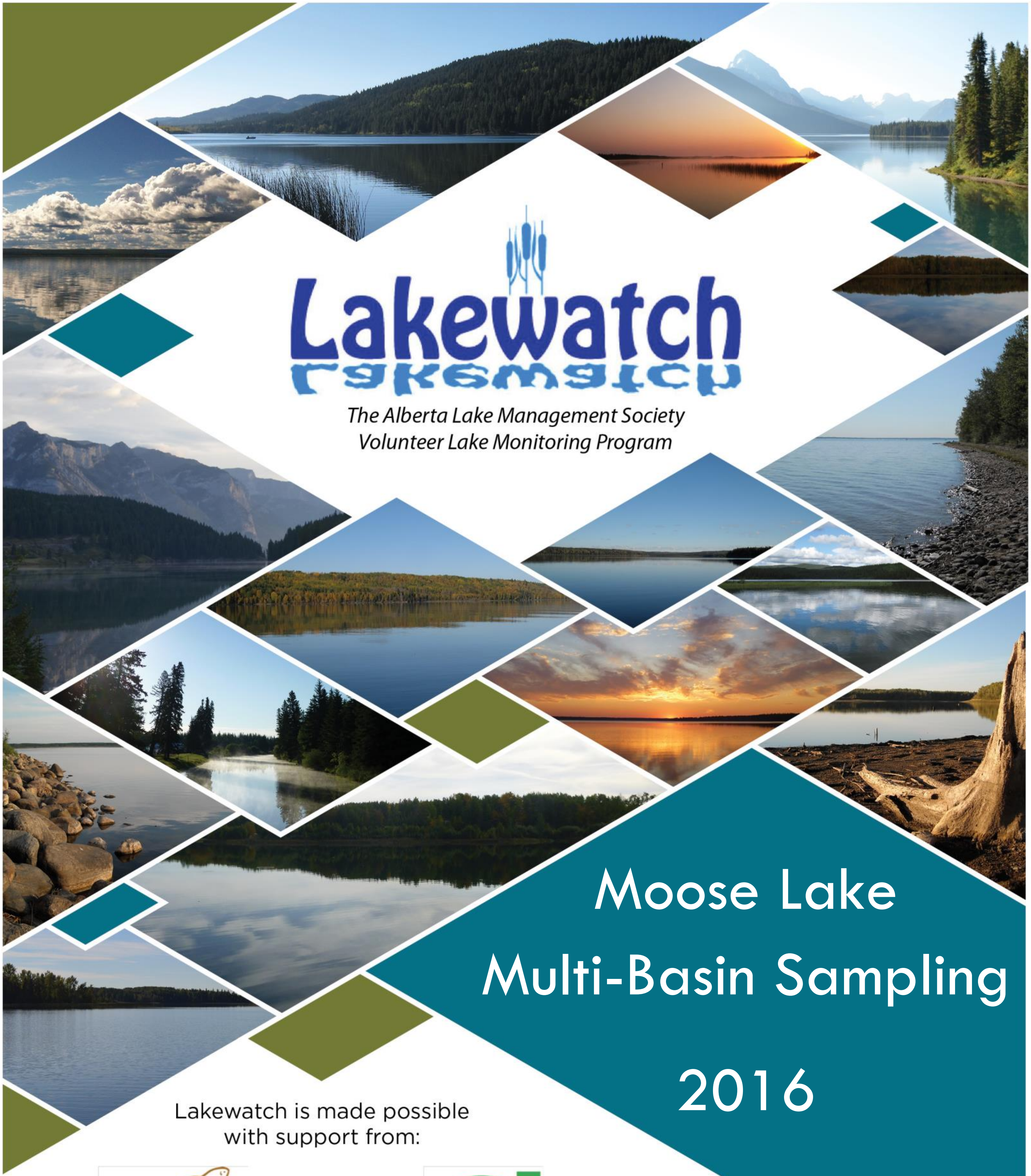

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Moose Lake
Multi-Basin Sampling
2016

Lakewatch is made possible
with support from:

Beaver River Watershed Alliance

Cargill

LICA
Lakeland Industry & Community Association

Alberta

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Environnement Canada | Environment Canada

Moose Lake Watershed Society

ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch and readers requiring more information are encouraged to seek those sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the LakeWatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

This report has been prepared with un-validated data.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. We would like to extend a special thanks to Grant Ferbey for the time and energy put into sampling Moose Lake in 2016. We would also like to thank Kellie Nichiporik of the Moose Lake Watershed Stewardship Society for assistance in the field and for funding the project. We would also like to thank Alicia Kennedy, Ageleky Bouzetos, and Breda Muldoon who were summer technicians in 2016. Executive Director Bradley Peter was instrumental in planning and organizing the field program. Alicia Kennedy was instrumental in report design. This report was prepared by Bradley Peter, Laura Redmond, and Alicia Kennedy. The Beaver River Watershed, the Lakeland Industry and Community Association, Environment Canada, and Alberta Environment and Parks are major sponsors of the LakeWatch program.

EXECUTIVE SUMMARY

In 2016, the Alberta Lake Management Society, with support from the Moose Lake Watershed Stewardship Society and local volunteers, monitored Moose Lake as four individual basins as well as a whole lake composite.

Average total phosphorus (TP) and total dissolved phosphorus (TDP) concentrations were highest in Franchere Bay and lowest in Vezeau Bay. Similarly, chlorophyll-*a* concentrations, and, as a result, Secchi disk depth, were highest in Franchere Bay and lowest in Vezeau Bay.

Microcystin concentrations were low throughout much of the summer with the exception of July 27th when microcystin values exceeded the recreational guidelines in Franchere Bay.

Thermal stratification was observed in each of the basins at least once throughout the summer. Vezeau Bay was the most strongly stratified basin and showed no sign of mixing throughout the summer. Oxygen concentrations responded strongly to stratification, often proceeding toward anoxia in the hypolimnion. Top and bottom grabs of total phosphorus during stratification events revealed large differences above and below the thermocline. Concentrations of TP and TDP were, in some cases, two orders of magnitude higher in the hypolimnion than the epilimnion.

The multi-basin sampling has been useful in identifying the heterogeneity that exists across Moose Lake, and helps to explain the patterns seen when the lake is sampled as a whole.

INTRODUCTION

Moose Lake is a large lake located 240 km northeast of Edmonton and 3.5 km west of the town of Bonnyville. Moose Lake has over 64 km of irregular shoreline and a 40 km^2 surface area.

Because of Moose Lake's irregular shoreline, the lake can be divided into a number of basins: Franchere Bay in the West, Main Basin in the Southeast, Pelican Narrows in the North, and Vezeau Bay in the Northeast (Page 2). While sampling of Moose Lake has occurred for many years, this sampling composited samples from across the lake into a 'Whole Lake' sample, with the lake's profile sampling (temperature and dissolved oxygen) occurring in the Main Basin (Page 2).

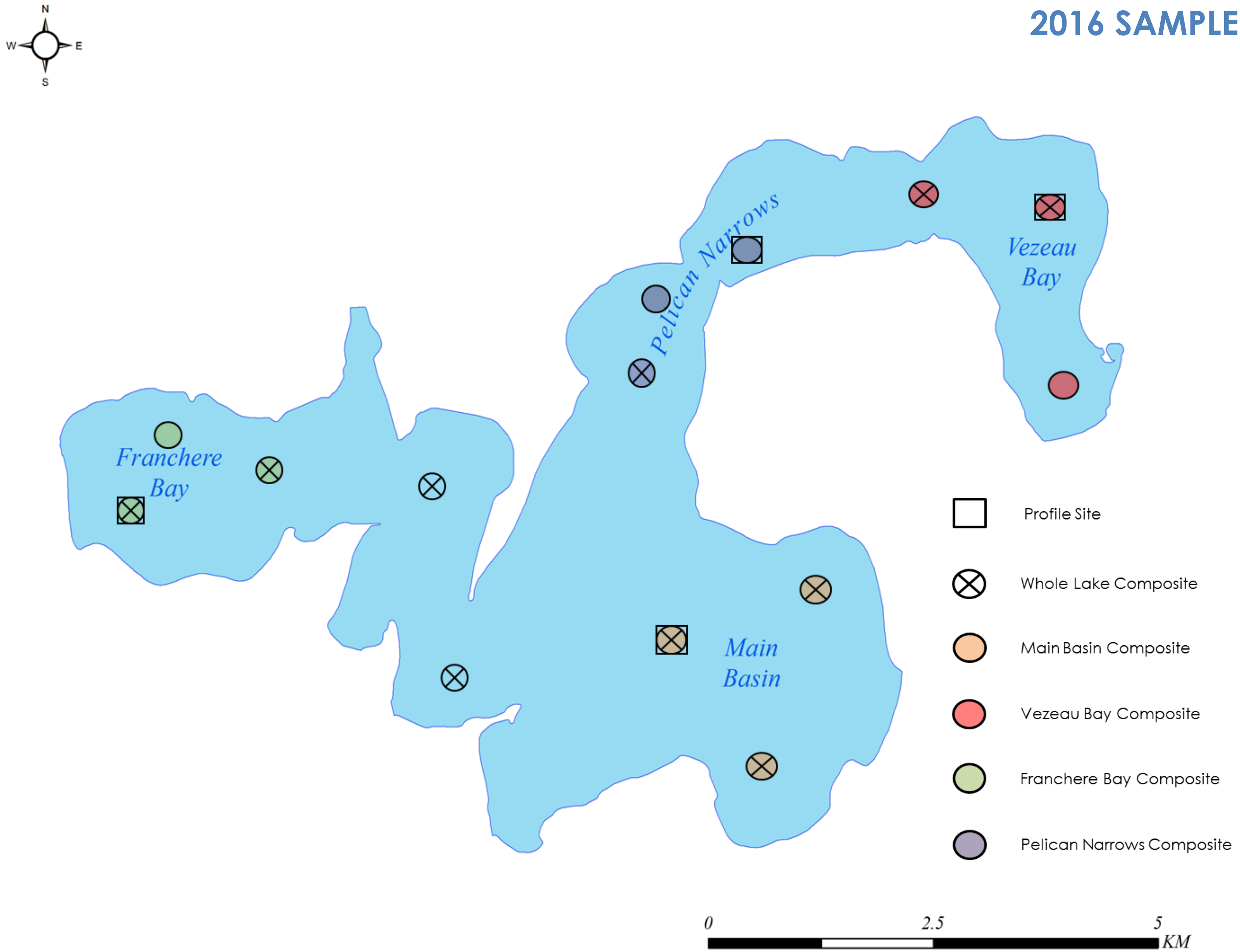
In 2016, the Alberta Lake Management Society (ALMS), with the support of the Moose Lake Watershed Stewardship Society (MLWSS) and local volunteers, conducted sampling to identify variations among Moose Lake's major basins. Sampling was conducted on June 16th, July 27th, and September 21st. Composite samples for water chemistry were collected from each basin, and a single Profile Site was selected in each basin for the collection of Secchi disk depth, temperature, dissolved oxygen, and discrete nutrient grabs.

This report will compare and contrast the variability among Moose Lake's major basins with regards to key parameters including phosphorus, chlorophyll-*a*, microcystin, Secchi disk depth, temperature, and dissolved oxygen.

For a complete description of the Moose Lake's whole lake sampling and for historical reports, visit www.alms.ca.

Moose Lake September 21 - Photo by Alicia Kennedy.

2016 SAMPLE SITES



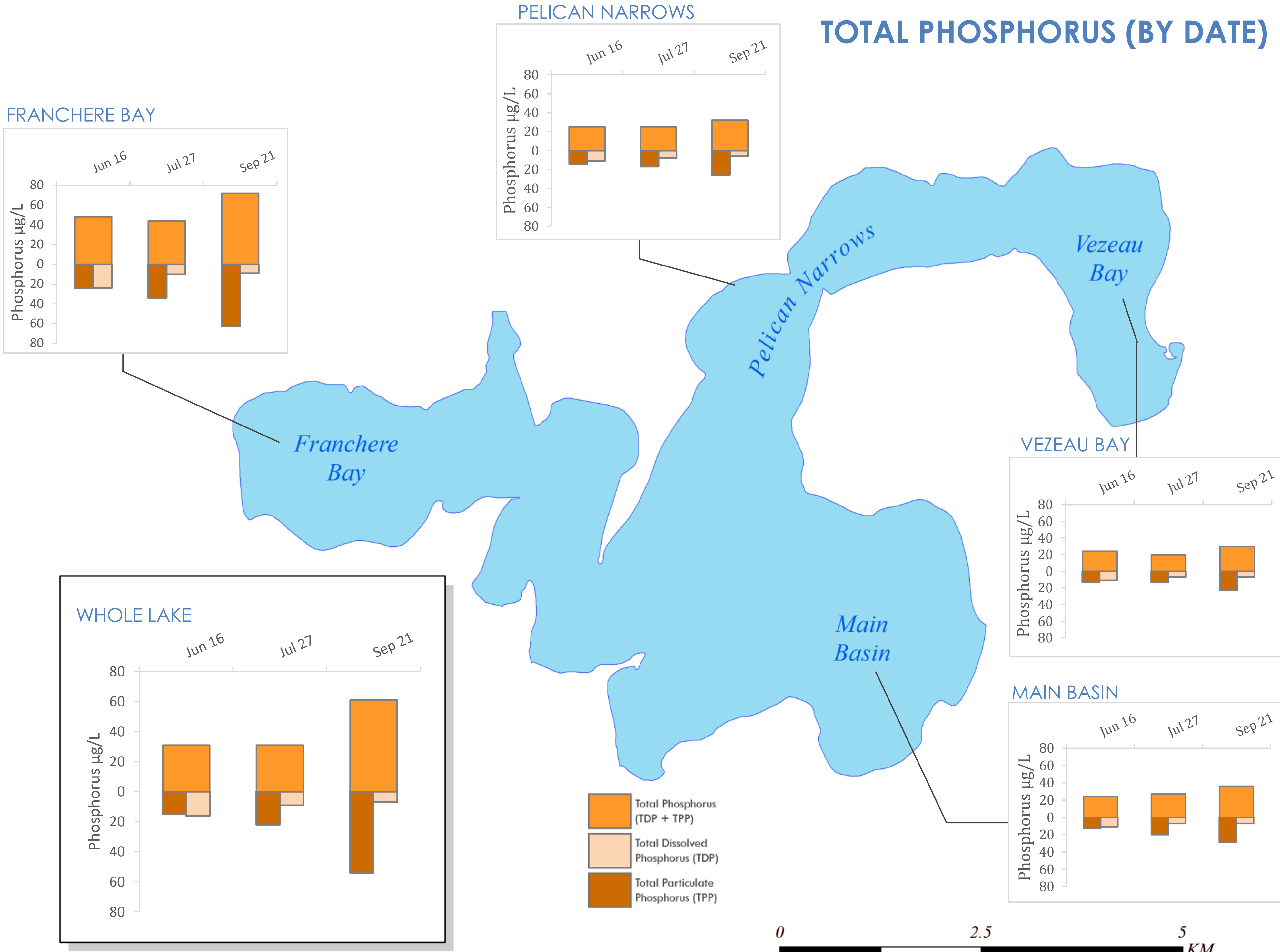
TOTAL PHOSPHORUS AND CHLOROPHYLL-A

ALMS measures a suite of water chemistry parameters. Phosphorus acts as one of the nutrients driving algae blooms in Alberta, while chlorophyll-a acts as an indicator of phytoplankton biomass, or how much algae is in the lake. These parameters together can help to identify the process of eutrophication, or excess nutrients, which can lead to harmful algae/cyanobacteria blooms. Taking these parameters together, lakes can be classified into oligotrophic (low nutrients), mesotrophic (moderately productive), eutrophic (productive) or hypereutrophic (highly productive).

Total phosphorus (TP) and total dissolved phosphorus (TDP) were measured in two different ways at Moose Lake. First, phosphorus was collected as part of the individual basin and whole lake composite sampling – this technique provides an estimate of the average phosphorus concentrations for their respective areas. Average phosphorus was highest in Franchere Bay, measuring 55 μg/L, and lowest in Vezeau Bay, measuring 25 μg/L (Page 5). The whole lake sampling produced an average phosphorus concentration of 41 μg/L, which falls well within the range seen across each individual basin. Moreover, the whole-lake concentration of 41 μg/L falls into the eutrophic classification – similar to Franchere Bay. The other basins (Pelican Narrows, Main Basin, and Vezeau Bay) fall toward the high end of the mesotrophic classification. In general, phosphorus concentrations increased throughout the summer – this is due to an accumulation of both external and internal sources of nutrients (Page 4).

Secondly, TP and TDP were collected as discrete grabs at 1.0 m below the surface and 1.0 m above the sediment at the profile sites of stratified basins. These phosphorus concentrations highlight a contrast between surface and bottom water nutrient concentrations which can become exaggerated under stratified conditions. In each instance, bottom water TP and TDP concentrations greatly exceeded the concentrations found in the overlying surface waters (Table 1). This suggests that internal processes such as phosphorus loading from the sediments and decomposition play an important role in Moose Lake's nutrient dynamics.

Similar to TP, average chlorophyll-*a* concentration was highest in Franchere Bay, measuring 52 μg/L, and lowest in Vezeau Bay, measuring 15 μg/L (Page 8). Average chlorophyll-*a* concentration determined from the whole lake sampling measured 27 μg/L, which falls into the hypereutrophic classification and lies well within the range seen across each individual basin. As is typical of many Alberta Lake, chlorophyll-*a* concentrations generally increased throughout the course of the summer (Page 7).



TOTAL PHOSPHORUS (BY DATE)
FRANCHERE BAY
PELICAN NARROWS
VEZEAU BAY
MAIN BASIN
WHOLE LAKE
Jun 16
Jul 27
Sep 21
Phosphorus µg/L
80
60
40
20
0
20
40
60
80
Franchere Bay
Pelican Narrows
Vezeau Bay
Main Basin
Total Phosphorus (TDP + TPP)
Total Dissolved Phosphorus (TDP)
Total Particulate Phosphorus (TPP)
0
2.5
5
KM

TOTAL PHOSPHORUS (AVERAGE)

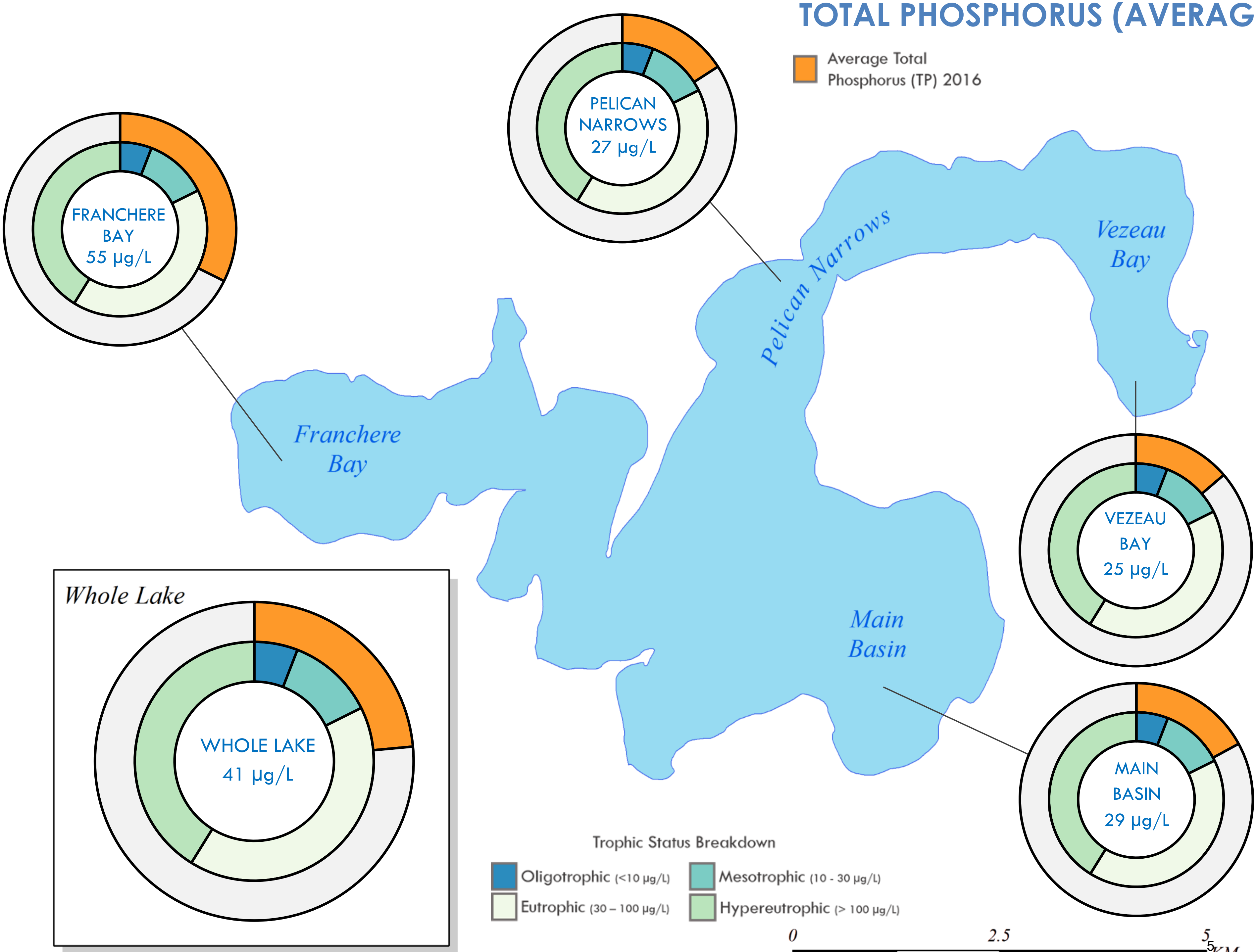
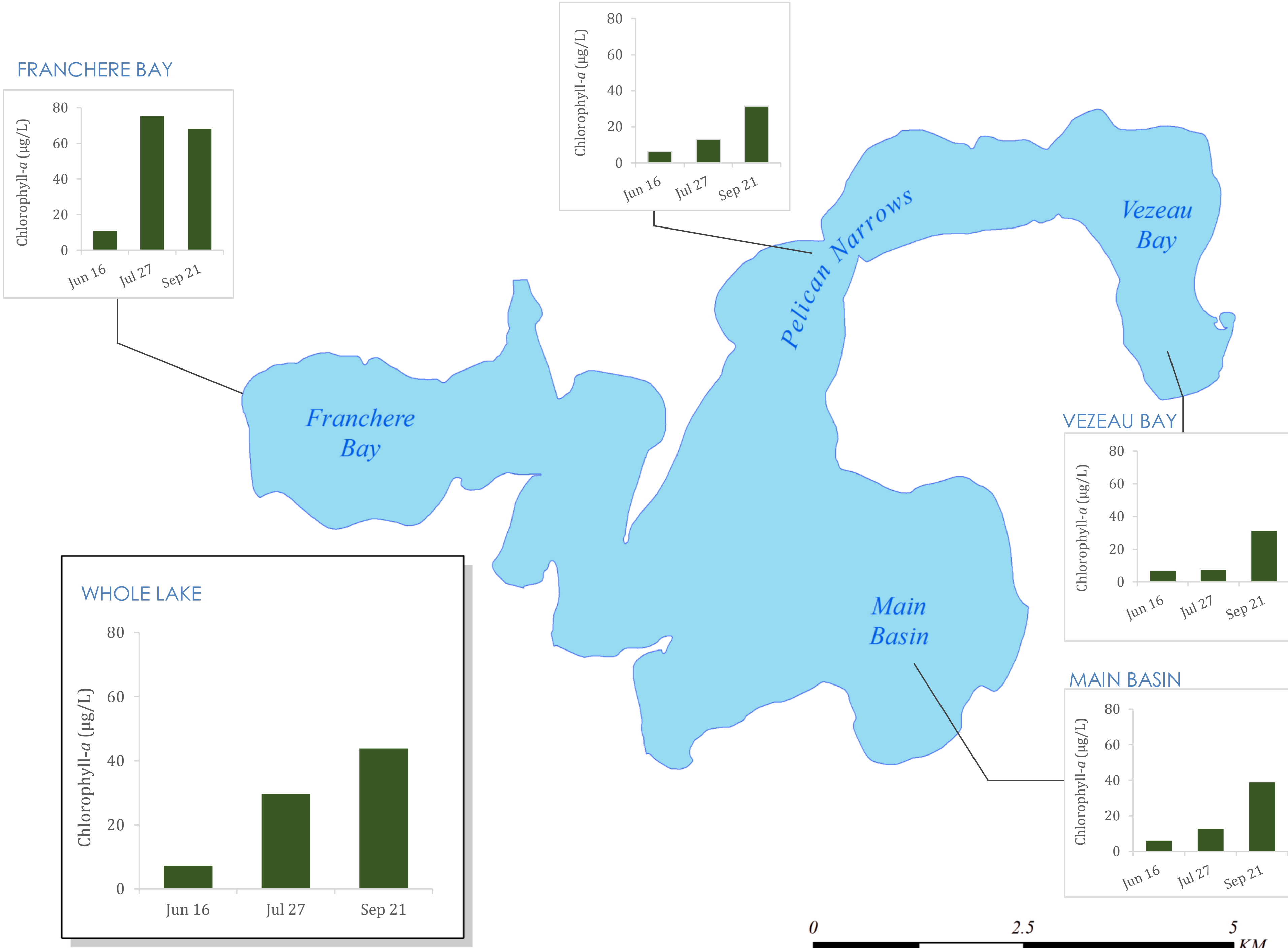


Table 1: Discrete grab samples from the top and bottom of the water profile collected from each of the four basins during the summer of 2016

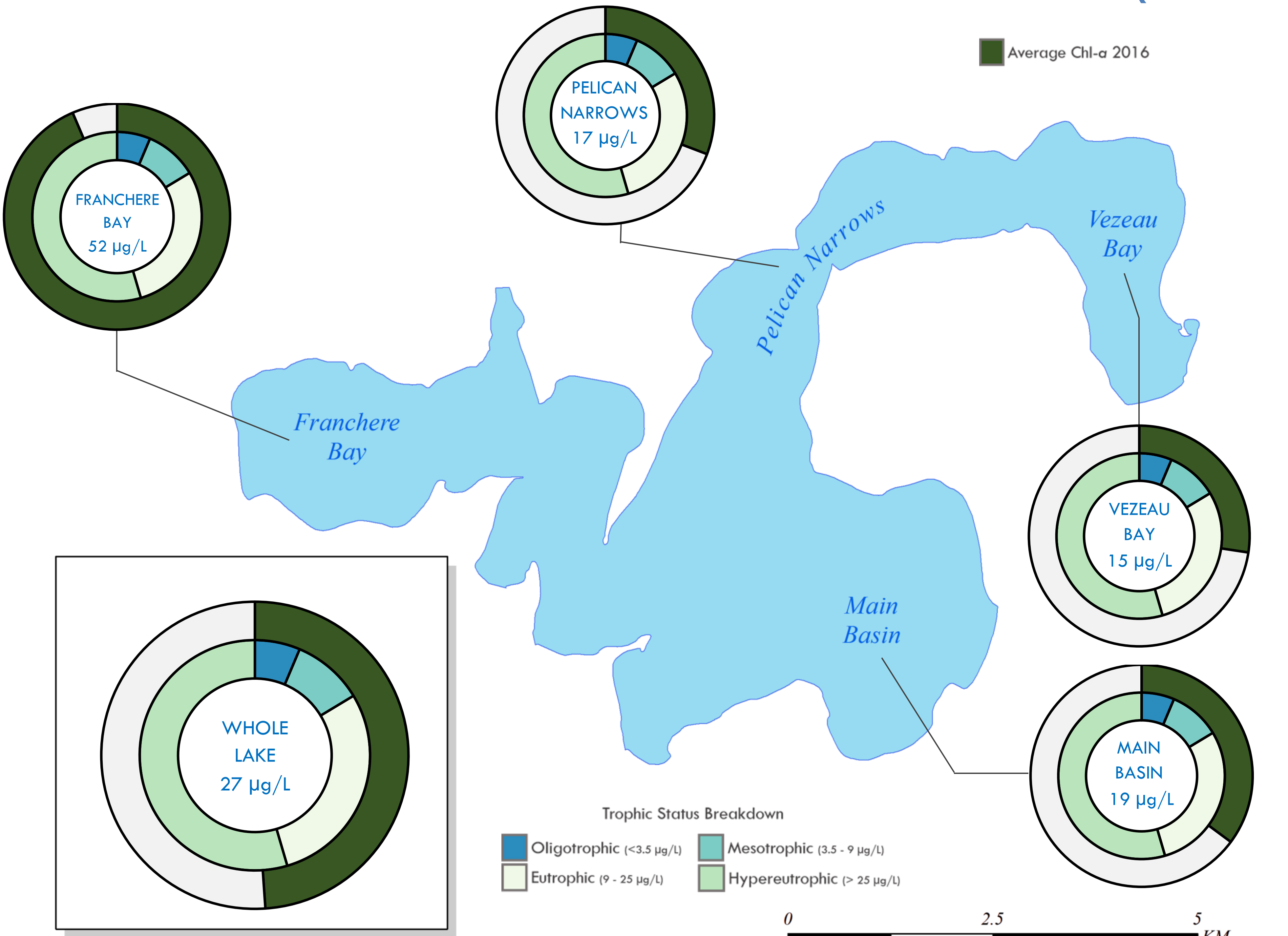
Basin	Date	Stratified (Y/N)	Top TP (µg/L)	Bottom TP (µg/L)	Top TDP (µg/L)	Bottom TDP (µg/L)
Main Basin	16-Jun	N	-	-	-	-
	27-Jul	Y	25	160	7	130
	21-Sep	N	-	-	-	-
Franchere Bay	16-Jun	Y	46	140	25	100
	27-Jul	Y	54	250	8	220
	21-Sep	N	-	-	-	-
Pelican Narrows	16-Jun	N	-	-	-	-
	27-Jul	Y	20	350	6	280
	21-Sep	N	-	-	-	-
Vezeau Bay	16-Jun	Y	28	120	17	86
	27-Jul	Y	15	250	7	210
	21-Sep	Y	28	370	5	330

TP: Total Phosphorus
TDP: Total Dissolved Phosphorus

CHLOROPHYLL-A (BY DATE)



CHLOROPHYLL - *A* (AVERAGE)



WATER CLARITY AND SECCHI DEPTH

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth. Two times the Secchi disk depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

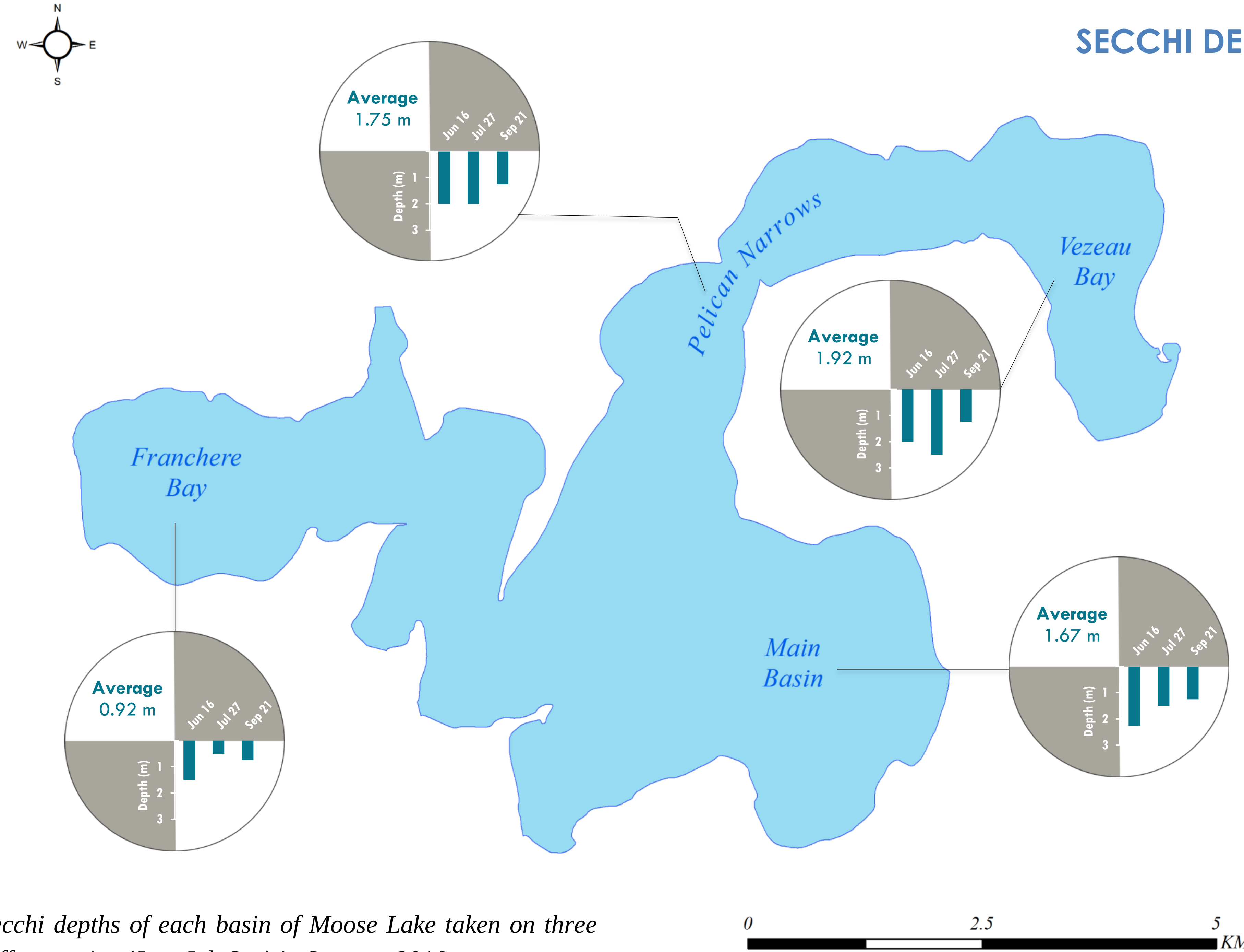
Secchi disk depth was measured three times over the course of the summer at the profile site within each basin of Moose Lake (Page 10). The lowest observed Secchi disk depth measurement occurred in Franchere Bay on July 27th, measuring 0.50 m, while the highest observed Secchi disk depth measurement occurred in Vezeau Bay, also on July 27th, measuring 2.50 m.

Average water clarity values behaved similarly: when looking at average Secchi disk depth measurements from across the summer of 2016, the basin with the lowest average water clarity was Franchere Bay, measuring 0.92 m, while the basin with the highest average water clarity was Vezeau Bay, measuring 1.92 m.

Secchi disk depth values generally decreased throughout the summer as chlorophyll-*a* concentrations increased, suggesting phytoplankton is the primary factor impeding water clarity in Moose Lake. Other factors which may contribute to differences in water clarity include dissolved organic compounds (which make the water brown) or suspended sediments, particularly in shallow areas.

Technician Alicia Kennedy and volunteer Grant Ferbey sampling Moose Lake in 2016.

SECCHI DEPTH



Secchi depths of each basin of Moose Lake taken on three different trips (Jun, Jul, Sep) in Summer 2016

MICROCYSTIN

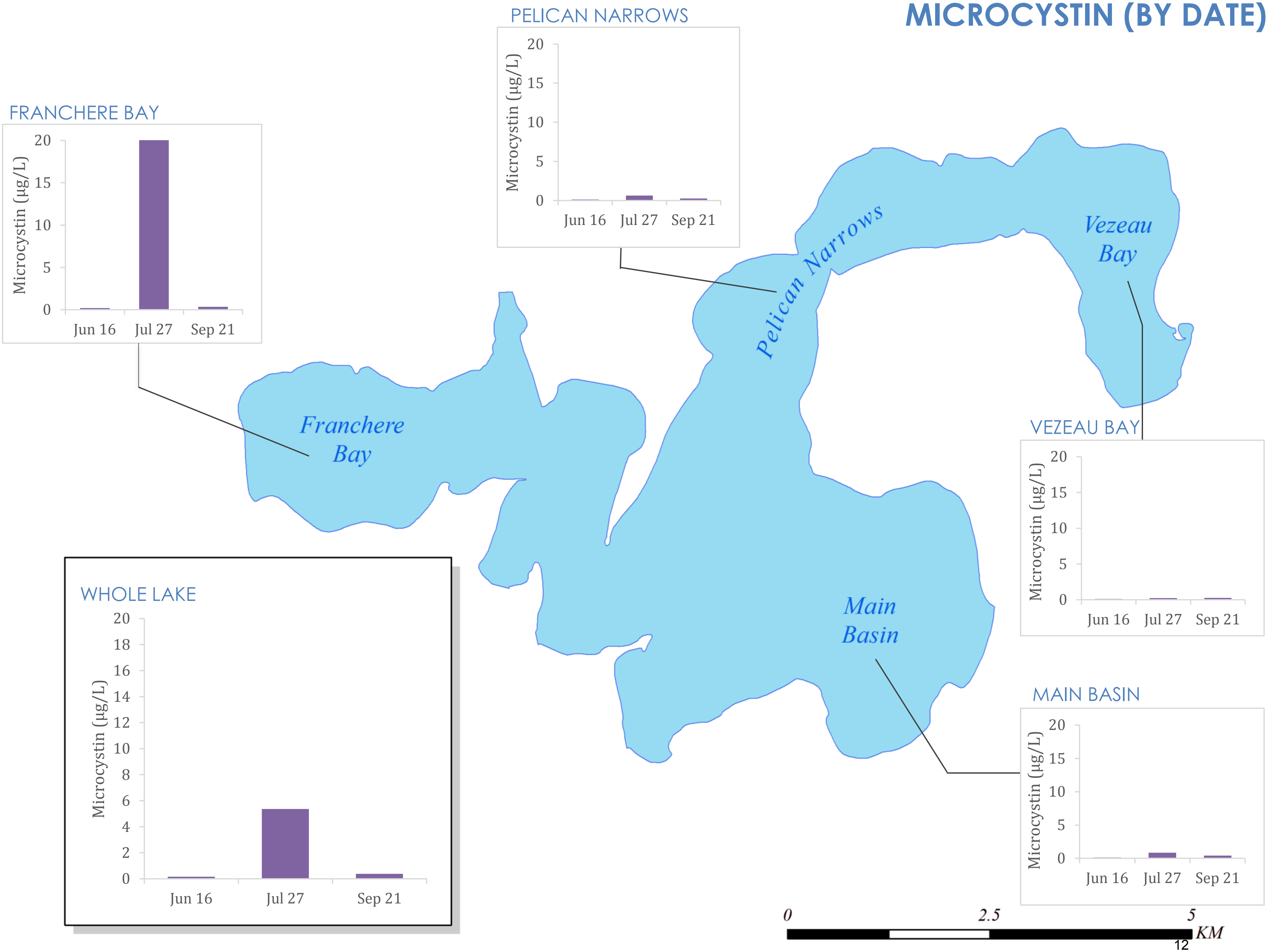
Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 μg/L.

Microcystin concentrations were low (<1 μg/L), on each sampling event in Vezeau Bay, Main Basin, and Pelican Narrows (Page 12). In contrast, a large spike in microcystin concentration was observed on July 27th in Franchere Bay, measuring 20.74. A microcystin value of this concentration exceeds the recreational guidelines of 20 μg/L. This microcystin spike also coincided with the season's highest chlorophyll-*a* concentration measured in Franchere Bay, suggesting there was a large cyanobacteria bloom event. This spike in microcystin observed in Franchere Bay on July 27th was captured in the whole-lake sampling, as the whole-lake microcystin concentration on July 27th measured 5.37 μg/L .

It is recommended that individuals avoid recreating in cyanobacteria blooms. Even if microcystin concentrations are low, cyanobacteria may still produce other toxins and cause skin irritation which can be a health concern.

Double-crested cormorants taking off at Moose Lake. Photo by Breda Muldoon.

MICROCYSTIN (BY DATE)



TEMPERATURE AND DISSOLVED OXYGEN PROFILES

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Temperature profiles revealed thermal stratification events in each of the basins of Moose Lake. These stratification events have important implications for dissolved oxygen concentrations.

In the Main Basin, stratification was observed only on July 27th (Figure 1). As this is the largest basin of Moose Lake, wind energy is more likely to mix the water column, preventing strong stratification throughout the summer. As a result, in the absence of stratification, the water column was well oxygenated in the main basin on June 16th and September 21st. On July 27th, however, oxygen proceeded toward anoxia around 9.0 m. (Figure 1)

In Franchere Bay, thermal stratification was observed on June 16th and July 27th (Figure 2). During stratification, dissolved oxygen concentrations proceeded toward anoxia around 9.0 m.

Similarly, Pelican Narrows experienced thermal stratification on June 16th and July 27th (Figure 3). As a result, anoxic dissolved oxygen concentrations were observed around 11.0 m on June 16th and 8.0 m on July 27th.

Finally, as the deepest basin of Moose Lake, Vezeau Bay demonstrated strong thermal stratification on each of the three sampling trips (Figure 4). This stratification resulted in anoxic conditions as early as 9.0 m on July 27th.

While each basin showed oxygen concentrations which proceeded toward anoxia below the thermocline, the water column above the thermocline in each of the basins remained well oxygenated. Surface water temperatures were high in mid-summer, with a maximum observed temperature of 23.7 °C occurring at the surface of Franchere Bay on July 27th.

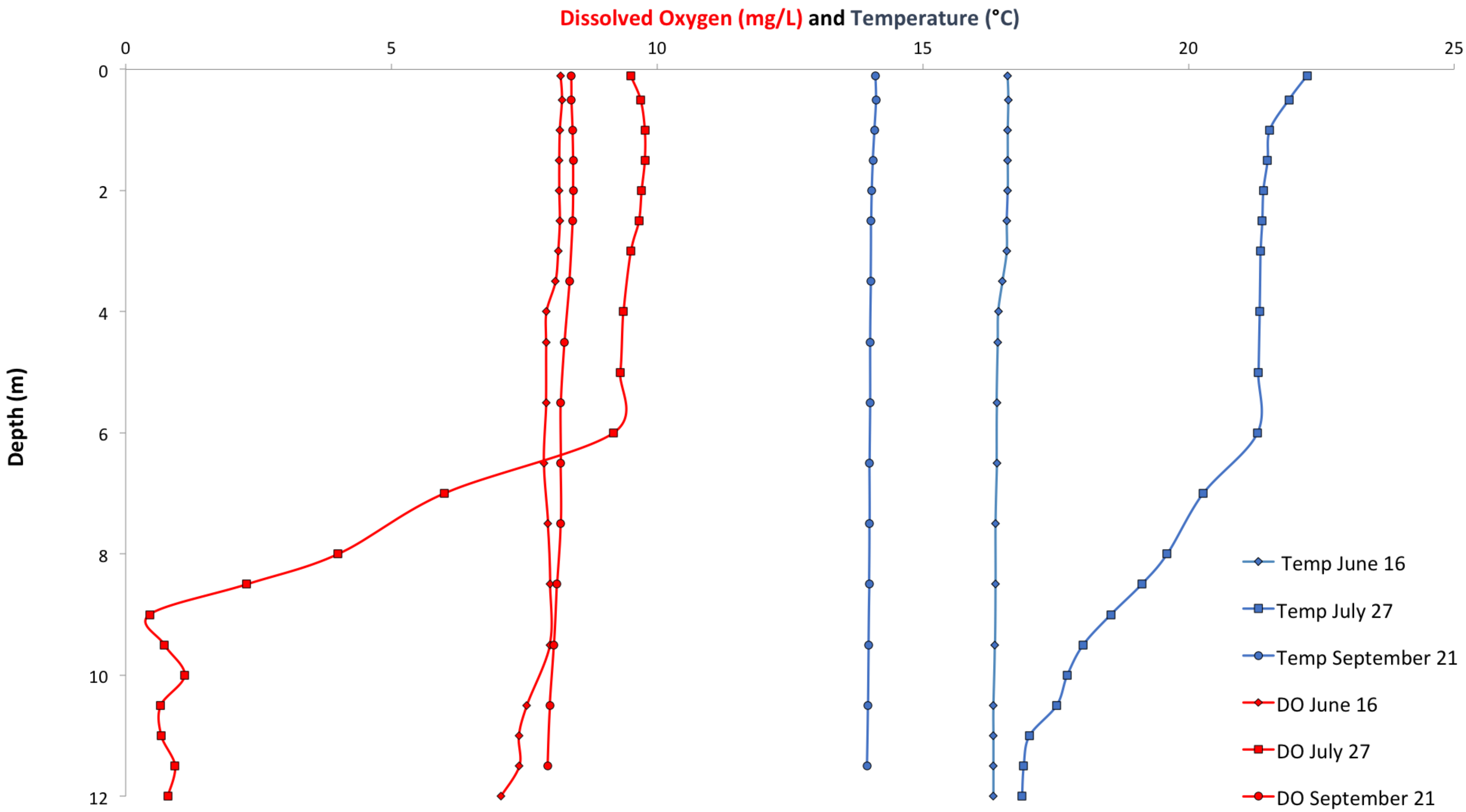


Figure 1: Dissolved oxygen and temperature profiles from Main Basin over three sampling dates during the summer of 2016

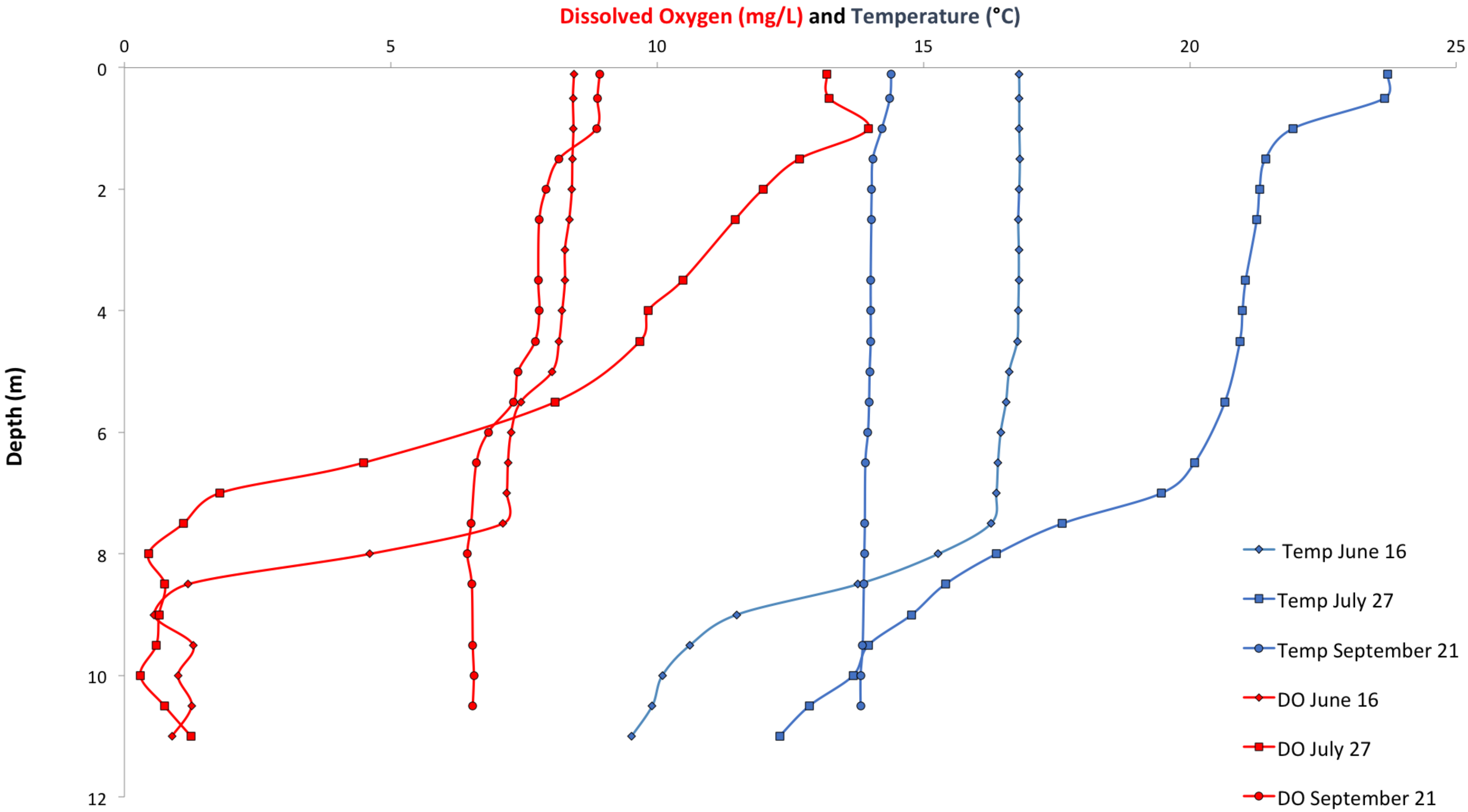


Figure 1: Dissolved oxygen and temperature profiles from Franchere Bay over three sampling dates during the summer of 2016

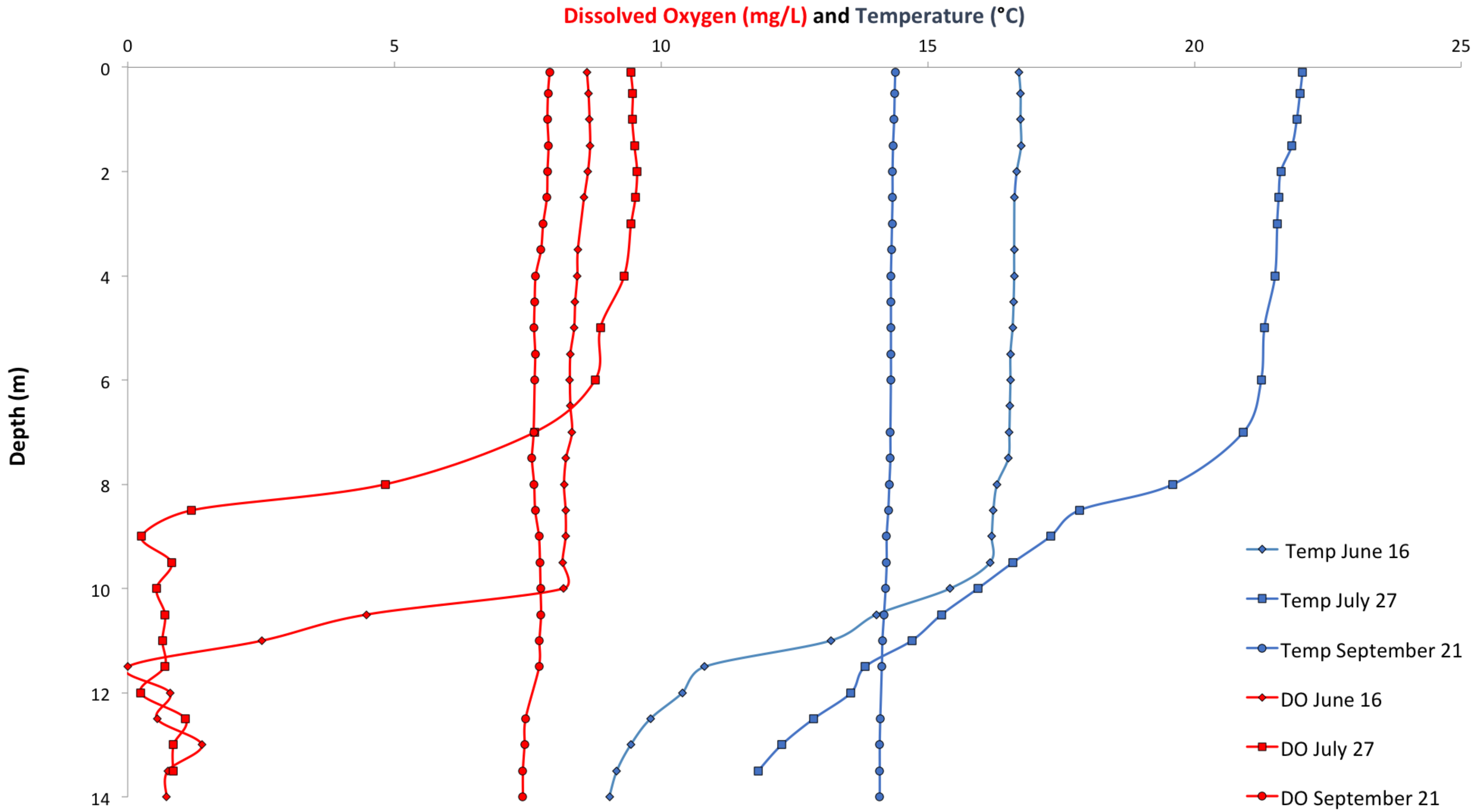


Figure 2: Dissolved oxygen and temperature profiles from Pelican Narrows over three sampling dates during the summer of 2016

PROFILE - VEZEAU BAY

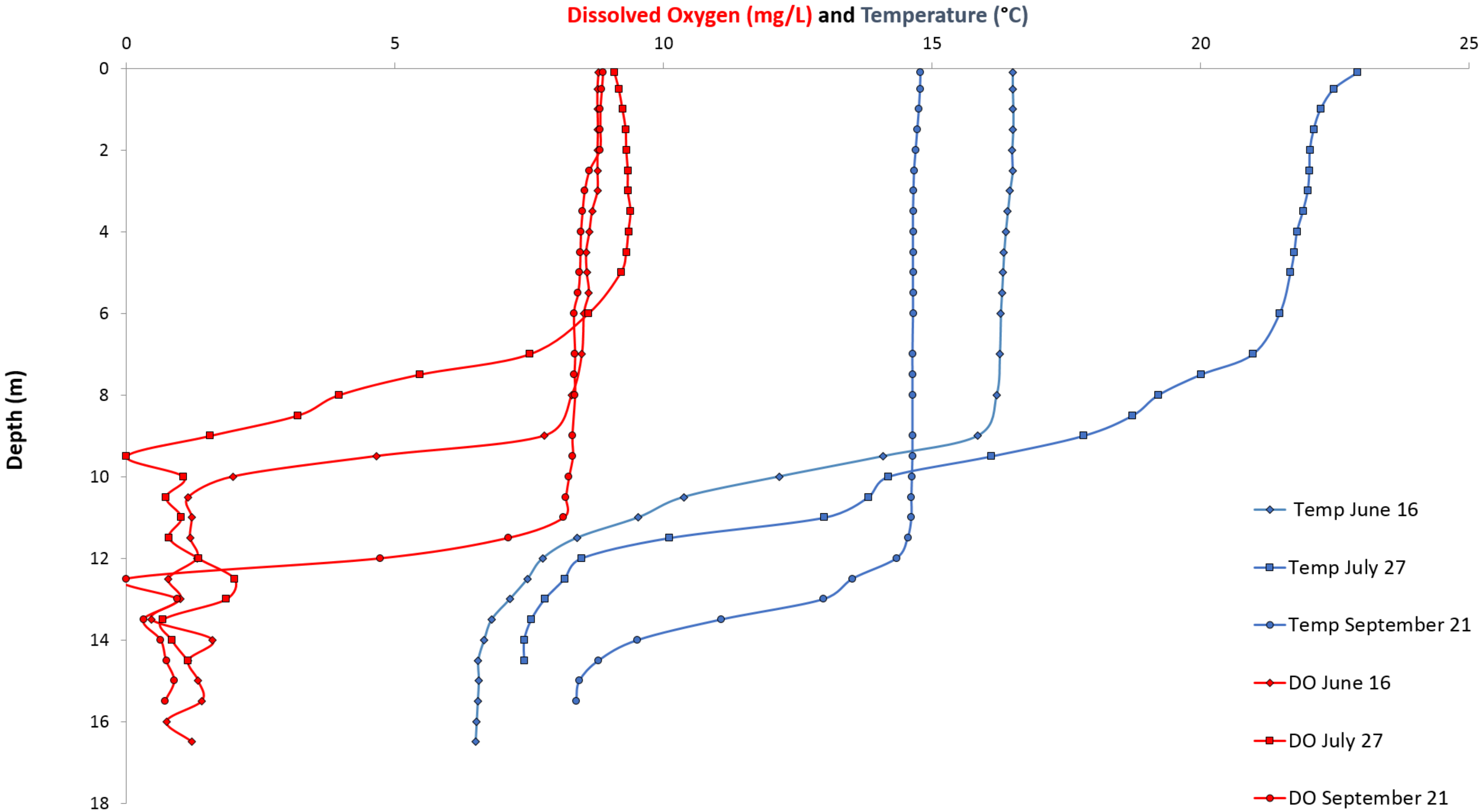


Figure 3: Dissolved oxygen and temperature profiles from Vezeau Bay over three sampling dates during the summer of 2016

Table 1: Water clarity and water chemistry values measured at each of the four basins and for the whole lake during the summer of 2016

Basin	Sample Date	TP (µg/L)	TDP (µg/L)	TPP (µg/L)	TKN (mg/L)	Chl-a (µg/L)	Secchi Depth (m)	Microcystin (µg/L)
Main Basin	16-Jun	24	11	13	1.4	6.2	2.25	0.13
	27-Jul	27	7	20	1.5	13.0	1.50	0.84
	21-Sep	36	7	29	1.7	38.8	1.25	0.43
	Average	**29**	**8**	**21**	**1.5**	**19.3**	**1.67**	**0.47**
Franchere Bay	16-Jun	48	24	24	1.5	10.9	1.50	0.19
	27-Jul	44	10	34	2.3	75.2	0.50	20.74
	21-Sep	72	9	63	2.1	68.3	0.75	0.35
	Average	**55**	**14**	**40**	**2.0**	**51.5**	**0.92**	**7.09**
Pelican Narrows	16-Jun	25	11	14	1.4	6.3	2.00	0.13
	27-Jul	25	8	17	1.5	13.1	2.00	0.63
	21-Sep	32	6	26	1.7	31.4	1.25	0.25
	Average	**27**	**8**	**19**	**1.5**	**16.9**	**1.75**	**0.34**
Vezeau Bay	16-Jun	20	11	13	1.5	6.8	2.00	0.12
	27-Jul	20	7	13	1.5	7.2	2.50	0.22
	21-Sep	30	7	23	1.6	31.2	1.25	0.25
	Average	**25**	**8**	**16**	**1.5**	**15.1**	**1.92**	**0.20**
Whole Lake	16-Jun	31	16	15	1.5	7.3	2.25	0.15
	27-Jul	31	9	22	1.7	29.6	1.50	5.37
	21-Sep	61	7	54	1.7	43.8	1.25	0.38
	Average	**41**	**11**	**30**	**1.6**	**26.9**	**1.67**	**1.97**

TP: Total Phosphorus
TDP: Total Dissolved Phosphorus
TPP: Total Particulate Phosphorus
TKN: Total Kjeldahl Nitrogen
Chl-*a*: Chlorophyll-*a*

A BRIEF INTRODUCTION TO LIMNOLOGY

INDICATORS OF WATER QUALITY

Water samples are collected in LakeWatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in LakeWatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

TEMPERATURE AND MIXING

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of the lake. As the difference in temperature between warm surface and cold deeper water increases, two distinct layers are formed. Limnologists call these layers of water the epilimnion at the surface and the hypolimnion at the bottom. The layers are separated by a transition layer known as the metalimnion which contains the effective wall separating top and bottom waters called a thermocline. A thermocline typically occurs when water temperature changes by more than one degree within one meter depth. The hypolimnion and epilimnion do not mix, nor do elements such as oxygen supplied at the surface move downward into the hypolimnion. In the fall, surface waters begin to cool and eventually reach the same temperature as hypolimnetic water. At this point the water mixes from top to bottom in what is often called a turnover event. Surface water cools further as ice forms and again a thermocline develops this time with 4° C water at the bottom and near 0° C water on the top.

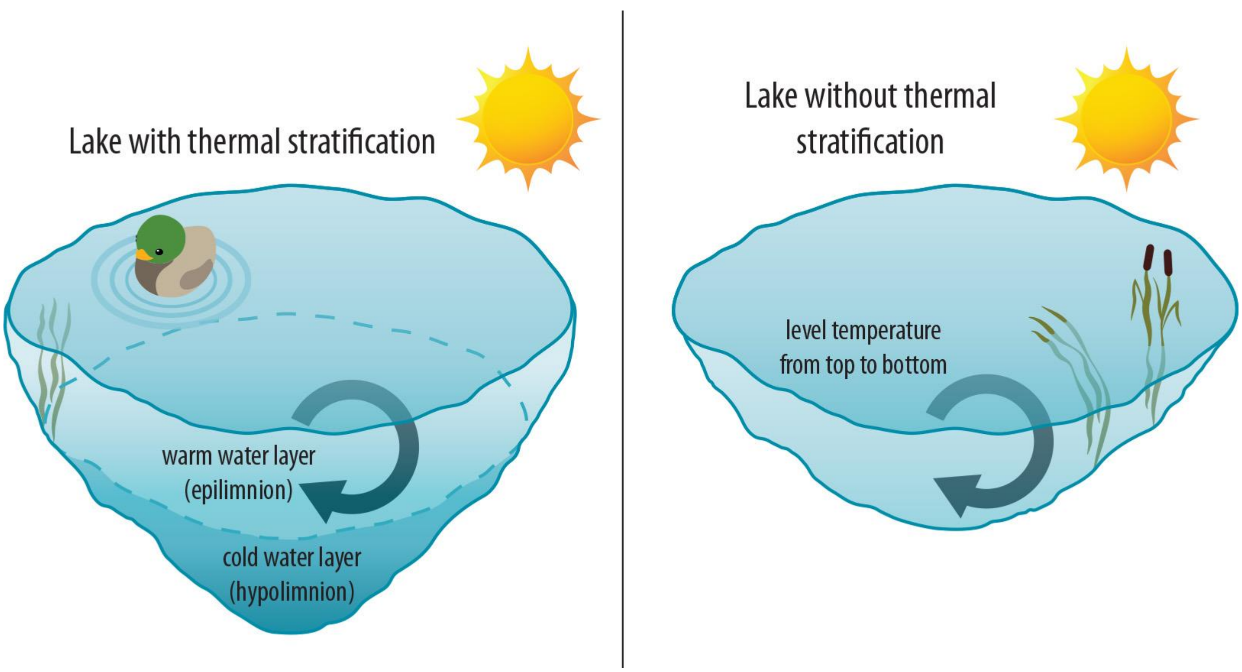


Figure A: Difference in the circulation of the water column depending on thermal stratification.

In spring another turnover event occurs when surface waters warm to 4° C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are termed **polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic** meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice free season the lake is polymictic.

DISSOLVED OXYGEN

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 $mg \bullet L^{-1}$ and should not average less than 6.5 $mg \bullet L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg \bullet L^{-1}$ in areas where early life stages of aquatic biota, particularly fish, are present.

GENERAL WATER CHEMISTRY

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

PHOSPHORUS AND NITROGEN

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

CHLOROPHYLL-A

Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the amount of algae in the water. Some highly productive lakes are dominated by larger aquatic plants rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

SECCHI DISK TRANSPARENCY

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and insects, depend on aquatic plants for food and shelter.

TROPHIC STATE

Trophic state is classification of lakes into four categories of fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are; **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic (Table 2)**.

A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

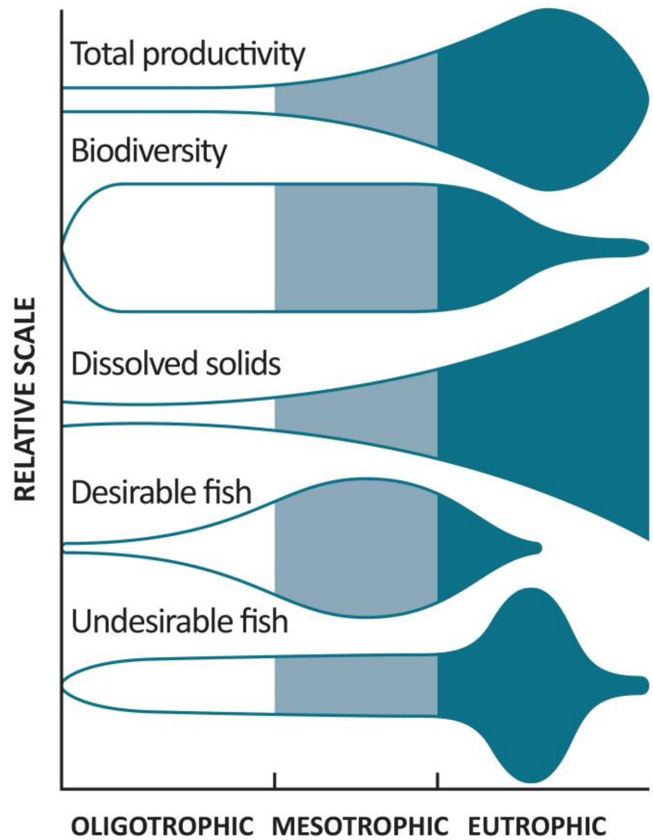


Table A - Trophic status classification based on lake water characteristics.

TROPHIC STATE	TOTAL PHOSPHORUS ($\mu g \bullet L^{-1}$)	TOTAL NITROGEN ($\mu g \bullet L^{-1}$)	CHLOROPHYLL A ($\mu g \bullet L^{-1}$)	SECCHI DEPTH (m)
Oligotrophic	< 10	< 350	< 3.5	> 4
Mesotrophic	10 – 30	350 - 650	3.5 - 9	4 - 2
Eutrophic	30 – 100	650 - 1200	9 - 25	2 - 1
Hypereutrophic	> 100	> 1200	> 25	< 1