The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Beartrap Lake

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2008 Report

Completed with support from:

Alberta Lake Management Society

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> *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 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 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 dedication of its volunteers and Lakewatch Chairs, Théo Charette and Ron Zurawell. We would like to thank Maxine Howland for her efforts in collecting data in 2008. We would also like to thank Lisa Brodziak and Sophie Damlencour who were summer interns with ALMS in 2008. Project Technical Coordinator, Jill Anderson was instrumental in planning and organizing the field program. Technologists, Shelley Manchur, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Théo Charette (ALMS President) and Jill Anderson (Program Manager) were responsible for program administration and planning. Théo Charette, Ron Zurawell (Limnologist, AENV), and Lori Nuefeld prepared the original report, which was updated by Sarah Lord for the 2008 report. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Beartrap Lake

Introduction

Beartrap Lake is located approximately 12 km east of the town of Bonnyville and just over 250 km northeast of the city of Edmonton (**Figure 1**). To get to Beartrap Lake from Edmonton, take HWY 28 East (for 169 km), then continue on HWY 28A (for 46 km), and finally follow HWY 28 (for another 19 km) until HWY 659. At HWY 657 turn right (heading South, for 6.5 km), and turn left (heading East) onto Township Rd 604 (for 5 km). At its widest point, Beartrap Lake is about 1.4 km wide and 1.64 km long. There is no indication that Beartrap Lake has ever been sounded in the past, as we were unable to locate bathymetric maps for this particular lake.

Figure 1. Landscape map of Beartrap Lake, courtesy of Google Earth 2007.

Fish species found in the lake include cool water sport fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*).

Results

Water Levels

Water level in Beartrap Lake has been monitored since 1973. Water levels are measured as the elevation in meters above sea level (m asl) of the surface of the lake. From 1973 to 1990 the lake experienced a gradual increase in water level, followed by a sharp decline in 1991 (**Figure 2**). From 1993 water level again increased from 1993 - 1997. The wettest year on record was 1997. Water level declined again from 1997 - 2002 and reached a record low in 2002. Water level has since increased. From 1973 - 2007, average water level elevation has declined. Variation in water levels has increased in the last 15 years.

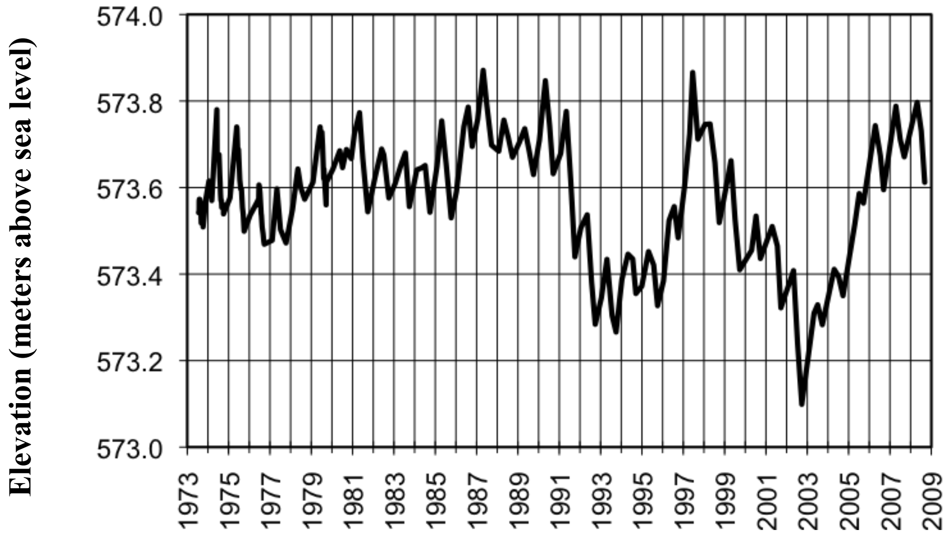

Figure 2. Historical water levels (meters above sea level (asl)) in Beatrap Lake, Alberta 1973 – 2009.

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.

Beartrap Lake was thermally stratified throughout most of the summer 2008 (**Figure 3**). June water temperature in Beartrap Lake was ~18º C from the water surface to 5 m depth (the epilimnion) (**Figure 3**), below which water cooled to ~5º C. The depth of the epilimnion increased to 7 m and warmed to ~21º C in July. Surface water temperature remained similar at 20º C on both sampling dates in August, with the epilimnion still extended to 7 m depth. The abrupt change in the thermocline pattern in September suggests Beartrap Lake underwent a complete mixing in early September, so that water temperature was constant at 15º C at all depths of the lake ("isothermic").

Dissolved oxygen (DO) concentrations illustrated a similar pattern (**Figure 3**). Surface water DO increased between June and July. In June the hypolimnion did not become completely anoxic. The depth at which DO approached zero (e.g. water became anoxic) was 7 m in July and 8 m in August. In September, the chemocline occurred at 7.5 m depth but data was only collected to 8.5 m depth, so although complete deep-water anoxia was not observed it may still have been present. Thus, from June to July, decomposition near the lakebed steadily consumed oxygen in the water column, until complete mixing occurred in September. Despite near-anoxic conditions at the lakebed, the oxygen levels in the surface layer were within the acceptable range for surface water quality throughout the summer, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L).

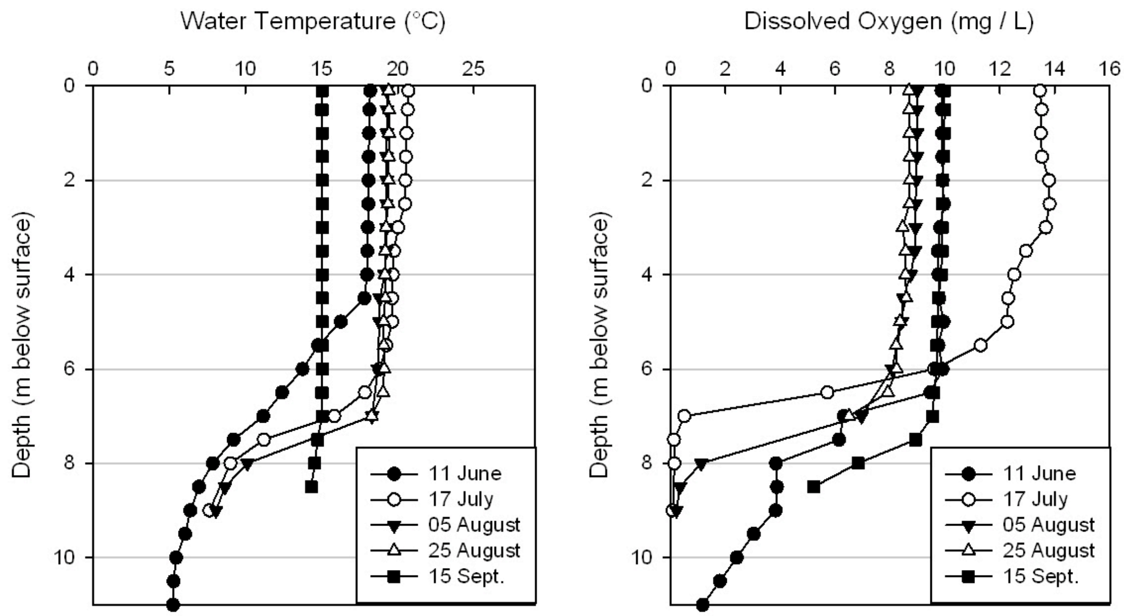

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Beartrap Lake during the summer of 2008.

Water clarity and Secchi Depth

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved coloured 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 biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

Beartrap Lake was slightly turbid in 2008. During the summer, light penetrated to an average ~30% of the total lake depth (average Secchi disk depth of 3.3 m; **Table 1**). Water clarity decreased significantly from June to July, as particles became suspended in the water column following spring runoff into the lake. The Secchi disk depth was lowest in early August (Secchi depth = 2.5 m) when algal production was rapidly increasing (**Figure 4**) and suspended particles were likely high. Algae consumed suspended particles, and as algal biomass peaked in late August, water again began to clear. Water clarity during late August (Secchi depth = 3.75 m) was nearly the same as in September (Secchi depth = 3.5 m). Maximum water clarity was observed in June (Secchi disk depth = 7.5 m). During September, suspended solids were removed from the water column via algal consumption or settling. Algal die-off and settling increased water clarity in September.

Water chemistry

Based on lake water characteristics, Beartrap Lake is considered eutrophic (see *A Brief Introduction to Limnology* at the end of this report). Given that lakes in Alberta tend to be productive, Beartrap Lake is fairly average in nutrient concentrations and algae biomass. Total phosphorus increased slightly between June and July, decreased from July to August as it was consumed by algal growth, and began to increase again (but remaining well below June/July levels) in September (**Figure 4**). Correspondingly, chlorophyll *a* concentrations (a measure of algae biomass) increased from June to July, began to decrease in late July through August to subside back to June levels, and underwent a second bloom in mid-September that slightly surpassed mid-July concentrations. Total Kjeldahl nitrogen remained nearly constant through the summer, indicating nitrogen consumption by algae in the lake were balanced by input from landscape runoff.

Beartrap Lake is well protected from acidification. In 2008, lake pH = 9.0 was well above that of pure water (i.e., pH 7). Beartrap Lake is a hardwater lake and ion concentrations are high (**Table 1**). Dominant ions include bicarbonate, carbonate, sodium, and magnesium. Atmospheric deposition of acidifying pollutants from human activities can often increase sulphate and nitrate/nitrite concentrations. Typically, increased magnesium, bicarbonate, and sulphate concentrations would indicate increased groundwater discharge, relative to surface runoff. Furthermore, reduced water levels can also cause a change in ion concentration. It is difficult to make conclusion regarding trends in ion concentrations due to the lack of long-term data for Beartrap Lake.

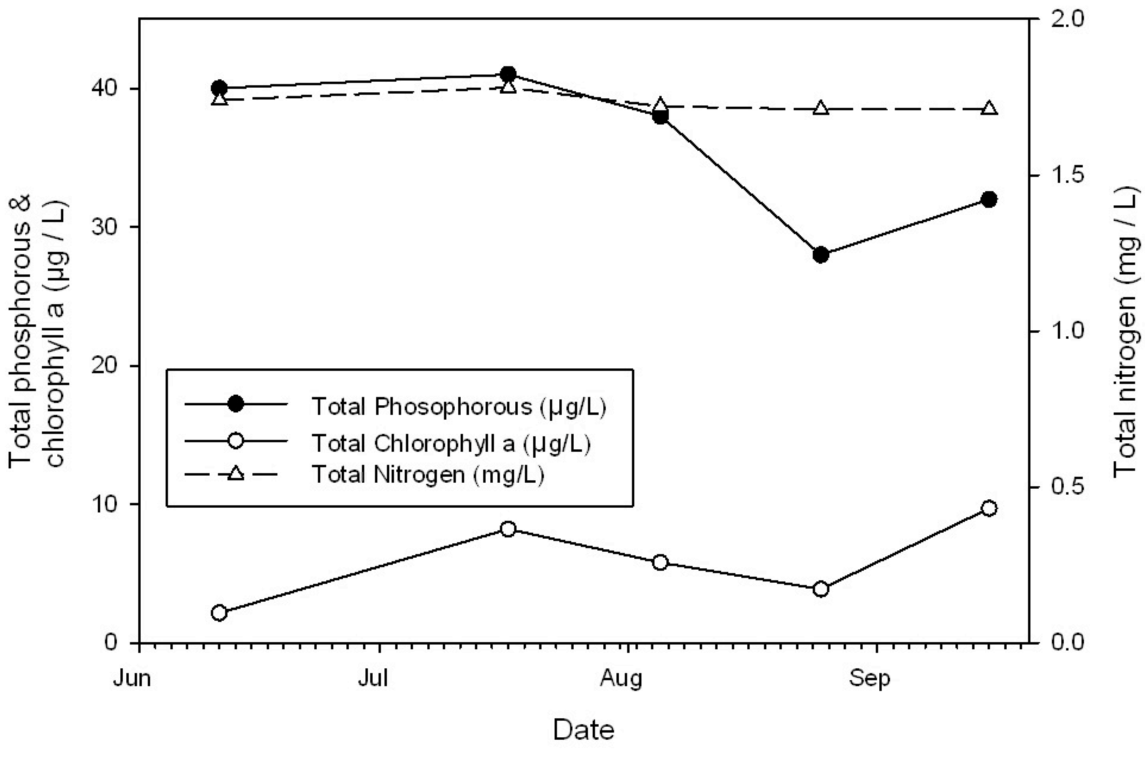

Figure 4. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Beartrap Lake during the summer of 2008.

The average concentrations of various heavy metals (as total recoverable concentrations) in Beartrap Lake during the summer of 2008 were below CCME guidelines for the

Protection of Freshwater Aquatic Life (**Appendix 1**), except for arsenic (5.23 μg/L) which was slightly above the recommended 5.00 μg/L threshold at both sampling times during the summer.

References

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

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Vollenweider, R.A., and J. Kerekes, Jr. 1982. Eutrophication of Waters. Monitoring, Assessment and Control. Organization for Economic Co-Operation and Development (OECD), Paris. 156p.

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Table 1. Mean water chemistry values for Beartrap Lake, summer 2007 – 2008.

Parameter	2007	2008
TP (μg/L)	26.5	34.8
TDP (μg/L)	13.8	17.6
Chl-*a* (μg/L)	5.0	6.0
Secchi (m)	2.5	3.3
TKN (μg/L)	1447.5	1730
NO_{2+3} (μg/L)	8*	46.8
NH_4 (μg/L)	36.5	44.6
Ca (mg/L)	8.6	9.0
Mg (mg/L)	101.8	96.0
Na (mg/L)	86	133
K (mg/L)	10.8	14.2
SO_4 (mg/L)	44.5	54.0
Cl (mg/L)	12	16.9
CO_3 (mg/L)	62.3	93.5
HCO_3 (mg/L)	457.3	618.5
pH	8.9	9.0
Conductivity (μS/cm)	1162	1150
TDS (mg/L)	702.3	716.7
Total Alkalinity (mg/L $CaCO_3$)	479.3	660

Note: TP = total phosphorus, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TKN = total Kjeldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate, Cond = Specific conductivity, TDS = Total dissolved solids.
*** one sample collected 27 June 2007.**

(Atlas of Alberta Lakes, Mitchell and Prepas, 1990).

Appendix 1

Mean concentrations of metals in Beartrap Lake, summer of 2006 - 2008. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life are presented for reference.

Metals (total)	2006	2007	2008	Guidelines
ALUMINUM µg/L	7.07	6.69	10.08	100[a]
ANTIMONY µg/L	0.0327	0.052	0.0642	6[e]
ARSENIC µg/L	4.42	4.56	5.23	5
BARIUM µg/L	1.24	4.04	4.58	1000[e]
BERYLLIUM µg/L	<0.003	<0.003	<0.003	100[d,f]
BISMUTH µg/L	<0.001	0.004	0.003	
BORON µg/L	284	292	295	5000[e,f]
CADMIUM µg/L	0.022	0.005	0.005	0.085[b]
CHROMIUM µg/L	0.52	0.402	0.450	
COBALT µg/L	0.0399	0.027	0.036	1000[f]
COPPER µg/L	0.257	0.354	2.00	4[c]
IRON µg/L	14.1	74.4	26.1	300
LEAD µg/L	0.0373	0.057	0.047	7[c]
LITHIUM µg/L	74.8	73.7	73.0	2500[g]
MANGANESE µg/L	7.33	5.73	8.06	200[g]
MOLYBDENUM µg/L	0.528	0.553	0.598	73[d]
NICKEL µg/L	0.127	0.232	0.171	150[c]
SELENIUM µg/L	0.199	0.687	0.222	1
STRONTIUM µg/L	24.6	20.1	21.7	
SILVER µg/L	<0.0005	0.0008	0.02375	
THALLIUM µg/L	<0.0003	<0.004*	0.0009	0.8
THORIUM µg/L	0.0095	0.007*	0.0148	
TIN µg/L	<0.03	0.122	0.062	
TITANIUM µg/L	0.551	1.10	0.821	
URANIUM µg/L	0.604	0.634	0.766	100[e]
VANADIUM µg/L	0.227	0.118	0.236	100[f,g]
ZINC µg/L	3.07	1.54	1.34	30

Values represent means of total recoverable metal concentrations.
* one sample collected 27 June 2007.
[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

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to 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 affected (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 fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

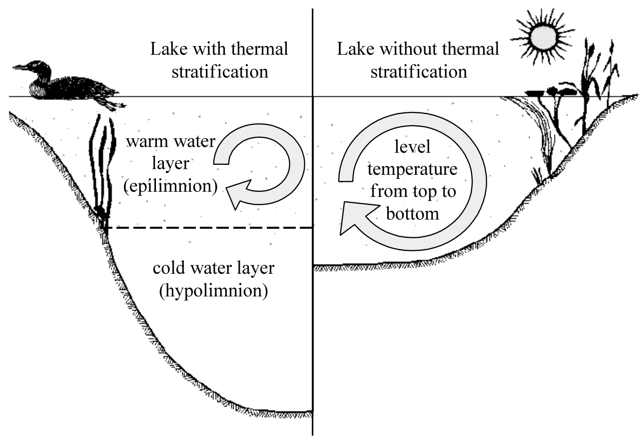

Figure 5: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 5). 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. A third layer, known as the metalimnion, provides an effective barrier between the epi- and hypolimnion. The metalimnion reflects a rapid transition in water temperature known as the **thermocline**. A thermocline typically occurs when water temperature changes by several degrees within one-meter of depth. The thermocline acts as an effective physico-chemical barrier to mixing between the hypolimnion and epilimnion, restricts downward movement of elements, such as oxygen, from the surface 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 state 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 terrestrial plants and plants and algae of tropical lakes, phosphorus is usually in shortest supply in temperate 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. Larger aquatic plants, known as macrophytes, rather than algae, dominate some highly productive lakes. 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, reflect lower-nutrient trophic states than would otherwise result if macrophyte-based chlorophyll were 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 low. Secchi disk depth, however, is not only affected by algae, high concentrations of suspended sediments, particularly fine clays or glacial till common in plains or mountain reservoirs of Alberta, also impact water clarity. 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.

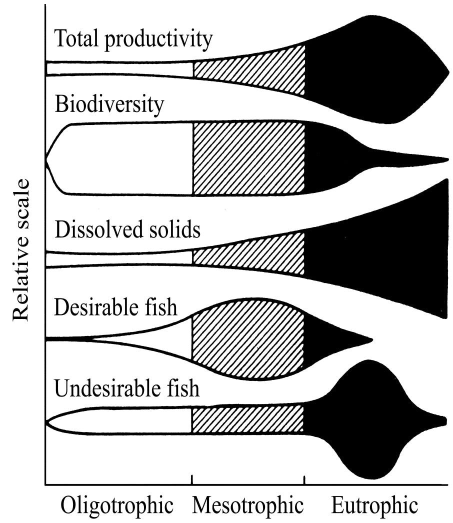

Figure 6: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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-a) concentrations, the trophic states are: oligotrophic, mesotrophic, eutrophic and hypereutrophic. The nutrient and algal biomass concentrations that define these categories are shown in Table 2 and a graph 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 Figure. 6.

Table 2: 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 and Kerekes (1982). The AENV and OECD cutoff 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.