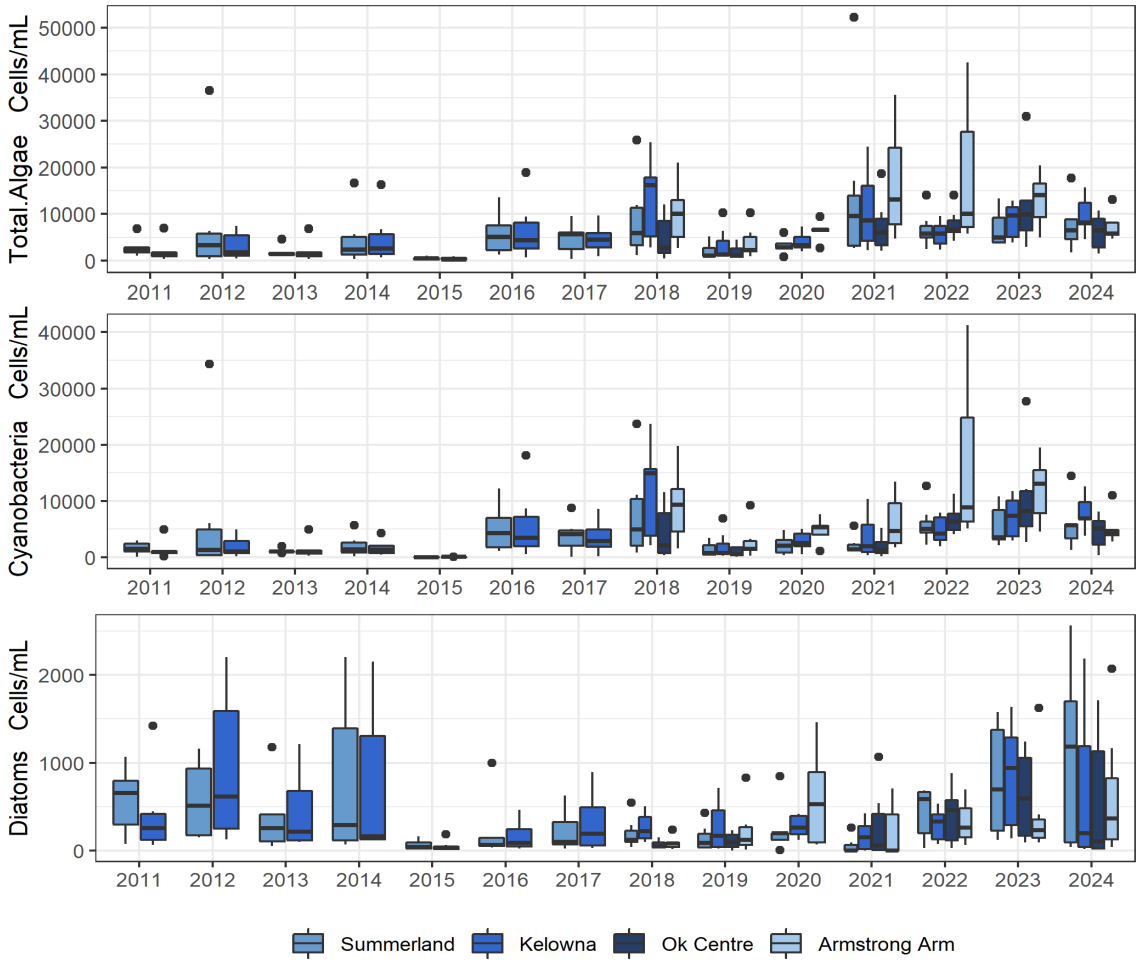


Figure 20: Total algae, cyanobacteria, and diatom counts in Okanagan Lake, 2011-2024

The Okanagan Lake objective for phytoplankton taxonomy states that no more than 5% of total cell counts should be heterocystous cyanobacteria in a given sample. These and other cyanobacteria can produce toxins that are harmful to human health when they are present in high concentrations. The heterocystous cyanobacteria objective was exceeded in 50% of samples from 2024 (Table 13). While problematic, the cyanobacteria densities observed during 2024 were not high enough to cause acute health concerns at any of the sites.

Table 13: Percent of total algae counts that were heterocystous cyanobacteria from 2023

Site	Objective	Trend	# Exceeding	Average	StdDev	Max	Min
Summerland	<5%	↑	2/7	4.0%	3%	9%	0%
Kelowna	<5%	↑	4/7	6.4%	6%	17%	0%
Ok Centre	<5%	-	2/7	5.2%	6%	19%	0%
Armstrong Arm	<5%	-	6/7	25.6%	20%	58%	4%

Note: Yellow shading indicates that the site did not meet the objective in some samples

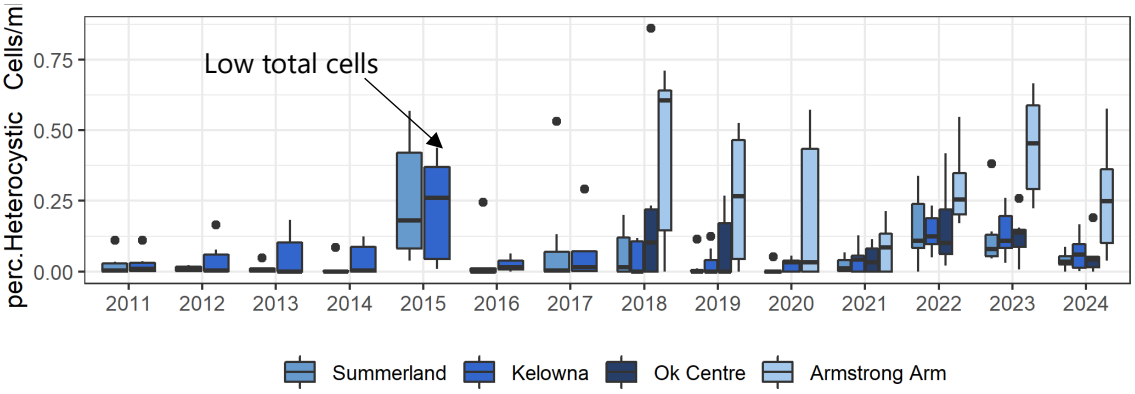


Figure 21: Percent of total algae counts that were heterocystous cyanobacteria, 2011-2023

2.3.2 Zooplankton

Biomass

Zooplankton biomass samples were obtained using a 150 µm net lowered to 45 m and raised vertically at a rate of approximately 0.5 m/second. The 150 µm net mesh size lets most phytoplankton pass through, while collecting most zooplankton. Samples were identified taxonomically and the biomass was calculated from the abundance.

The Okanagan Lake objective is a growing season average of >50 µg/L (Nordin, 2005). This objective was met at none of the sites during 2024 with all sites also below the 2015-2024 average (Table 14, Figure 22). While biomass during 2021 was unusually high, skewing trend results, there appeared to be a declining trend in zooplankton biomass from 2015-2024. The cause of the elevated 2021 zooplankton density or the much lower zooplankton biomass during 2023-2024 remains uncertain.

Table 14: Zooplankton biomass in µg/L at Okanagan Lake sampling sites, 2023

Site	Objective	Trend	Average	StdDev	Max	Min
Summerland	>50 µ/L	-	8.3	4.0	15.8	4.3
Kelowna		-	11.2	4.1	15.7	5.3
Okanagan Centre		↓	9.3	2.9	12.0	4.0
Armstrong Arm		↓	12.5	4.1	16.5	6.7

Note: Data includes only Apr-Aug results, Mar and Sep results not released by lab at time of writing.

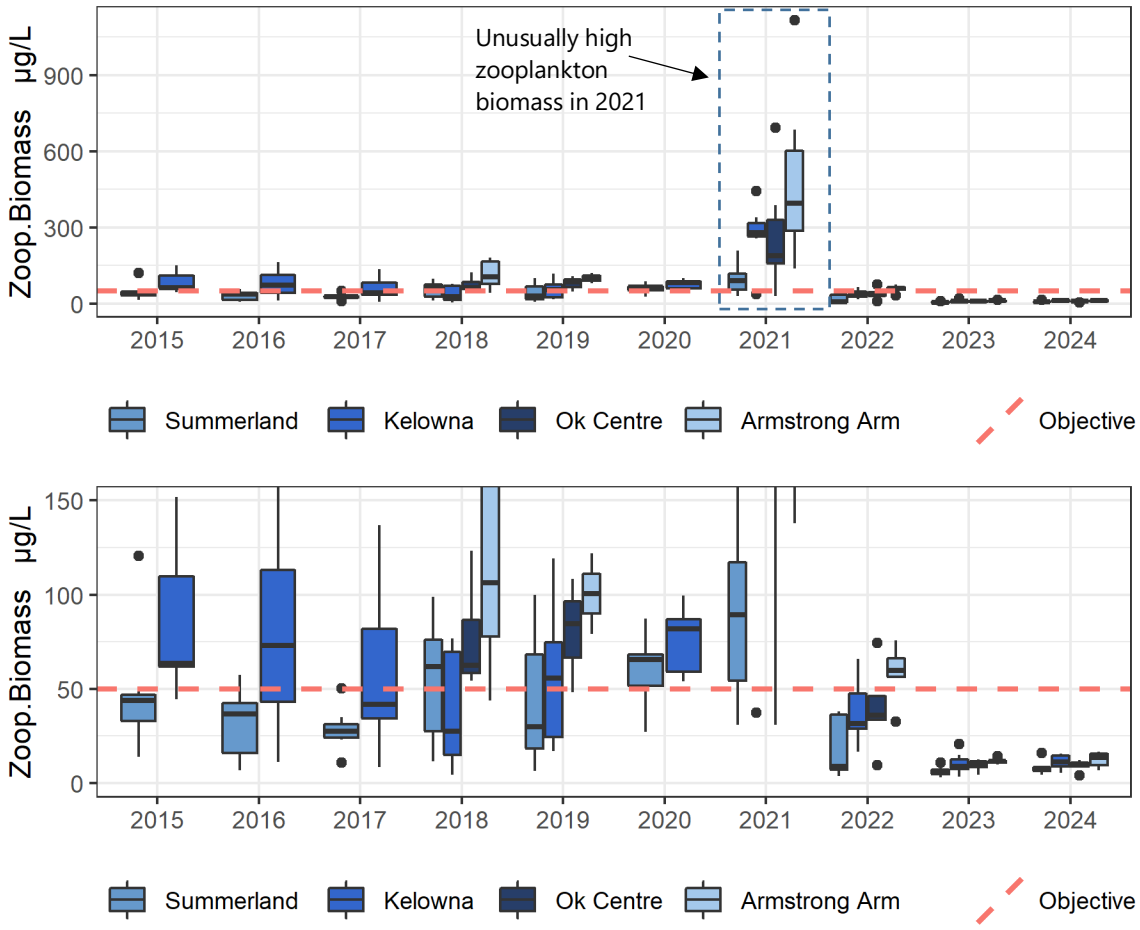


Figure 22: Zooplankton Biomass at the Okanagan Lake sampling locations by year, 2015-2024

Note: top and bottom panes are the same graph but the y-axis is changed to highlight variation in the data

Zooplankton Taxonomy

Zooplankton samples were taxonomically identified to the species level and then grouped for analysis in this report. Copepods were the most numerous during every year of the study and averaged between 59% at Kelowna and 83% at Summerland during 2024 (Table 15).

The objective for Okanagan Lake is a minimum of 5% of the sample counts be cladocerans. Most samples at Okanagan Centre met this objective and approximately half of the samples met this objective at Summerland. However, Armstrong Arm and Kelowna had poorer objective attainment during 2024.

The average zooplankton abundances were consistent with values found in the literature (Andrusak et al., 2000; Rae and Andrusak, 2006; Andrusak et al., 2006). There was a decreasing trend in total zooplankton abundance in the Armstrong Arm from 2018-2024 (Table 15).

Table 15: Growing Season average percent cladocerans zooplankton, 2024

Site	Objective	# of samples meeting objective	Trend	Average	Std Dev	Max	Min
Summerland	>5% / sample	4/6	-	11.1%	6.6%	19.0%	2.9%
Kelowna		0/6	-	1.0%	1.0%	2.7%	0.2%
Okanagan Centre		5/6	-	12.2%	9.9%	26.3%	1.8%
Armstrong Arm		1/6	-	3.3%	4.8%	12.9%	0.2%

Notes: Green shading = met sample in most samples, yellow shading = met objective in approximately half of samples, red shading = rarely met objective

3.0 Conclusions

This report summarizes the 2024 findings within the context of the 2011-2024 dataset. This report also extracts trends from the data accumulated by the Okanagan Lake Collaborative Sampling program to date (2011-2024) and compares those to the long-term historical database (1973-2024). The effects of Climate Change are already being felt in the Okanagan in recent years with repeated swings between large freshets and intensely dry summers; 2024 was hotter and much drier than usual and followed after the exceptionally dry 2023, the driest year on record for the Okanagan. While the results to date indicate that all of Okanagan Lake exhibits evidence of human activities, the Armstrong Arm is most impacted by continued human activities and watershed degradation, a situation likely to get worse because of the White Rock Lake wildfire; major flooding occurred on the Whiteman Creek drainage during freshet 2023; fortunately the freshet was very weak in 2024 leading to minimal new watershed erosion. This site had the most exceedances and the most problematic trends, that is, trends moving parameters towards greater exceedances and poorer water quality.

Dissolved Oxygen Each year the temperature of Okanagan Lake increases seasonally in the surface waters until the lake becomes thermally stratified, usually in May. This physical dynamic isolates the deep water from the atmosphere and leads to oxygen depletion below the thermocline in Armstrong Arm. The Armstrong Arm therefore failed to meet the dissolved oxygen objective in 2024, as it has in each year of this study.

Nutrients
Silica analysis of water samples revealed a long period of stable conditions over the past 20 years.

Total nitrogen had been identified as increasing during this study but appears to have stabilized in recent years except for the Armstrong Arm where a declining trend was observed from 2017-2024. Total nitrogen exceeded the water quality objectives at Summerland, Kelowna, and Okanagan Centre during 2024. There was a multi-decade long increasing trend in nitrate in Okanagan Lake deep water samples but concentrations were stable or declining throughout the lake during the past 5 years, likely related to recent years of extreme drought. This is part of a decades long increasing trend in hypolimnetic nitrate in Okanagan Lake that has continued through multiple wet-dry climate cycles and is likely caused by increasing human impacts within the Okanagan region.

Phosphorus concentrations were highest in the Armstrong Arm where they exceeded the objective during 2024. There were increasing trends in TP from 2011-2024 at all four sites driven in part by increases during wet years such as 2017-2018. The Armstrong Arm is more heavily impacted by human activities and has numerous phosphorus sources such as nutrient enrichment of the Deep Creek watershed from over 100 years of agriculture, and the rise may become exacerbated by nutrients shed from the areas burned during the 2021 White Rock Lake fire. Dissolved phosphorus (TDP) and ortho-P represent the more bioavailable forms of phosphorus and were stable or declining at Summerland, Kelowna, Okanagan Centre while TDP increased at the Armstrong Arm. TDP was elevated at Okanagan Centre since the 2021 White Rock Lake and 2023 McDougall Creek wildfires heavily damaged the north basin

watershed. Samples from the Armstrong Arm exceeded the nitrogen-phosphorus ratio objective in 2024, with a decreasing trend in that ratio from 2011-2024 at all sites.

Phytoplankton Productivity Chlorophyll-a (chl-a) concentrations increased each spring during the annual spring high algal growth period and then decreased over the summer and into the fall. Peak chl-a was moderate at all sites during 2024. Previous research by ENV has identified a one-year lag between major nutrient inputs and increases in phytoplankton productivity so it was expected that 2024 productivity would be higher after the large 2022 freshet. As expected, the phytoplankton biovolume was high and did not meet the objective at any site during 2024.

The taxonomic data indicated that cyanobacteria numerically dominated the phytoplankton samples in 2024, as in every year studied. Samples from all sites exceeded the <5% heterocystous cyanobacteria objective during 2024 with Armstrong Arm particularly affected by these cyanobacteria.

Table 16 to Table 18 summarize the findings of this report for 2011-2024 by pairing trends to objective exceedances. Special focus should be paid to parameters that did not meet the objective and for which the data trended in the adverse direction over the course of the sampling program.

The following areas of concern have been identified that may require further investigation on the part of the Ministry:

- Chronically low Secchi depth in the Armstrong Arm
- Increasing nitrate in hypolimnion of Okanagan Lake since 1970s (although stable or declining during past 5 years)
- Increasing total phosphorus at all sites since early 2000s
- Decreasing N:P ratio in the Armstrong Arm
- High densities of potentially toxic cyanobacteria in Armstrong Arm during 2018-2024
- Phosphorus loading to the Armstrong Arm and north basin of Okanagan Lake from the White Rock Lake wildfire (2021) and the McDougall Creek wildfire (2023).
- Low zooplankton biomass

Positive developments:

- Stable or decreasing nitrogen in Okanagan Lake during past 5 years
- Declining chlorophyll-a concentrations

Armstrong Arm frequently exceeds most objectives and is the site most at risk of water quality degradation including harmful algae blooms, poor drinking water quality, anoxic conditions, and further eutrophication. There is also high likelihood of further degradation because of the White Rock Lake wildfire. It must be acknowledged that Armstrong Arm is shallower and therefore would be more productive than the deep basins of Okanagan Lake regardless of human activity. However, human activities in the watershed have significantly impacted this northern-most basin of the lake.

The period of 2016-2024 was marked by multiple extreme weather events that have left a distinct mark on the water quality record of Okanagan Lake. Climate Change and is expected to increase the frequency and intensity of extreme weather events in the future. Climate Change also compounds the loss of resilience in Okanagan watersheds leading to greater water quality changes from those extreme weather events.

Table 16: Okanagan Lake Water Quality Objectives

Objectives (Nordin, 2005)	**Summerland**	**Kelowna**	**Ok Centre**	**Armstrong Arm**
Secchi Depth (growing season average)	7m	6m	6m	5m
Dissolved Oxygen (minimum in bottom waters)	-	-	-	>5 mg/L
TP (mg/L as P) (maximum at spring overturn)	0.007	0.008	0.008	0.01
Chlorophyll-a (µg/L) (maximum seasonal average)	<4.5	<4.5	<4	<5
TN (mg/L as N) (maximum at spring overturn)	0.230	0.230	0.230	0.250
N:P Ratio (spring weighted ratio)	>25:1	>25:1	>25:1	>25:1
Algae Taxonomy (% heterocystous cyanobacteria)	<5%	<5%	<5%	<5%
Algae Biomass (µL/L) (growing season average)	<0.75	<0.75	<0.75	<0.75
Zooplankton Biomass (µg/L) (growing season average)	>50	>50	>50	>50
Zooplankton Taxonomy (% cladocerans)	>5%	>5%	>5%	>5%

Table 17: Attainment of Okanagan Lake water quality objectives compared to growing season averages during 2024

Objective	Summerland	Kelowna	Ok Centre	Armstrong Arm
Secchi Depth	7.6	7.3	7.4	4.4
Dissolved Oxygen	8.50	8.60	8.70	1.10
TP (mg/L) 0:10m:	0.005	0.006	0.008	0.0
20-45m:	0.005	0.005	0.006	0.0
Chlorophyll-a (µg/L)	1.2	1.5	1.8	1.4
TN (mg/L) 0-10m:	0.218	0.223	0.205	0.216
20-45m:	0.243	0.239	0.222	0.288
N:P Ratio 0-10m:	56:1	46:1	38:1	16:1
20-45m:	48:1	45:1	39:1	18:1
Algae Taxonomy (% heterocystous cyanobacteria)	4.0%	6.4%	5.2%	25.6%
Algae Biovolume (µL/L)	0.846	1.106	1.149	1.576
Zooplankton Biomass (µg/L)	8.3	11.2	9.3	12.5
Zooplankton Taxonomy (% cladocerans)	11.1%	1.0%	12.2%	3.3%

Legend:

Achieved objective	Achieve objective in some but not all samples	Did not achieve objective

Table 18: Summary of trends (2011-2024) and the water quality objectives for Okanagan Lake collaborative sampling program during 2024

Objective	Summerland	Kelowna	Ok Centre	Armstrong Arm
Secchi Depth	-	-	-	-
Dissolved Oxygen	-	-	-	-
TP (mg/L) 0:10m:	↑	↑	↑	↑
Chlorophyll-a (µg/L)	↓	↓	↓	↓
TN (mg/L) 0-10m:	-	-	-	↓
N:P Ratio 0-10m:	↓	↓	↓	↓
Algae Taxonomy (% heterocystous cyanobacteria)	↑	↑	-	-
Algae Biovolume (µL/L)	↑	↑	↑	-
Zooplankton Biomass (µg/L)	-	-	↓	↓
Zooplankton Taxonomy (% cladocerans)	-	-	-	-

Legend:

Achieved objective	Achieve objective in some but not all samples	Did not achieve objective

↑ = Increasing Trend ↓ = Decreasing Trend - = No Trend

4.0 Recommendations

The following recommendations are made for the program moving forward:

- Continue the monitoring program, unchanged in 2025

5.0 References

Andrusak, H., Matthews, S., Wilson, A., Andrusak, G., Webster, J., Sebastian, D., Scholten, G., Woodruff, P., Rae, R., Vidmanic, L., Stockner, J., & Branch, E. (2006). *Okanagan Lake Action Plan Year 10 (2005) Report - Introduction* (Vol. 10, Issue 2005).

Andrusak, H., Sebastian, D., Mcgregor, I., Matthews, S., Smith, D., Ashley, K., Pollard, S., Scholten, G., Stockner, J., Ward, P., Kirk, R., Lasenby, D., Webster, J., Whall, J., Wilson, G., & Yassien, H. (2000). *Okanagan Lake Action Plan Year 4 (1999) Report*. *4*(1999).

Bergman, B., Gallon, J. R., Rai, A. N., & Stal, L. J. (1997). N2 fixation by non-heterocystous cyanobacteria. In *FEMS Microbiology Reviews* (Vol. 19, Issue 3, pp. 139–185). https://doi.org/10.1016/S0168-6445(96)00028-9

Clemens, W. A., Rawson, D. S., & McHugh, J. L. (1939). *Biological Survey of Okanagan Lake B.C.* http://a100.gov.bc.ca/appsdata/acat/documents/r1954/oklkstudy_1362690263031_964b8eb84253194546e8eed7b6cea9606f70d159938f36e216459469b9d7bcce.pdf

Felip, M., & Catalan, J. (2000). The relationship between phytoplankton biovolume and chlorophyll in a deep oligotrophic lake: decoupling in their spatial and temporal maxima. *Journal of Plankton Research*, *22*(1), 91–106. https://doi.org/10.1093/plankt/22.1.91

Larratt, H. (2009). *Deep Okanagan Lake Biology Report*.

Mas-Pla, J., & Menció, A. (2019). Groundwater nitrate pollution and climate change: learnings from a water balance-based analysis of several aquifers in a western Mediterranean region (Catalonia). *Environmental Science and Pollution Research*, *26*(3), 2184–2202. https://doi.org/10.1007/s11356-018-1859-8

Nordin, R. (1985). *Water Quality Criteria for Nutrients and Algae. Overview Report.*

Nordin, R. N. (2005). *Water Quality Objectives for Okanagan Lake* (Issue January).

Okanagan Basin Water Board. (2021). *Okanagan Drought Bulletin – August 14, 2021 – Okanagan Basin Water Board*. https://www.obwb.ca/okanagan-drought-bulletin-august-13-2021/

Rae, R., & Andrusak, H. (2006). *Ten- Ten - Year summary of the Okanagan Lake Action Plan* (Issue January).

Schelske, C. L. (1988). Historic Trends in Lake Michigan Silica Concentrations. *Internationale Revue Der Gesamten Hydrobiologie Und Hydrographie*, *73*(5), 559–591. https://doi.org/10.1002/iroh.19880730506

Sokal, M. (2013). *Okanagan Lake Collaborative Monitoring Agreement 2013 Summary Report*.

Stuart, M. E., Gooddy, D. C., Bloomfield, J. P., & Williams, A. T. (2011). A review of the impact of climate change on future nitrate concentrations in groundwater of the UK. *Science of the Total Environment*, *409*(15), 2859–2873. https://doi.org/10.1016/j.scitotenv.2011.04.016

The Weather Network - B.C. sets new Canadian record for hottest temperature ever recorded. (n.d.). Retrieved March 9, 2022, from https://www.theweathernetwork.com/ca/news/article/canadas-hottest-june-temperature-recorded-amid-western-canada-heat

Water Office. (2017). *Real-Time Hydrometric Data Graph for Okanagan Lake At Kelowna (08nm083) [Bc]*. https://wateroffice.ec.gc.ca/report/real_time_e.html?mode=Graph&type=&stn=08NM083&startDate=2016-06-21&endDate=2017-12-21&prm1=46&y1Max=&y1Min=&prm2=-1&y2Max=&y2Min=

Wehr, J. (2002). *Freshwater algae of North America: ecology and classification*. http://books.google.ca/books?hl=en&lr=&id=IikPwCt1ioEC&oi=fnd&pg=PP2&dq=Freshwater+Algae+of+North+America:+Ecology+and+Classification+&ots=hL32vxVcVg&sig=wMq94pq1DoQb6FBYBpZWg8_QayU

6.0 Appendices

6.1 Appendix 1: 2011-2024 Sampling Data

All data used in this report can be found in the data transfer file
MoE-Synth-DB.xlsx

6.2 Appendix 2: Statistics and Graphing Overview

Statistical analyses were performed on data to support interpretations made throughout this report. The use of the word 'significantly' within this report is understood to signify that the claim being made has stood up under statistical analysis. Unless otherwise stated, all statistical analyses were performed to a confidence of greater than or equal to 95% ($p \leq 0.05$). The ± symbol indicates plus or minus the standard deviation throughout this report.

Trends were determined through Mann-Kendall linear regression. Mann-Kendall is a non-parametric test for linearity in data. The test produces a Tau-value and a p-value. The Tau value gives the direction of the data and the p-value indicates whether the trend is statistically significant.

Throughout this report the monthly sampling data was grouped seasonally for additional analyses. March, April, and May data were combined as "Spring"; June, July, and August as "Summer"; and September as "Fall".

Correlations were performed using the Pearson's Correlation method and all R values reported at Pearson's Correlation Coefficients.

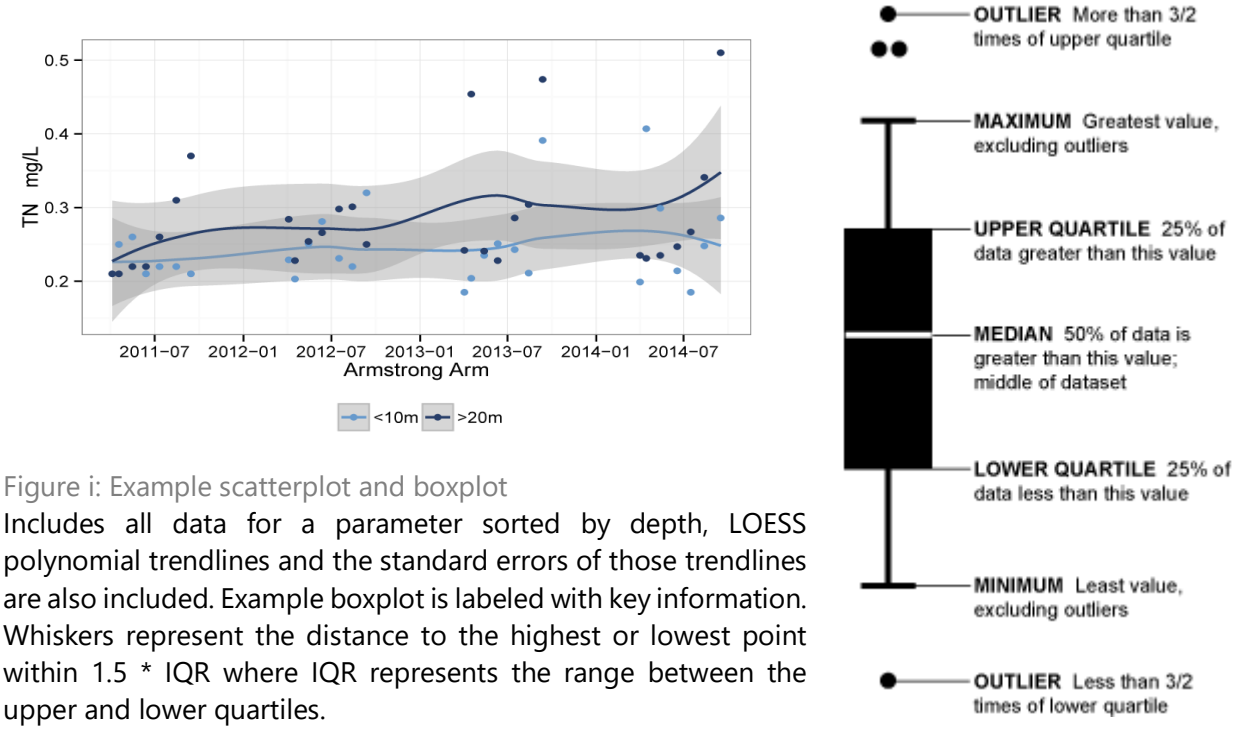
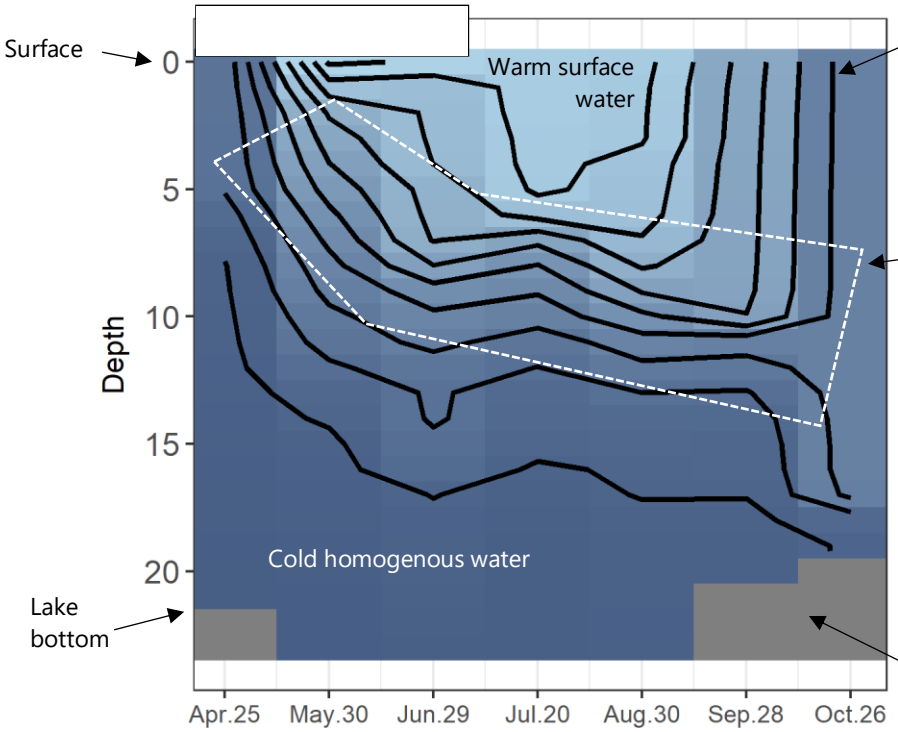


Figure i: Example scatterplot and boxplot

Includes all data for a parameter sorted by depth, LOESS polynomial trendlines and the standard errors of those trendlines are also included. Example boxplot is labeled with key information. Whiskers represent the distance to the highest or lowest point within 1.5 * IQR where IQR represents the range between the upper and lower quartiles.

How to Read Temperature/DO Profile Plot

Temperature and dissolved oxygen profiles were routinely collected as part of this study. They are displayed in several locations throughout this report. An example of a temperature graph and a dissolved oxygen graph, descriptions of their key features and how to read them are presented here.



Isoclines = areas of equivalent temperature. That is, the space between two lines is approximately the same temperature. Large spaces between lines indicate homogenous water column while many lines close together indicates stratified conditions

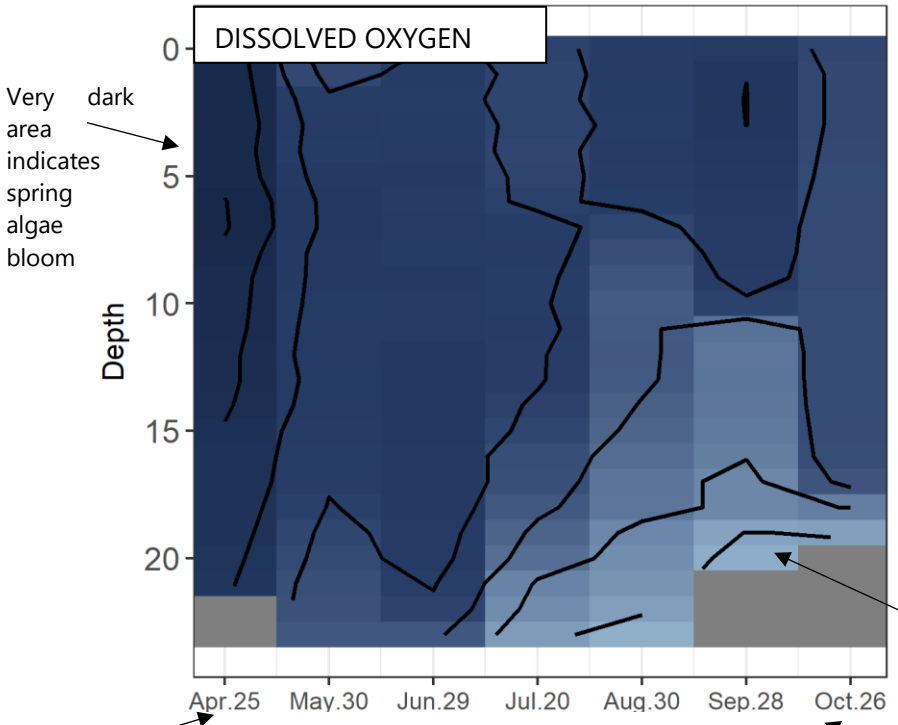
°C

20
15
10
5

Tight concentration of lines = rapid change in temperature over short depth (i.e. thermocline)

Scale: Lighter shading = warmer water

Gray area indicates lake bottom. This appears on the plot when profiles were taken at sites with different depths on different dates. For example, on Jul 20, the profile was at a site 24 m deep but on Oct 26, the profile was done only at a site 19 m deep. This can occur when weather conditions move the sampling boat into a slightly different location on the lake.



mg/L

13
10
7
4
1

Scale: Lighter shading = Low DO (anoxic conditions)
Darker shading = High DO (algae blooms)

Light area indicates oxygen depletion along sediments

Each vertical column in graph represents conditions within a column of the lake on given date. For example, on Apr 25, DO was very high through entire water column but on Sept 28, there was significant oxygen depletion in the deep water

----------End of Report----------