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Lakewatch

Laurier Lake

The Alberta Lake Management Society
Volunteer Lake Monitoring Report

> *And you really live by the river? What a jolly life!"*
>
> *"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing."* *Kenneth Grahame The Wind in the Willows*
>
> *"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water."* *BBC World Water Crisis Homepage*

A note from the Lakewatch Coordinator Preston McEachern

Lakewatch has several important objectives, one of which is to document and interpret water quality in Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between aquatic scientists 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. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these sources.

Since 2002, Lakewatch Reports have undergone a substantial change in format from previous years. I am no longer the author as much as an editor including text and figures from others who have done an excellent job describing lakes throughout Alberta. I have attempted to give due credit to these outstanding people and apologize for blatant plagiarism where it occurs. As editor, feel free to castrate me for errors. I have included easily accessible information that is likely to have been updated in recent years and readers are encouraged to help update these reports by sending new information to me.

Another exciting event occurred in 2003. Laboratory analyses have been switched from the University of Alberta Limnology Lab to the Alberta Research Council lab in Vegreville. The ARCV has a very broad spectrum of analyses possible and their detection levels are very good. Thus, we have added metals to our suite of analyses in 2003.

I would like to thank all people who share my love for aquatic environments and particularly those who have helped in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that water will not be the limiting factor in the health of our planet.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Alberta Environment employees. Shelley Manchur, Mike Bilyk, Brian Jackson John Willis, and Doreen LeClair from Alberta Environment were instrumental in funding, training people and organizing with Lakewatch data. Jean-Francois Bouffard was our summer field coordinator and was a valuable addition to the program. Francine Forrest, Jean-Francois Bouffard, and Théo Charette helped in report writing. Finally, our volunteer for Laurier Lake was Bev Smith. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred. Financial support from Alberta Environment, the Lakeland Industry & Community Association (LICA) and the Summer Temporary Employment Program (STEP) was essential in 2003.

Fig. 1: Laurier Lake	Photo: L. Kowalchuk, ALMS

Laurier Lake

Laurier Lake is one of four beautiful lakes that were left behind 10 000 years ago when glaciers carved a setting of hummocky terrain of kettles, eskers and lake basins. Archeological evidence indicates the area was inhabited at least 7 000 years ago. The first Europeans came through the area in 1754 by way of the nearby North Saskatchewan River. The Frog Lake Reserve, adjacent to the Whitney Lakes Provincial Park, is where the Frog Lake Massacre occurred on April 2, 1885 (Alberta Recreation, Parks and Wildlife Foundation 1992). After the North West Rebellion, as tensions calmed, settlers began arriving to farm. Whitney Lakes Provincial Park was established in 1982. It boasts of a diverse setting of jack pine, meadows, aspen groves, willow thickets, marshes, fens and mixed wood forests. As many as 148 bird species have been observed in the park with an excellent viewing point on the west side of Laurier Lake (SRD 2002). The land surrounding Laurier Lake includes a mixture of recreational cottage development, cleared agricultural land and natural deciduous forest. Protected Crown land makes up the north shore of the lake the rest of the shoreline is privately owned (Mills 1988). The lake is enjoyed for recreational activities such as hiking, wildlife viewing and water-based recreation. Popular activities include: wind surfing, water-skiing, sailing, swimming and fishing. Yellow perch, walleye and northern pike are the sport fish of Laurier Lake. Fish stocking occurred in 1953. Sport and forage fish were transferred from Moose Lake to Laurier Lake. The lake has not been managed for commercial or domestic fishing.

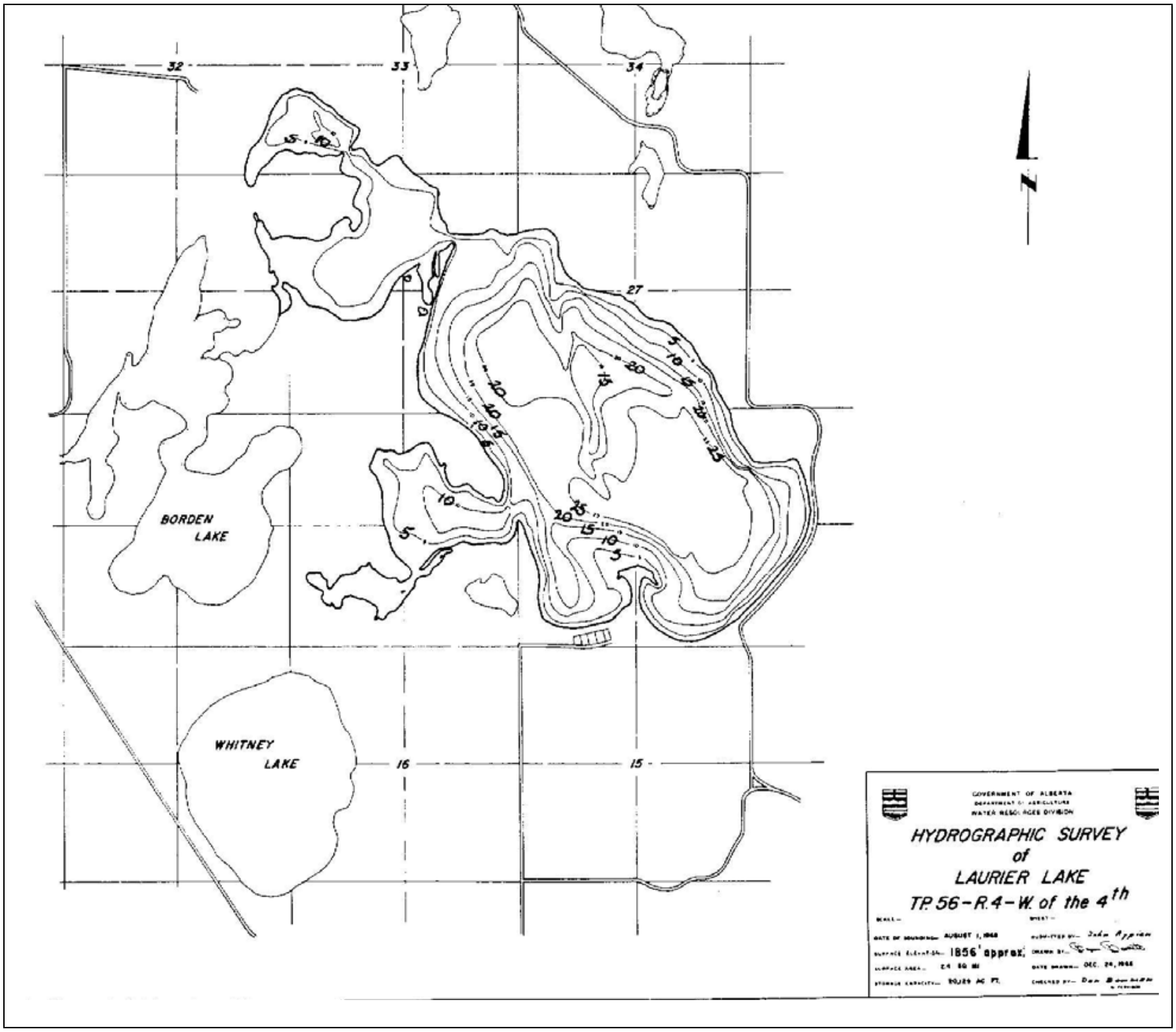


Fig. 2: Bathymetry of Laurier Lake. Contours are 5 ft. intervals.

Laurier Lake has a surface area of 6.42 km^2 with a maximum depth of 9.1 m (Fig. 2). The lake has been both mesotrophic and eutrophic. Its location and surrounding topography make Laurier open to prevailing winds. These winds mix the water column and Laurier usually does not thermally stratify throughout most of the summer. Mixing also allows nutrients and organic material to remain suspended in the water column making the lake naturally fertile. Algal blooms are known to occur during summer months due to the lakes natural fertility. Detailed studies on phytoplankton have not been completed for the lake. Common emergent plants that fringe the lake are bulrushes, cattails and sedges.

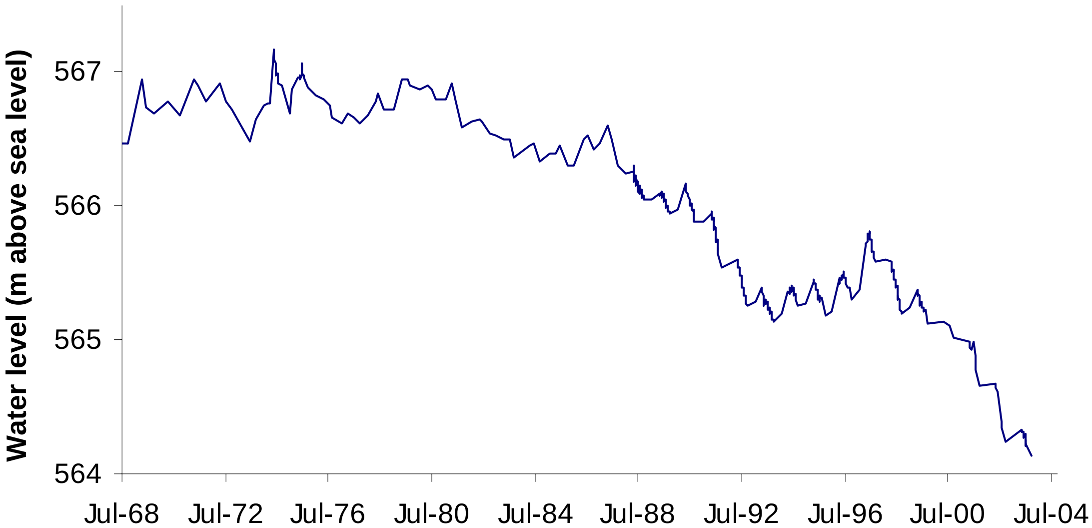
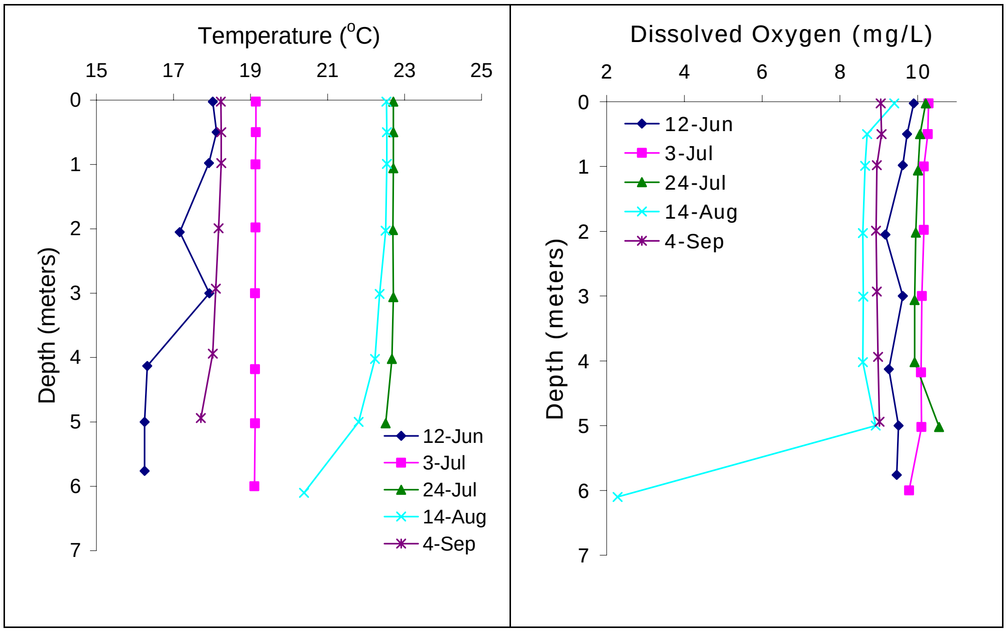


Fig. 3: Water levels in Laurier Lake from 1968 to July 2003.

Water levels

Laurier Lake shares a 92-km^2 drainage area with Ross, Borden and Whitney lakes. The lake is fed by one intermittent and three permanent streams. The outflow, on the northwest end, drains into Borden Lake and subsequently to the North Saskatchewan River (Mills 1988). Water levels in Laurier Lake have been monitored since 1968. From the historical records, the water level was at a maximum in 1974 but dropped almost 3 m to a minimum recorded level in October 2003 (Fig. 3). Water levels have been slowly dropping for the last 2 decades. The average elevation is 565.7 m. The average water level in 2003 was 1.5 m less than the historical average. Alberta experienced a relatively wet year in 1997 that restored water levels in many lakes. In Laurier Lake, the wet year of 1997 temporarily halted water level declines. The reprieve was short-lived and water levels began to decline precipitously following 1997.



Figs. 4 & 5: Temperature and dissolved oxygen profiles for Laurier Lake, summer 2003.

Results

Water Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. Please refer to the end of this report for descriptions of technical terms.

Thermal stratification was not apparent in Laurier Lake during the summer of 2003, except just above lake bottom in mid-August (Fig. 4). Dissolved oxygen concentrations were between 8 mg/L and 11 mg/L through most of the summer. During mid-August, dissolved oxygen dropped sharply to near anoxic levels below the thermocline. Otherwise, Laurier Lake's water column was well-airated during the summer of 2003.

Water clarity and Secchi Depth

Water clarity is influenced by suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is the Secchi depth. After ice and snowmelt a lake can have low clarity due to spring runoff and suspended sediments in the lake. Lake water usually clears in the spring but then becomes less clear as algae grow through the summer.

In 2003, Laurier Lake's water was quite clear with a mean Secchi disk depth of 4.4 meters. Water clarity was best in early summer (Secchi 6.25 m) and declined to a low of 2.8 m by late July. Secchi depths subsequently increased back up to 3.75 m in mid August and 4.5 m in early September. The very high water clarity in early and late summer samplings, combined with the relatively shallow bottom of Laurier Lake meant that for much of the summer the entire water column contained enough

Table1: Historical water quality in Laurier Lake.

Parameter	JUNE 1978	AUG 1980	AUG 1987	1997	1998	2000	FEB 1999	SEPT 2001	2002	2003
Total P (µg/L)	-	-	-	32	48	37	16	-	36	27
TDP (µg/L)	-	-	-	-	-	-	22	-	15	15
Chla (µg/L)	-	-	-	5.3	8.9	5.5	1.1	-	5.8	2.6
Secchi (m)	-	1.3	1.2	4.6	1.3	1.8	1.7	2.3	2.5	4.4
Total N (mg/L)	-	-	-	-	-	-	-	-	2.5	2.6
NO_{2+3} (µg/L)	<50	50	<1	-	-	-	6	-	3.8	211
NH_4 (µg/L)	-	-	-	-	-	-	25	-	23	41
Ca (mg/L)	23	27	19	20	21	13	18	-	12	10
Mg (mg/L)	48	54	52	73	81	83	86	-	99	106
Na (mg/L)	49	45	59	86	92	98	103	-	77	128
K (mg/L)	14	14	17	24	25	25	27	-	26	31
SO_4 (mg/L)	36	40	41	62	66	73	74	-	94	99
Cl (mg/L)	5	6	9	12	13	15	17	-	12	18
CO_3 (mg/L)	-	-	-	39	62	66	-	-	102	112
HCO_3 (mg/L)	-	-	-	493	468	469	-	-	515	522
TDS (mg/L)	-	-	-	562	598	602	-	-	-	764
PH	-	-	-	8.8	8.9	8.0	-	-	9.2	9.2
Total Alkalinity (mg/L $CaCO_3$)	310	329	360	470	488	493	562	-	592	615

Note. TDP = total dissolved phosphorus, Chla = chlorophyll *a*, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulfate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate, TDS = total dissolved solids.

light for algal growth. These patterns in clarity were not consistent with water greenness, thus other factors are responsible for water clarity patterns in Laurier Lake.

Water chemistry

In 2003, Laurier Lake was mesotrophic with what is considered medium nutrient concentration compared to lakes throughout Canada. In the Alberta context, Laurier Lake is relatively clean compared to the average in these characteristics. Nutrient concentrations seem to have remained relatively stable on an annual mean basis. There is no evidence to suggest increased nutrient loading from cottages or other land use activities around Laurier Lake. Total nitrogen concentrations are very high relative to total phosphorus. Dissolved nitrogen forms were fairly high in 2003. Metal concentrations were low and none surpassed provincial and federal Water Quality Guidelines for the Protection of Aquatic Life. In general, the water quality of Laurier Lake was good and the water was clear.

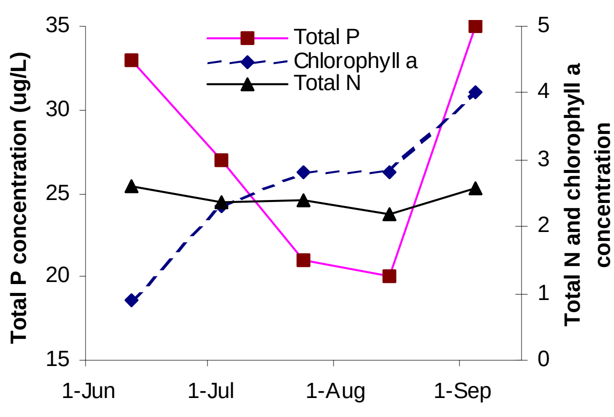


Fig. 6: Total phosphorus, chlorophyll *a* (µg/L) and total nitrogen (mg/L) for Laurier Lake, summer 2003.

Algal biomass, measured as chlorophyll *a*, in Laurier Lake was relatively low compared to nutrient concentrations. Algal biomass is considered typical of an oligotrophic system, which is somewhat rare in Alberta. Not only was algal growth low but it did not fluctuate much or indicate that blooms were likely to occur.

Laurier Lake is well buffered: its pH of 9.2 is well above that of pure water (i.e., pH 7). Ion levels were high in 2003 and were dominated by bicarbonate, carbonate, sulfate, sodium, and magnesium. Calcium concentrations have declined following a trend with the decline in water level in Laurier Lake. Over the same period, magnesium, sodium and potassium concentrations have roughly doubled. The major anions, sulfate, chloride and bicarbonate have also roughly doubled as water levels have declined. Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The changing ion concentrations in Laurier Lake suggest a fundamental change in its hydrology. Low rainfall has likely reduced the contribution of runoff to Laurier Lake. With a reduction in runoff and particularly throughflow (lateral flow through surface soil), groundwater has likely become a more important source of water to Laurier Lake. The increase in ion concentrations such as magnesium and sulfate is likely related to changing hydrology and decreased runoff or throughflow. This presupposes that the main source of calcium is from surface soils while groundwater is magnesium and sodium sulfate or chloride dominated. Evaporative concentration could also play a role in the changing ion chemistry of Laurier Lake.

Sulfate concentrations increased 2.5-fold over the past 3 decades. Increases in sulfate concentrations can be associated with atmospheric deposition from petroleum activities, (e.g. sour gas). Given the extreme loss of water that has occurred in Laurier Lake over the last two decades and the doubling of magnesium, potassium and alkalinity it is unlikely the changes are a result of atmospheric deposition of acidifying pollutants from petroleum activities.

Decline in water level is a problem common to other lakes in Alberta due to our recent dry climate. The lake will continue to become more saline as long as runoff remains low. As water levels decline, the potential for internal loading of nutrients from bottom sediments generally increases and could result in declines in water quality that include the occurrence of algal blooms. On a positive note, water quality in Laurier Lake is still above average in the Alberta context.

A brief introduction to Limnology

Indicators of water quality

Water samples are collected in Lakewatch to determine the water quality of lakes. 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

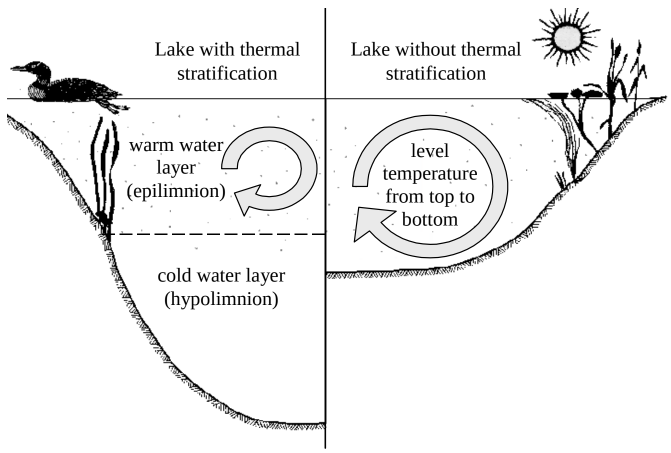


Fig. 7: Difference in the circulation of the water column depending on thermal stratification.

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 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 0° C water on the top.

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/L and should not average less than 6.5 mg/L over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg/L 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, known as macrophytes, rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. As a result, lakes like Chestermere which are dominated by macrophytes can be at 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 Depth

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. Secchi disk depth is the oldest, simplest, and quickest quantitative measure of water clarity. A Secchi disk is a black and white disk that is lowered down through the water column until it can no longer be seen. Secchi disk depth is the midpoint between the depth at which it disappears when lowered and reappears when it is pulled up again. The Secchi disk depth in lakes with high algal biomass will generally be shallow. However, Secchi disk depth is not only affected by algae. 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 shallow Secchi disk depths despite low algal growth and nutrient concentrations.

The euphotic zone, calculated as twice the Secchi disk depth, is the portion of the water column that has sufficient light for aquatic plants to grow. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Aquatic plants are important because they ensure clear lake water by reducing shoreline erosion and stabilizing lake bottom sediments. Many lakes in Alberta are shallow and have bottom sediments with 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 fish, depend on aquatic plants for food and shelter.

Trophic state

Trophic state is a classification system for lakes that depends on 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**. 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. A majority of lakes in Alberta are meso- to eutrophic because they naturally contain high nutrient concentrations due to our deep fertile soils. Thus, lakes in Alberta are susceptible to human impacts because they are already nutrient-rich; any further nutrient increases can bring about undesirable conditions illustrated in Fig 8.

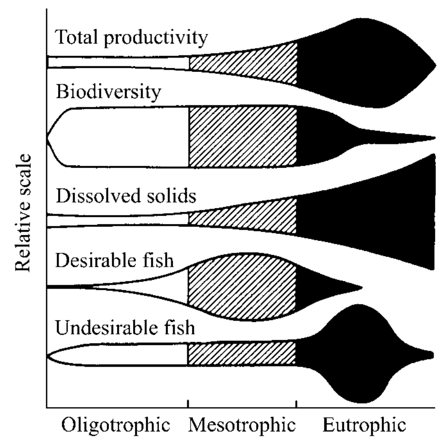


Fig. 8: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

Trophic status based on lake water characteristics.

Trophic state	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (µg/L)	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

Note: These values are from a detailed study of global lakes reported in Nurnberg 1996. Alberta Environment uses slightly different values for TP and CHL based on those of the OECD reported by Vollenweider (1982). The AENV and OECD cutoffs for TP are 10, 35 and 100; for CHL are 3, 8 and 25. AENV does not have TN or Secchi depth criteria. The corresponding OECD exists for Secchi depth and the cutoffs are 6, 3 and 1.5 m.