The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Tucker Lake

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2006 Report

Completed with support from:

Alberta Lake Management Society
P.O. Box 4283
Edmonton, Alberta T6E 4T3

> *Water is integral to supporting and maintaining life on this planet as it moderates the climate, creates growth and shapes the living substance of all of Earth's creatures. It is the tide of life itself, the sacred source.*
> David Suzuki (1997). The Sacred Balance.

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality 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, 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 usually available for lakes that have been included in Lakewatch and readers requiring more information are encouraged to seek these 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.

Acknowledgements

The Lakewatch program is made possible through the Lakewatch Chairs, Théo Charette and Ron Zurawell, and the volunteers. Blair Graham was the main volunteer for Tucker Lake. He supplied the watercraft and made sampling possible through the dedication of his time. Our summer field technicians and volunteer coordinators, Megan Mclean and Amand Krowski, were valuable additions and contributors to this year's program. Numerous Alberta Environment staff also contributed to successful completion of the 2006 program. Project Technical Coordinator, Shelley Manchur was instrumental in planning and organizing the field program. Technologists, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair was responsible for data management. Théo Charette (ALMS Director) was responsible for program administration and planning. Zofia Taranu, Erika Brwon and Jesse Vermaire prepared this report. Alberta Environment and Lakeland Industry and Community Association (LICA) financially supported the Lakewatch program.

Tucker Lake

Tucker Lake is located within a low-lying, rolling hill catchment. It is an isolated lake approximately 280 km northeast of the city of Edmonton. The primary urban centers are Bonnyville (south), as well as Grande Centre and Cold Lake (southeast). To reach Tucker Lake from Edmonton, take Highway 28 and Highway 28A heading northeast (direction Bonnyville), then north on Highway 41 towards La Corey. Then head east onto Highway 55 for approximately 5.5 km and take the first turn (north) after Jackfish Creek. Take this gravel road for 3 km, east for 0.75 km, north for 3.25 km, and finally east for 6 km. At the end of this gravel road is the western shore of Tucker Lake. Inadequate lake access and lack of facilities limits recreational use of the lake, although boat access is available at the end of the entrance road. Sport fishing in spring and summer months (for northern pike and yellow perch) as well as swimming and camping are the preferred activities of those visiting the lake. The origin of the name "Tucker" in unknown, however, the lake is often referred to Little Jackfish Lake due to the abundance of small northern pike fish (Chipeniuk 1975).

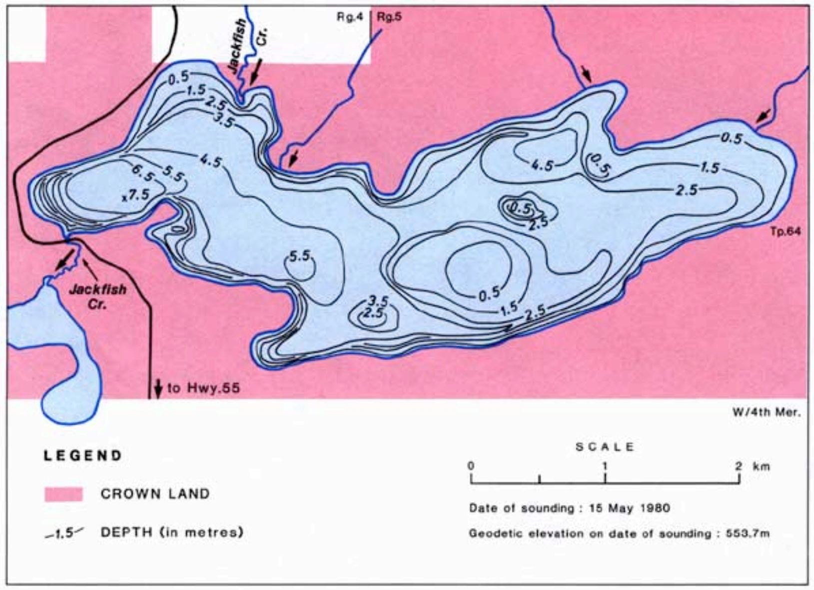


Figure 1: Bathymetry of Tucker Lake.

No cottages occupy the shoreline of the Tucker Lake, which to the exception of a section of privately owned land on the northwest bay is entirely Crown Land.

The drainage basin of Tucker Lake is 46 times the size of the lake and is entirely located to the north of the lake. All inflowing streams are consequently located on the northern shore of Tucker Lake. Jackfish Creek, which is the largest of the four streams, drains from Bourque Lake along the lake's northwestern shore. Tucker Lake's catchment is located in the Boreal Mixedwood Ecoregion (Strong and Leggat 1981). The dominant tree species in the dry subregion (small area south of the lake), is trembling aspen, while the moist subregion (area north of the lake) is composed of balsam poplar and trembling aspen. Jack pine, white spruce, black spruce, willows and sedges grow in both subregions.

Tucker Lake is of moderate size (surface area of 6.65 km^2) and shallow (mean depth of 2.9 m). The deepest region of the lake is located in the western bay and slopes rapidly to a 7.5 m deep hole. For the most part, however, the depth of this western basin is 6.5 m. The eastern basin fluctuates in depth between 2.5 and 4.5 m, intermittent by numerous shallow spots of only 0.5 m.

The average concentrations of algae in Tucker Lake are quite high and as such the lake is classified as hyper-eutrophic. To date, the highest chlorophyll a concentration on record was of 106 µg/L, sampling on September 6th, 2006. In 1982, macrophyte vegetation of Tucker Lake (described by McGregor 1983) grew around the entire shoreline, and was of greatest density in the shallow, northeast portion of the lake. The emergent macrophytes identified at this time were the great bulrush (*Scirpus validus*), yellow water lily (*Nuphar variegatum*), sedges (*Carex* sp.) and reed grass (*Phragmites* sp.). Common submerged macrophytes include coontail (*Ceratophyllum demersum*), northern watermilfoil (*Myriophyllum exalbescens*), and finally the Richardson (*Potamogeton richardsonii*), flatstemmed (*P. zosteriformis*) and Sago (*P. pectinatus*) pondweeds.

Results

Water Levels

Water levels for Tucker Lake have not been recorded to date. In the surrounding region, however, there have been reports of lake level lowering in recent times due to increased drought episodes. To help approximate changes in water levels in Tucker Lake and determine what trends we could have expected within this lake, we opted to examined changes in water levels of a nearby lake. Namely, Moore Lake is located ~ 2 km southeast of Tucker Lake, and as such, we assume that both systems are subjected to similar microclimates. The water levels of Moore Lake (also referred to as Crane Lake) were recorded regularly from the period of 1980 to 2006. The elevation of this lake varied slightly, but overall, remained close to a mean lake level of 549.49 m above sea level (**Figure 2**). There was a slight decreasing trend in water level from 1987 to 1992 but of only about 0.4 meter. This was followed by a period of increase in elevation (by 0.7 m) from 1992 to 1997. A cycle was also observed during recent sampling years. The maximum lake level throughout recorded history was 549.9 m in June 2006, and the minimum water level of 549.1 m occurred in October 1992. To summarize then, given that Moore Lake has not witness any indication of lake level lowering, we assume that likewise, Tucker Lake , should have had relatively stable lake levels over the past 26 years.

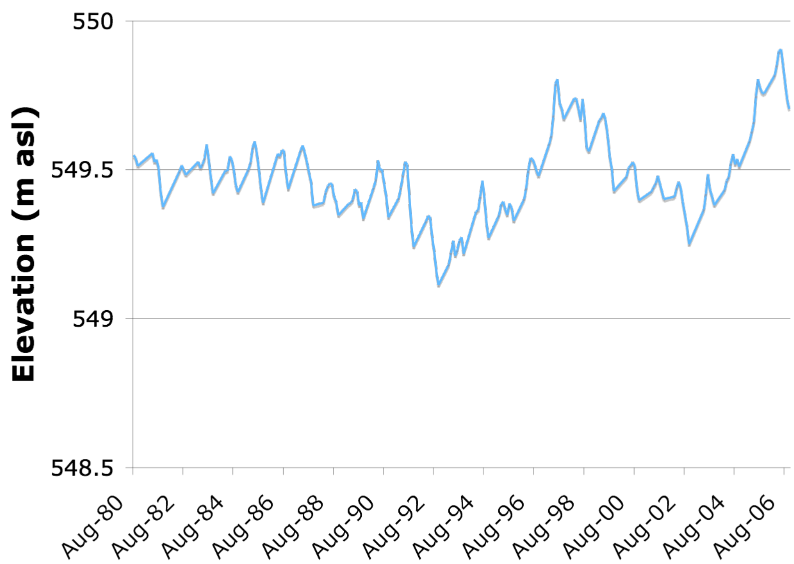
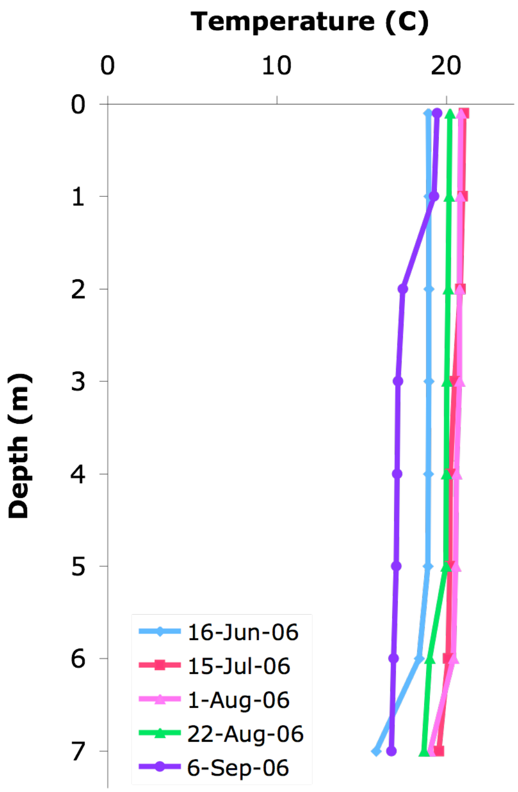


Figure. 2: Water levels for nearby Moore Lake (~ 2 km SE of Tucker Lake) for the period of 1980 to 2006.

Water Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. For descriptions of technical terms, please see end of report.



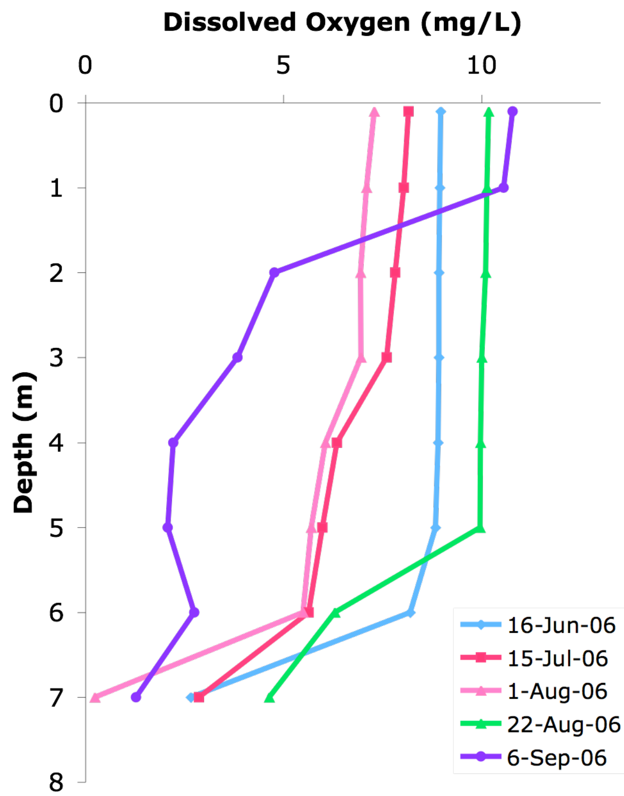


Figure 3. Temperature and dissolved oxygen concentrations with depth of Tucker Lake, summer 2006.

In summer 2006, Tucker Lake was well mixed during the open-water season and did not exhibit indications of strong thermal stratification of its water column. Thermal stratification refers to the condition where water temperature changes by more than one degree within 1-m depth (**Figure 3**). By mid-June, however, a small thermocline formed at the 6-m depth, and again in early September at the 1-m depth. Dissolved oxygen (DO) depletion to levels below 5 mg/L occurred at all sampling dates despite the lack of a thermocline for most dates. A thermocline may have existed prior to sampling; however, the rapid decline in DO suggests that the lake is extremely sensitive to oxygen depletion. This extreme sensitivity is possibly due to the lake's heighten algal biomass. Upon senesce and sedimentation to the lake bottom, the algal biomass decomposes, and as this process requires oxygen, highly productive lakes experience large decreases in DO concentrations even if the water column mixes periodically (i.e. is not stratified).

Water clarity and Secchi disk depth

During the melting of snow and ice in spring, lake water can become cloudy from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth

Tucker Lake is a hyper-eutrophic lake according to the nutrient, chlorophyll and Secchi disk depth transparency criteria. In 2006, the water quality of this lake was classified as turbid, with a Secchi disk depth of 3.25 m in mid-June and of 0.75 m by late August. Water clarity decreased steadily from June to September, following the increase in algal biomass, or water greenness, observed during this time period (**Figure 4**). There were notable increases in phosphorus and nitrogen concentrations throughout the summer. The recorded increase in TP is indicative of internal loading from the lake's sediments.

Water chemistry

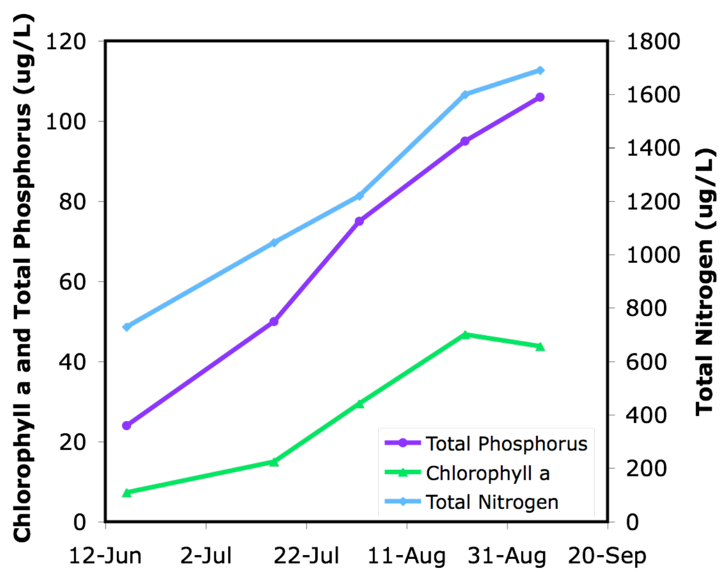


Figure 4: Total phosphorus, chlorophyll-*a* (amount of algae), and total nitrogen concentrations in Tucker Lake, summer 2006.

Tucker Lake had very high nutrient concentrations and algal biomass compared to other lakes in Canada, and as such is considered to be a hyper-eutrophic lake (Refer to: *Trophic status based on lake water characteristics: A Brief Introduction to Limnology at the end of this report)*. In the context of the province of Alberta, where lakes are naturally nutrient-rich, Tucker Lake has average algae and nutrients concentrations. In 2006, total phosphorus concentrations were high following spring mixing, and increased from June to September (**Figure 4**). The recorded increase in TP (from 24 μg/L up to 106 μg/L) is indicative of internal phosphorus loading from the lake's sediment. Chlorophyll a also increased from June to August, experiencing a slight decrease at the September sampling. Total nitrogen concentrations in Tucker Lake increased from 760 μg/L in mid-June to 1690 μg/L by the end of the summer. Phosphorus concentrations typically increase in Alberta lakes during the summer as a result of recycling of nutrients from bottom sediments. In 1982, the phosphorus budget of Tucker Lake was calculated and it was found that the internal loading of phosphorus from the sediments was quite significant. In fact, it was found that 75% of the mean daily TP loading was from internal sources. The inflow from Bourque Lake accounted for 29% of the total summer load. Chlorophyll *a*, which is a measure of algal biomass, followed patterns in total phosphorus concentrations up until the end of the growing season (**Figure 4**).

Like most lakes in Alberta, Tucker Lake is well buffered from acidification; its pH of 8.55 is well above that of pure water (i.e., pH 7). Bicarbonate, calcium, magnesium, and sodium are the dominant ions in Tucker Lake (**Appendix 1**). Mean calcium concentrations were relatively high (32.7 mg/L), but concentrations of the following ions were relatively low: magnesium (22.2 mg/L), sodium (20 mg/L), and potassium (3.4 mg/L) (**Appendix 1**). Chloride concentrations were low for a eutrophic lake (1.5 mg/L).

The average concentrations of various heavy metals (as total recoverable concentrations) were below CCME guidelines for the Protection of Freshwater Aquatic Life. Results of the metal analyses, compared to guideline values, are listed in **Appendix 2**. Further sampling of Tucker Lake is required to detect long-term trends in water quality.

Appendix 1

Table1: Mean chemical characteristics of Tucker Lake.

Parameter	2006
Total P (µg/L)	70
TDP (µg/L)	17
Chlorophyll *a* (µg/L)	28.5
Secchi disk depth (m)	1.55
Total N (µg/L)	1257
NO_{2+3} (µg/L)	5
NH_4 (µg/L)	17.4
Ca (mg/L)	32.7
Mg (mg/L)	22.2
Na (mg/L)	20
K (mg/L)	3.4
SO_4 (mg/L)	3.5
Cl (mg/L)	1.5
CO_3 (mg/L)	9.3
HCO_3 (mg/L)	249
Total Alkalinity (mg/L $CaCO_3$)	219
pH	8.55
Total dissolved solids (mg/L)	215

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

Appendix 2

Metals (total)	2006	Guidelines
ALUMINUM ug/L	6.625	100[a]
ANTIMONY ug/L	0.0167	6[e]
ARSENIC ug/L	4.855	5
BARIUM ug/L	44.6	1000[e]
BERYLLIUM ug/L	<0.003	100[d,f]
BISMUTH ug/L	0.007	
BORON ug/L	78.4	5000[e,f]
CADMIUM ug/L	0.0049	0.085[b]
CHROMIUM ug/L	0.198	
COBALT ug/L	0.02295	1000[f]
COPPER ug/L	0.1905	4[c]
IRON ug/L	79.15	300
LEAD ug/L	0.0435	7[c]
LITHIUM ug/L	21.5	2500[g]
MANGANESE ug/L	27.1	200[g]
MOLYBDENUM ug/L	1.185	73[d]
NICKEL ug/L	0.249	150[c]
SELENIUM ug/L	0.272	1
STRONTIUM ug/L	191.5	
SILVER ug/L	<0.0005	
THALLIUM ug/L	0.0032	0.8
THORIUM ug/L	0.0059	
TIN ug/L	<0. 03	
TITANIUM ug/L	1.765	
URANIUM ug/L	0.119	100[e]
VANADIUM ug/L	0.164	100[f,g]
ZINC ug/L	4.935	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5; calcium ion concentration [Ca^{+2}] ≥ 4 mg/L; and dissolved organic carbon concentration [DOC] ≥ 2 mg/L.
[b] Based on water Hardness of 300 mg/L (as $CaCO_3$).
[c] Based on water Hardness > 180 mg/L (as $CaCO_3$).
[d] CCME interim value.
[e] Based of Canadian Drinking Water Quality guideline values.
[f] Based of CCME Guidelines for Agricultural Use (Livestock Watering).
[g] Based of CCME Guidelines for Agricultural Use (Irrigation).

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

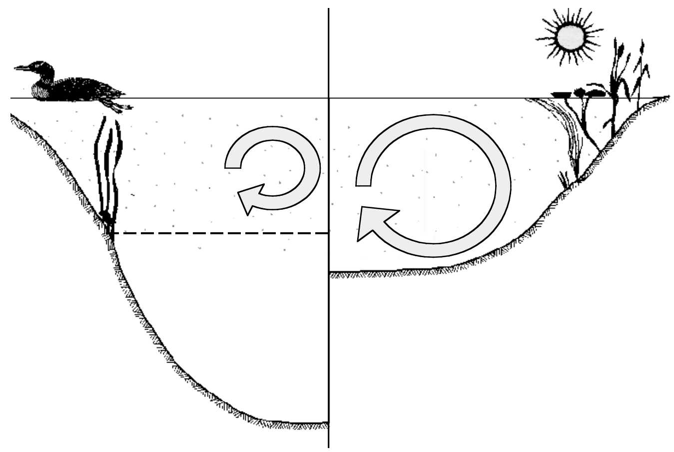


Fig. 1: Difference in the circulation of the water column depending on thermal stratification.

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 2.

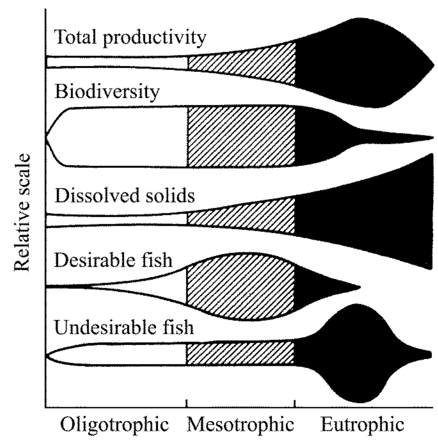


Fig. 2: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

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.

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