2019 Washington Lakes Water Quality Report

Prepared January 2020

By

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WLWA Water Quality Monitor

Special Thanks to Midcoast Conservancy and
Lake Stewards of Maine/Volunteer Lake Monitoring Program

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Washington Lakes Watershed Association

Washington Lakes Water Quality Report—2019

Executive Summary

Prior to 2015, the WLWA (Washington Lakes Watershed Association), with the help of the Town engaged a paid analysis and report on lakes water quality but only on an every three years basis due to cost. Starting in 2015, under the auspices of VLMP/LSM*, WLWA volunteers undertook to create the report on an annual basis to give the town more frequent and comprehensive view of lakes quality. This is the fifth report in that series. 2019 continues to add to the comprehensive data set created by WLWA, certified by LSM and accepted into the State of Maine database maintained by the Department of Environmental Protection (DEP).

Crystal Lake (Midas 4900)

Our lakes have had reasonably consistent testing results over the past years. This year, however, showed a change in the results of testing on Crystal Lake.

In particular, Crystal experienced a significant reduction in Dissolved Oxygen in deeper water during the latter part of the summer. Typically, Crystal remains cold and with good oxygenation at depths with temperature at or below 15 degrees C despite the fact it is shallower than Washington. Because of this Crystal is a natural home to some cold water fish species (cold water fish such as trout require both cold water and oxygen to breathe). This reduction in DO at depth stresses the fish, and would precipitate a fishery change, should it continue for subsequent years. But, more bothersome is that in addition Crystal showed a new high in Chlorophyll (more plant material), consistently lower Secchi disk readings (lower water clarity), and record high conductivity (an indicator of increased possible runoff pollution).

These results were reviewed by Scott Williams, Executive Director of Lake Stewards of Maine (LSM/VLMP) who indicated that several other Maine lakes showed similar changes this summer. It has the signs of increased runoff (due to heavy rains) following periods of dryness in which organic matter breaks down, making phosphorus more soluble when carried by the storm water into the lake, resulting in higher algae (hence lower clarity and higher chlorophyll.

One year, in itself, is not a determinant, but Crystal bears close following for the next few years to see if 2019 is a trend or an anomaly.

Washington Pond (Midas 4894)

Washington Pond appeared to be more stable, with many water quality indicators continuing at a consistent level, although conductivity and chlorophyll were slightly elevated, DO and Secchi disk readings remained within range compared with past data.

Weather

Precipitation patterns have a profound effect on runoff, and in 2019 we had several rain events greater than 2”. Temperature also affects lakes, and July through October temperatures were well above normal. It is necessary to keep in mind that annual weather variations make long-term trend analysis uncertain. We may be seeing some effect of climate change. It is unclear just how this will affect the long term health of our lakes.

Invasive Species

There were no invasive plant species inspections of either lake in 2018 or 2019. Although we do not think we have any invasives, we cannot be sure without looking at high probability sites. ***This is a major weakness in our “preventative” activities and we urgently need volunteers to take on this important task***. It may be that we need to consider a closer WLWA relationship with Midcoast Conservancy to increase the resources available to Washington.
The full report with detailed analysis of various parameters follows. In addition this includes detailed descriptions and discussion of how these affect Lakes Quality.

We desperately need volunteers to carry on this important Lakes Quality Monitoring, both water testing and invasive plant patrolling. It is fun and interesting and educational, a wonderful way to spend time on our lakes in the summer. Please help.

The author is indebted to LSM/VLMP Staff and Executive Director Scott Williams (support, training and education), Midcoast Conservancy (loan of instrumentation), Linda Bacon and the Maine DEP (historical database) and the WLWA (lab test costs and moral support).

As in years past, we will close with this statement from Scott Williams:

> *The most effective way to insure that all indicators of water quality remain stable or even improve over time – is through watershed stewardship. This includes raising awareness among landowners about ways in which the effects of development on water quality can be minimized, and developing a community plan to protect and manage the watershed. Citizen watershed surveys can be very effective in raising community awareness and identifying and resolving land use problems. The Maine Volunteer Lake Monitoring Program offers workshops for groups interested in conducting watershed surveys.*

I urge you to become more involved, volunteer time, and support the Washington Lakes Watershed Association and their work. <u>With climate change, never has this been more important.</u>

Roger Cady
January 2020

*LSM/VLMP Lake Stewards of Maine (formerly known as Maine Volunteer Lake Monitoring Program).

Sampling Methodology

During the 2019 summer season, under the auspices of Washington Lakes Watershed Association (WLWA) readings were taken of both Secchi Disk (water clarity) and Dissolved Oxygen readings at least every two weeks on Washington Pond and Crystal Lake. In addition, as has been customary, in late August or early September we take comprehensive water samples which are analyzed by the State HETL (Health and Environmental Testing Lab) Laboratory. All data is submitted to the State DEP via LSM who certifies the data.

Midcoast Conservancy has been extremely helpful to loan us Dissolved Oxygen instrumentation for the entire summer. This has enabled bi-weekly DO data collection on both Washington Pond and Crystal Lake. We are indebted also for equipment to aid in the sample collection for laboratory analysis.

All water quality monitoring and sampling was completed by certified volunteer lake monitors and was completed in accordance with standard procedures for the monitoring of Maine lakes and ponds established by the Maine Department of Environmental Protection and the Lake Stewards of Maine and their Maine Volunteer Lake Monitoring Program. We owe a great debt of gratitude to LSM/VLMP for their support and training for certified monitors. The 2019 sampling was done in a manner consistent with the historical sampling of these bodies of water, and the results are comparable.

This is the first year that WLWA has run the comprehensive tests as Midcoast Conservancy personnel were not available to assist. We hope that the beneficial relationship with Midcoast will continue and can expand in 2020.

Tests Carried Out Twice a Month

Water Clarity

Water clarity readings are made using a Secchi disk and monitoring scope to determine the depth at which the disk can still be seen. The higher the number (deeper sight depth), the clearer the water. Readings were taken twice each month during the 2019 season and added to previous years data for Washington Pond dating back to 1977. Graphs compare Secchi disk depth readings for the summer period as well as showing annual data in the form of High, Low, and Average depth for each year, to give an historical reference for the bi-weekly readings.

Dissolved Oxygen and Temperature profiles

Lake water has an amount of oxygen dissolved in the water. This oxygen provides for respiration requirements of animal life, from the smallest forms up through fish in our lakes. Wind continues to cause mixing and the introduction of oxygen, as does photosynthesis by plant organisms, while respiring organisms and decomposition reduce the oxygen. Deeper water tends toward depletion in oxygen due to lower mixing and less light which reduces photosynthesis. This reduction affects fish, which must have at least 1-3 ug/l (1 ug/l is equivalent to 1 part per billion - ppb) of oxygen for adequate respiration. Various species of fish have varying temperature requirements, also. Cold water classified fish (such as Trout) do not flourish if the water is warmer than 15 -16 degrees C, hence depleted oxygen below this temperature stresses the fish. Furthermore, depleted oxygen at the bottom of a lake facilitates an anoxic process that causes the phosphorus captured and relatively harmless in the bottom sediments to be re-introduced into the water column. The level of phosphorus in our northern lakes is the single element that limits algae growth, so increasing phosphorus can promote algae blooms. More information on DO and lake turnover (spring and fall) is included in Appendix II.

Tests Carried Out Annually

Our comprehensive tests provide that we collect water samples for laboratory analysis in two ways. The first is we collect water from a column of water from surface to within a couple of feet of the bottom. This sample of water from all depths is called the Core sample. In addition, a sample of water is collected only from just above the bottom to provide an analysis of the element phosphorus near the bottom (bottom grab).

Laboratory Analysis then reports on the following parameters from the core sample:

Phosphorus (partial determinant potential for algae growth)
Chlorophyll-a (indicator of algae and other microscopic plant materials present)
Conductivity (indicator of dissolved solids in the water and pollution level from runoff
pH (indicator of alkaline or acid levels in the lake which will affect certain plant species)
Alkalinity (indicator of ability of lake to buffer changes in pH from plant or introduced causes)
Color (indicator of amount of humic acids and tannins leached into the lake, and it affects water clarity)

The reader is referred to Appendix I for more detailed explanation of each measured parameter and Appendix II for comparison with other Maine lakes.

2019 Weather Influences

Weather conditions can strongly influence indicators of water quality. In general high temperatures can increase bio-production (more algae growth) and more rainfall causes higher pollutant runoff (primarily adding phosphorus) resulting in more bio-productivity since phosphorous is the limiting nutrient in most Maine lakes. 2019 temperatures were not consistently higher than historical, but rather seemed to oscillate. We experienced a particularly warm January to February which probably did not affect lake chemistry, however July-September was significantly warmer than ”normal”. The adjacent chart shows the running mean temperature deviation for Portland.

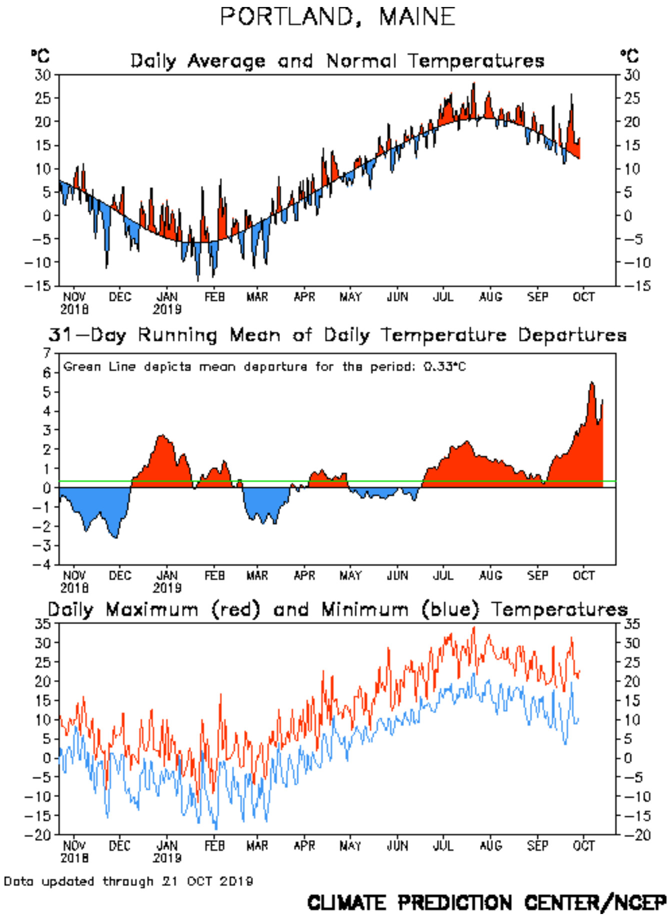


Figure 1

Precipitation

While rainfall accumulation was above normal by four inches November 2018-October 2019, the significant parameter to keep an eye on is peak rainfall events, which increase significantly the potential for runoff pollution. Runoff has the single greatest pollution impact because it increases Phosphorus introduced from eroding soil where it naturally occurs. We have had several two inch rain events in 2019, and the events of December, January, and February occurred during unusually warm periods, increasing the erosion potential. Although we do not see visual evidence of changing erosion around either Crystal or Washington, something has definitely changed in the Crystal watershed (see analysis in Crystal portion of this report).

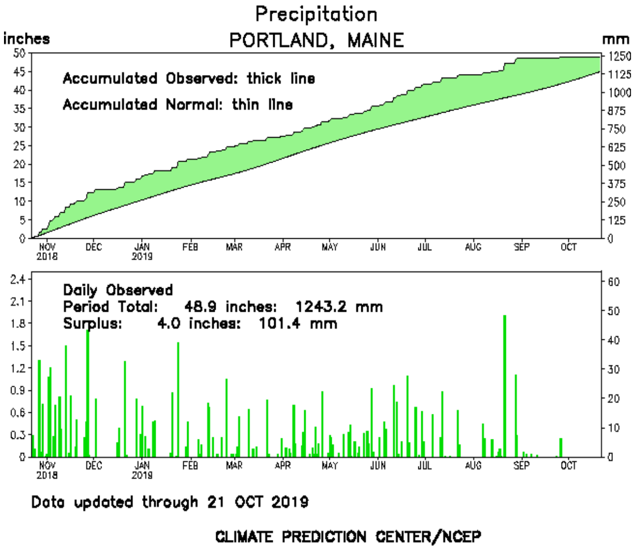


Figure 2

Crystal Lake (Midas 4900)

Several tests showed significant deviations from historical data in Crystal Lake. The following will go through the various findings for 2019 and compare them to historical data.

Water Clarity

Secchi disk readings were consistently lower for Crystal during the entire summer. Figure 3 shows average monthly readings compared with prior years. It can be noted that there is significant deviation. In Figure 4 we look at annual high-low-average numbers dating back to 1997, it is clear that Crystal water clarity is at its lowest since 1997-1998. Red line is average and the black bars indicate range of annual readings. Average water clarity was lower than 1998, the previous low.

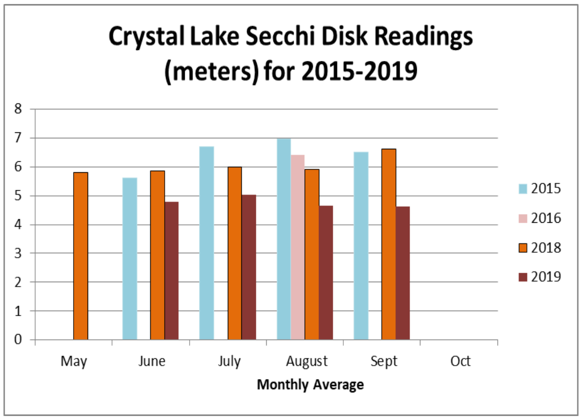


Figure 3

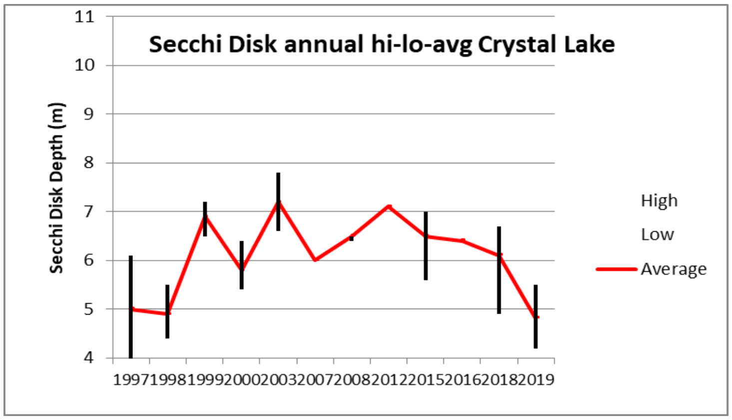


Figure 4

Dissolved Oxygen

Figure 5 shows an astounding drop in DO at lower levels of the lake, compared with historical mid-August data; the lowest level since readings have been taken starting in 1997. Figure 6 provides an insight into the DO/Temperature profile of the lake over the course of the summer. *(Figures 5 and 6 on next page)*

Using this data, and extrapolating the DO concentration at the 15 and 16 degree level in the water column, Figure 7 shows that from late July to sometime in late September, there was total depletion of oxygen in the water at 15 degrees (or below) and mid-August to mid September at 16 degrees or below.

Date	6/7/2019	6/19/2019	7/3/2019	7/16/2019	7/31/2019	8/14/2019	9/4/2019	9/19/2019/	9/29/2019
DO at 15 deg	9.5	7.4	4	2.4	1.0	<1	<1	<1	4.7
DO at 16 deg		7.5	4.8	3.6	1.8	<1	<1	4	5.1

Figure 7

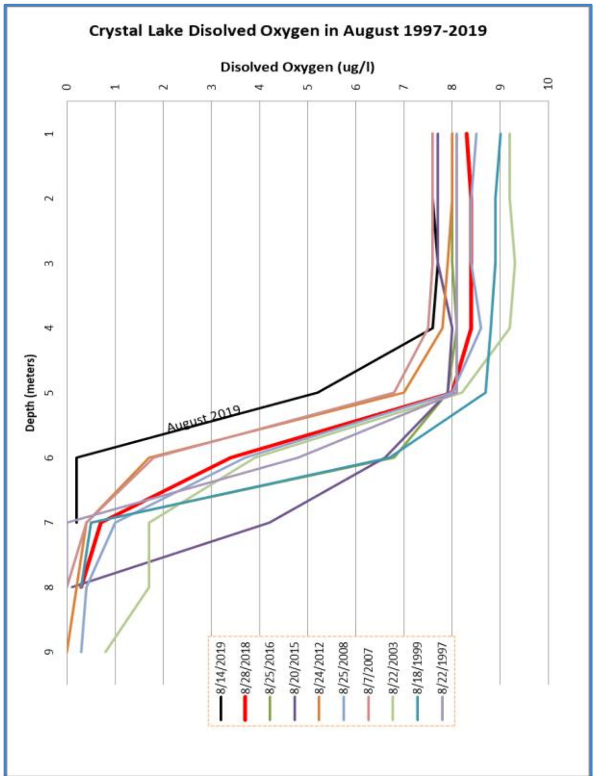


Figure 5

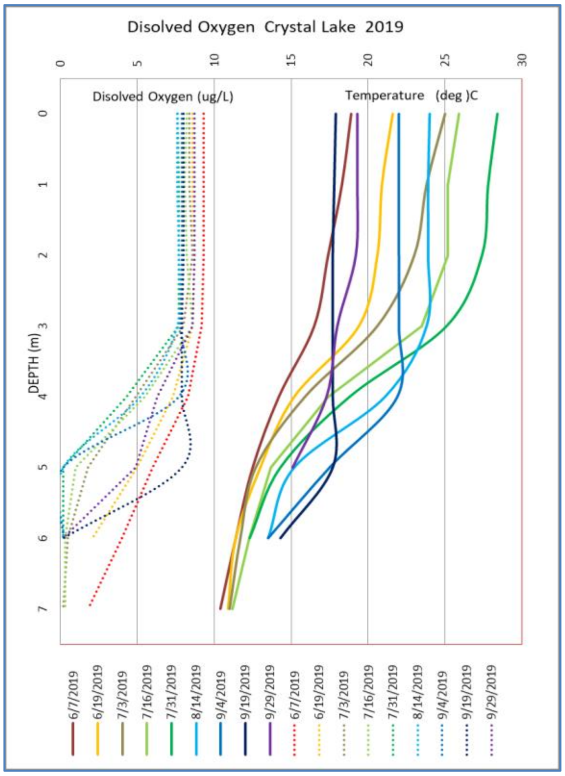


Figure 6

Chlorophyll-a

Measurements of cholorophyl indicate amount of green pigment found in all plants and therefore is an indicator of amount of algae in the water. Figure 8 indicates these readings since 1997, and it was higher than any previous historical level. Variations are expected but new record values increase importance of this measurement.

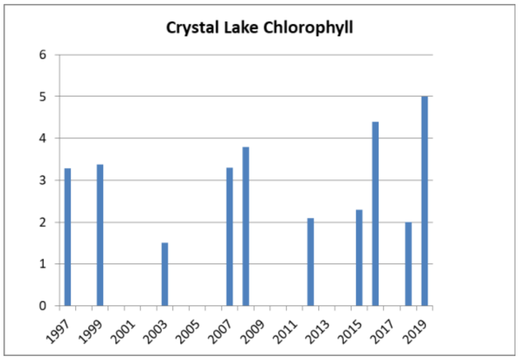


Figure 8

Phosphorus

Both readings of this element (Figure 9) in the water column (blue) and at the bottom sample (red), are within historical ranges. Both readings were typical, however bottom readings were high.

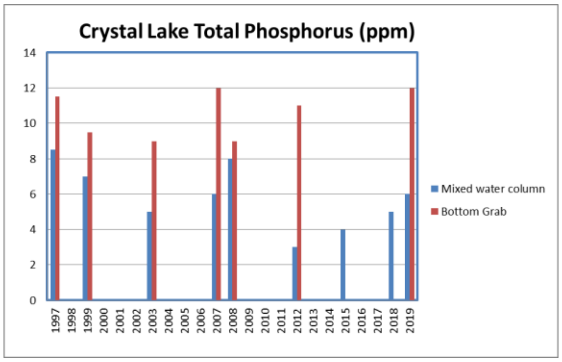


Figure 9

Crystal Lake Water Chemistry

			Long Term Readings through 2018			
Parameter	**2018**	**2019**	**Low**	**High**	**Average**	
Conductivity	lost	51.0	5.0	46.0	30.0	New High
Alkalinity	lost	5.0	4.0	5.8	4.3	
Color	lost	20.0	8.0	30.0	12.0	
pH	lost	6.8	6.4	6.9	6.6	
Chlorophyll-a	2.0	5.0	2.0	4.2	3.1	New High
Phosphorus	5.0	6.0	3.0	8.5	6.1	

lost=sample lost or contaminated at HETL lab

Figure 10

Conductivity

This measurement is an indicator of potential runoff pollution as it is an indicator for the amount of dissolved solids in the water. This has been measured only three times for Crystal, but 2019 set a new high. Unfortunately, samples taken in 2018 were lost by the HETL lab, so we have no comparison directly with last year, however the reading in 2016 was 5. We will make sure that this parameter is checked in 2020. Figure 10 includes the data.

pH, Alkalinity

Measure of alkaline or acid state of the water, pH affects what plants find home in the lake. (Figure 10). Alkalinity is a measure of the ability of the lake to buffer changes to pH. Both have remained stable.

Color

This measures pigmentation due primarily to humus and tannins in the water. Color is in the mid of historical range.

Commentary

The result of these tests raises the potential of fairly significant change in the lake in 2019. Three factors are outside of normal ranges: Dissolved Oxygen/Temperature profiles, Chlorophyll-a, and Conductivity. In addition, Water Clarity has tied with to new low. If this persists, then the reduced oxygenation at lower levels of the lake can in the long term cause strain on cold water fish species. It also could promote increased Phosphorus release from bottom sediments, which would promote greater algae growth. Chlorophyll-a test results point to more algae in the water during the test in 2019. Conductivity is an indicator that there may be higher runoff pollution in Crystal in 2019. This may indicate that we should schedule a watershed survey of the Crystal basin in 2020.

This set of changes could be explained by changes in the rainfall which results in larger individual rain events, increasing storm water runoff into the lake. Runoff is high in phosphorus which is naturally found in Maine soil. It also comes from organic matter on land which is a source of water soluble phosphorus. Increasing P increases the metabolic rate of planktonic algae. This causes decline in water clarity, and the increase in Chlorophyll confirms such activity. As the algae falls to the bottom, and decays, it uses up oxygen in the hypolimnia layer (lower colder water layer) resulting in a lower dissolved oxygen reading.

It is important to note that a single year does not, in itself, say this will be a permanent thing but it puts us on alert that there is a potential for change. Running comparison of the next couple of years with historical data is most important. In the case of Crystal, the historical data is rather sparse and has not been consistently collected year after year, making such comparisons more difficult. It is unfortunate that we (WLWA) did not collect Crystal data in 2017 due to manpower shortage, and further that several of the chemical analysis sample parameters for 2018 were either lost or contaminated in the State HETL lab (which is the recommended standard lab for processing test results).There should not be undue alarm at this time, but we are on alert.

Washington Pond (Midas 4894)

Water Clarity

Scchi disk readings for Washington Pond were pretty typical, nothing major to note. Figure 11 gives the average monthly readings, while Figure 12 shows values against a range of annual average prior readings dating back 42 years.

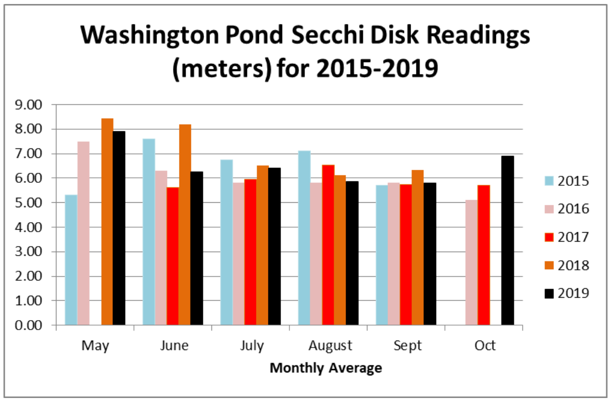


Figure 11

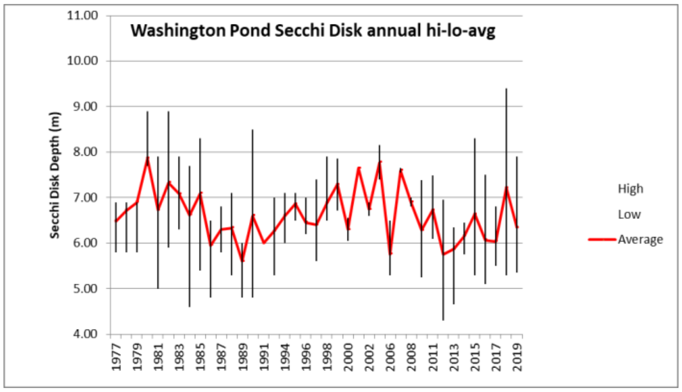


Figure 12

Dissolved Oxygen

We have the advantage that dissolved oxygen profiles were taken in several years since the 1990's on Washington Pond as well as those taken four times each the summer of 2015 through 2017 and twice a month in 2018-2019 by the WLWA water quality team. To simplify presentation the graph in Figure 13 (next page) shows the results of DO readings in August for year to year comparison, current year in black, 2018 in dashed blue, and 2017 in red.. 2017-18 fall in the middle of the data set while 2019 is toward the upper end.

Figure 14 shows the temperature profiles that we saw for the 11 DO readings in 2019.

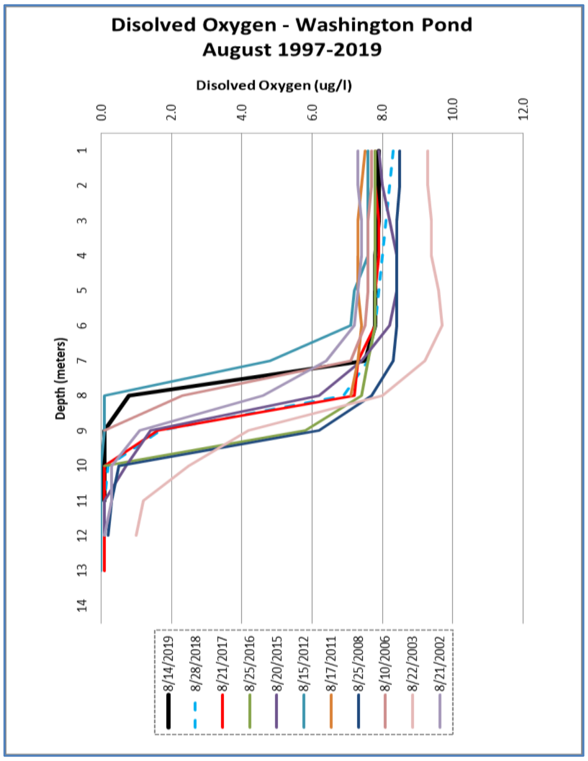


Figure 13

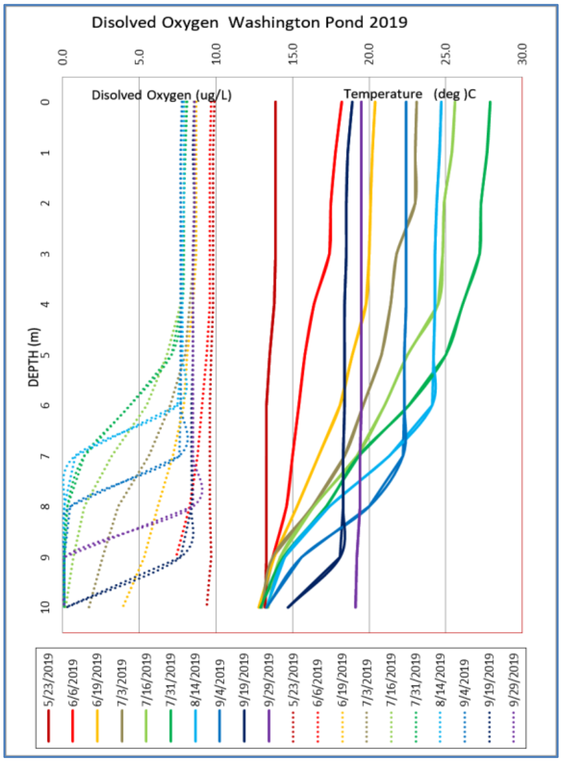


Figure 14

According to Inland Fisheries and Wildlife biologist Scott Davis, who presented at the 2015 annual meeting of WLWA, the observed lack of any cold water regions containing oxygen levels above 2-3 ppm (necessary for good fish health) is a concern for the viability of cold water fish stocking programs on Washington Pond. The State now no longer stocks Trout in Washington Pond.

Chlorophyll a

Samples from a 10 meter core sample in early September showed Chlorophyll at 4.0 ug/l, (Figure 15) higher than last year but well within historical range of 1.8 to 5 so not a significant change. Chlorophyll-a (CHL) is the pigment measured in lake water that is used to determine the concentration of algae in the water.

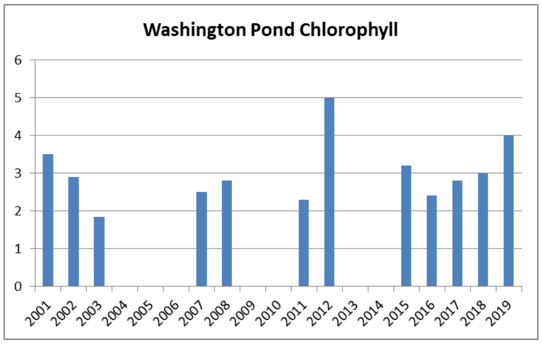


Figure 15

Phosphorus

A phosphorus sample taken from the core water column sample measured 6 parts per billion (ppb), slightly below historical average of 6 ppb. As phosphorus is the nutrient that most directly influences the growth of algae in lakes and ponds and phosphorus concentrations in the 12-15 ppb range have been associated with algal blooms in some Maine lakes, these lower sample concentrations are a good trend. A bottom sample showed higher concentration than past history. (Figure 16). Bottom samples help us understand the potential for anoxic release of phosphorus from the bottom sediments. This parameter will be closely watched in the future as it could indicate anoxic re-introduction of Phosphorus into the water column.

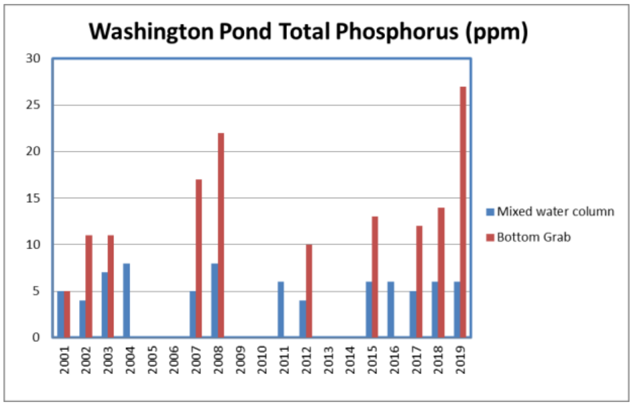


Figure 16

Washington Pond Water Chemistry

			Long Term Readings thru 2018		
Parameter	**2018**	**2019**	**Low**	**High**	**Average**
Conductivity	36.4	38.9	24.0	40.0	34.0
Alkalinity	5.0	6.0	4.3	8.0	5.0
Color	7.0	12.0	5.0	15.0	7.0
pH	6.7	6.7	5.6	7.1	6.6
Chlorophyll-a	3.0	4.0	1.8	5.0	2.8
Phosphorus	6.0	6.0	4.0	8.0	5.8

Figure 17

Ph and Alkalinity

The pH of the sample was 6.7, typically average and alkalinity was 6.0, within historical range.(see Figure 17)

Color

This indicator of humic content was also up at 12, slightly higher than historical average.

Commentary

In general, Washington Pond continues to be quite stable with water quality very good. No significant issues were uncovered in 2019. Low oxygen bottom conditions promote anoxic release into the water column of phosphorous that is bound in the bottom sediments and increases potential for higher bio-productivity of the lake. *This is a balance we must watch if climate change affects bio-productivity and hence oxygenation.*

Items Common to both lakes

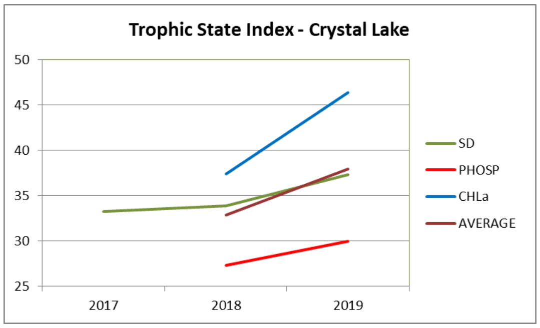
Algae

Gloeotricchia echinulata, a planktonic blue-green algae that looks like small grains in the water, has been on the increase in Maine lakes in recent years. This phenomenon is not well understood. Gleo was sighted in Washington Pond for only about two weeks in late August of 2016, the first time it was recorded in Washington Pond. We encountered it in 2017 for a longer period of time, but in relatively sparse densities mid August to late September. 2018 it started occurring in early July and peaked in early September. By mid-September it was completely gone. In 2019 it was sighted only once in very low concentration. Crystal had sparse population in 2018 and none in 2019.

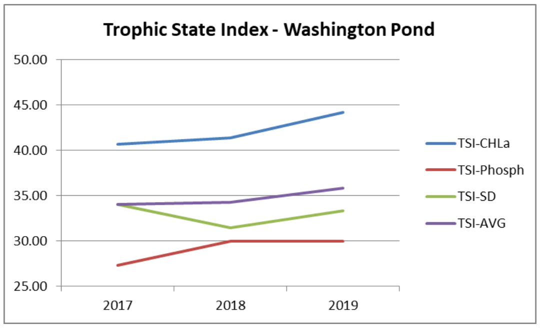
Lakes Classification

<u>Trophic State Index</u>

Trophic State is a classification system to help determine whether a lake is oligotrophic (good water quality), mesotrophic, (fair water quality) or eutrophic (poor water quality). Various definitions can be found but typically the oligotrophic-mesotrophic line is somewhere between 40 and 50 on the TSI index. TSI can be based on three different parameters, Secchi Disk (SD readings, Chlorophyll-a readings, and Phosphorus levels. Figure 18 and 19 show recent data for both lakes. The average is the best line to track.



This places both lakes in an Oligotrophic State with an anoxic hyperlimnia due to bottom oxygen depletion. We would like to see the TSI remain under 40. Above 40 would push our classification towards Mesotrophic and a lower overall water quality.



Conclusions

We are blessed with two very fine lakes in the Town of Washington, and we need to keep them that way. Water quality is affected by many things, and climate change will no doubt be one. There are things which we, as residents, can control. One is to limit any runoff directly into the lake. This occurs frequently where unpaved launch sites approach the water’s edge. Sand and silt contains harmful phosphorous (naturally occurring) and this can and does affect water quality.

This means additional diligence, especially if changes continue in Crystal Lake.

In addition we do not have any known animal or vegetable invasive species in the lake. This remains only as we are diligent in not bringing them into the lake on boats or trailers during launch and retrieval. *We should have an invasive plant patrol for our lakes,* and we need volunteers to step up and start this important preventative operation on our lakes; it can be a fun and social event along with doing important work. Please, if you can, volunteer to help. Training and education is available, and you don't have to do everything yourself.

Roger C. Cady
January 2020

Appendix I – Water Quality Indicators and Their Measurement

Secchi Disk Transparency -A Secchi Disk measures water transparency (how clear the water is). This simple test can characterize lake water quality and identify changes over time. (VLMP)

Dissolved Oxygen & Temperature - An adequate supply of dissolved oxygen (DO) in lake water is essential to fish and other aquatic life forms. DO is a sensitive indicator of lake water quality (VLMP).

More about Dissolved Oxygen & Temperature at Water on the Web. (included in Appendix III of this report)

Phosphorus - Phosphorus is the nutrient that most influences the growth of algae in lakes. (VLMP)

Chlorophyll a - Chlorophyll a, a pigment found in algae and other plants, can be used to estimate the population of algae in a lake. (VLMP)

Color - Natural water color is important to consider when assessing water quality. (VLMP)

Specific Conductance - Monitoring conductivity can help determine if pollutants are entering a lake. (VLMP)

pH (Acidity) - Among other effects, pH helps determine which plant and animal species can live in a lake. (VLMP)

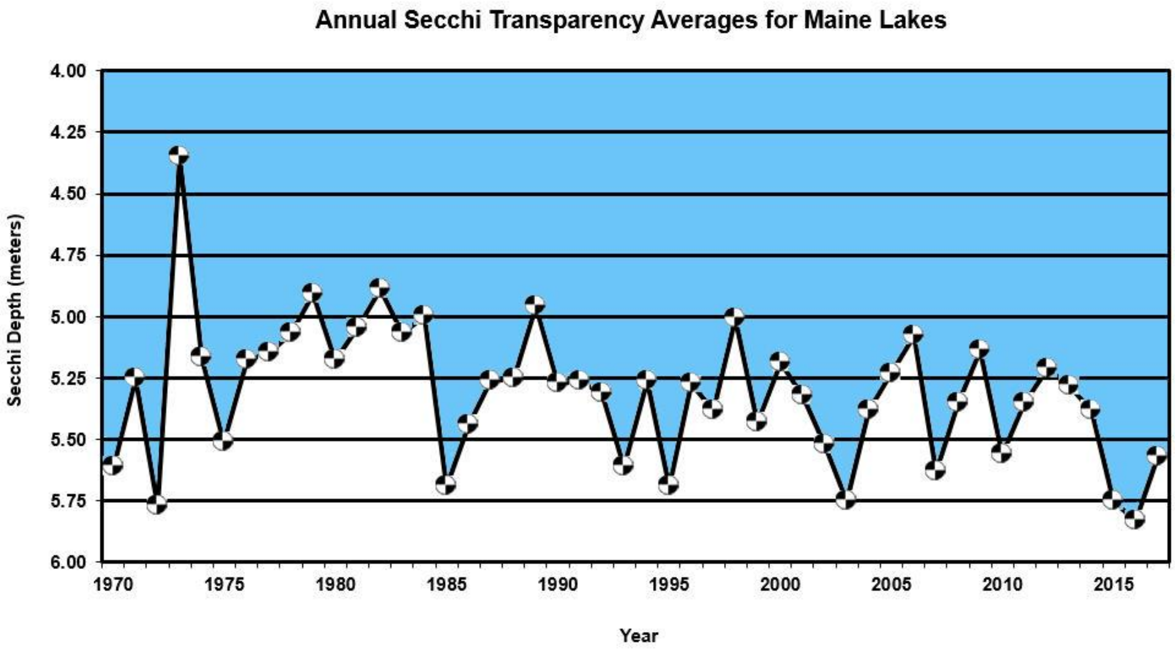
Alkalinity - Alkalinity of the lake determines the capacity of the water to buffer from changes in pH. (VLMP)

Methods and Information on LSM Measured Lake Water Quality Indicators

There are many imminent threats to Maine lakes. Near the top of the list, and perhaps the most pervasive, is the potential for lakes to become nutrient enriched and more biologically productive as a result of development in lake watersheds. This condition is characterized by declining water clarity (transparency), resulting from an increase in the growth of algae. Excess algae in lake water can cause a disturbance to the normal equilibrium of the aquatic ecosystem. As algae die and decompose, bacteria consume oxygen that is dissolved in the water. Increased algal growth can lead to a decline in oxygen levels, especially during the warm summer months. Oxygen loss can reduce critical habitat for coldwater fish (trout and salmon), and it can accelerate the decline of water quality.

The enrichment of lakes with the nutrient phosphorus and excess algae, resulting from watershed development, is referred to as “cultural eutrophication” (CE). Stormwater runoff from disturbed or developed areas of lake watersheds typically carry high concentrations of phosphorus, sediment particles, and other pollutants considerable distances, eventually flowing into a lake. Lake watershed boundaries may be situated close to the shoreline, or they may extend for miles away from the lake. In either case, stormwater runoff from developed areas of lake watersheds is a potential threat to water quality, unless conservation practices are in place to control stormwater runoff.

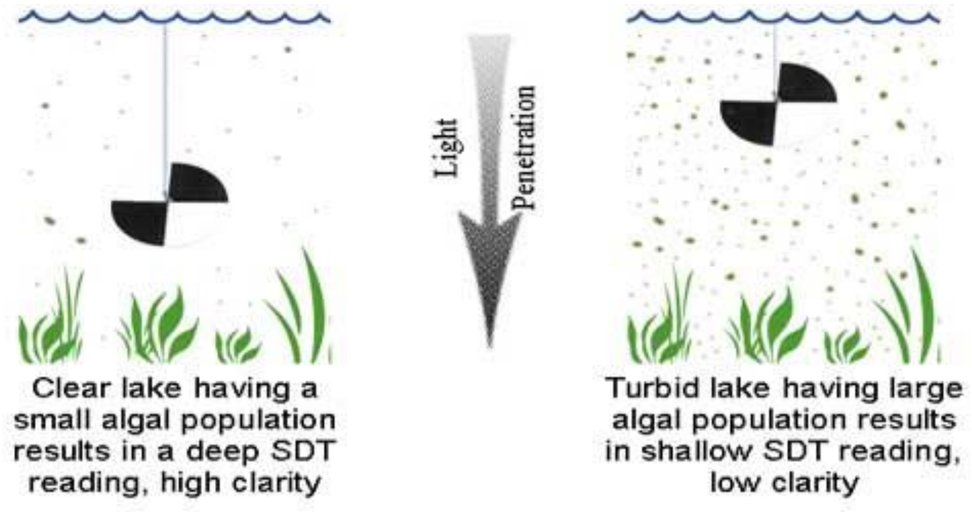
For this reason, the primary focus of volunteer water quality monitoring is the collection of information related to changes in lake biological productivity over time. Water quality data gathered by volunteers can be used to determine whether individual lakes are becoming more productive, less productive, or are stable. Many years of data are generally required to make these determinations with confidence. To learn more about becoming a volunteer water quality monitor, visit our [Training & Certification]() page.



Measuring Lake Water Clarity (Transparency) With A Secchi Disk

[Secchi Disk Transparency Long-term Data Distribution]()

One simple method of assessing the effect of cultural eutrophication in lakes is to measure the concentration of planktonic (suspended) algae in the water. Algae are at the base of the lake ecosystem food web. Volunteer water quality monitors begin monitoring their lake by measuring Secchi disk transparency. The Secchi disk is a simple device that is used to estimate algal concentrations, based on water clarity. Volunteers in the LSM are provided with a viewing scope and a Secchi disk that is attached to a calibrated line. They are instructed on the procedure for taking a Secchi disk reading by training staff. Ideally, readings should be taken a minimum of twice monthly from May through September or October. This frequency is optimum for identifying water quality trends over time. Readings are generally taken at the deepest point in a lake.



Clear lake having a small algal population results in a deep SDT reading, high clarity

Turbid lake having large algal population results in shallow SDT reading, low clarity

The Secchi disk is generally a reliable device for quickly and inexpensively assessing lake water quality. The primary uses of Secchi transparency data are:
1) to characterize or define the existing water quality of a lake, and
2) to identify and track long-term water quality trends.

Secchi disk transparency is an *indirect* water quality indicator, because an assumption is made that water clarity is affected primarily by algal growth in the water. That assumption is reasonable in most cases. However, other factors may influence transparency, including the amount of sediment that is suspended in the water, and natural water color.

Natural color and suspended sediments vary widely from one lake to another. Color is influenced by the concentration of natural dissolved organic substances in the water. These “humic acids” can stain the water in some lakes to the point where light penetration into the water column is substantially attenuated. Shallow lakes may be subject to moderate concentrations of re-suspended bottom sediments in the water column, resulting from wind turbulence. Both color and sediment can limit the utility of Secchi transparency data as an indicator of biological productivity. However, for most Maine lakes, Secchi transparency is a reliable and relatively accurate method for assessing water quality.

The tiny plants (algae or phytoplankton) and animals (zooplankton) that are suspended in lake water influence transparency. These living aquatic communities undergo seasonal and annual growth cycles, resulting in changes in their overall density, and in their location in the water column. Secchi transparency is often at a low point soon after the ice melts in the spring. That is when lakes mix, or “turn over,” causing nutrients and sediments from the lake bottom to become suspended in the water for a period of time.

Silica that is swept up from the bottom sediments stimulates the growth of diatoms, a type of algae that experiences peak growth in the spring and fall (see diagram below). Diatom “blooms” often result in a brief period of reduced transparency in lakes. As the water warms and stabilizes during the summer, other types of algae will dominate the water column, depending on water temperature, nutrient levels and other factors. Some lakes become progressively less clear through the summer months, while others may become clearer. The concentration of phosphorus in the water, the shape and depth of the lake basin, the orientation of the basin to prevailing winds, and the weather all influence water clarity, or transparency. Individual lakes are unique in the way that they respond to these influences. Volunteer lake water quality monitors learn over time what is “normal” for the lake that they monitor.

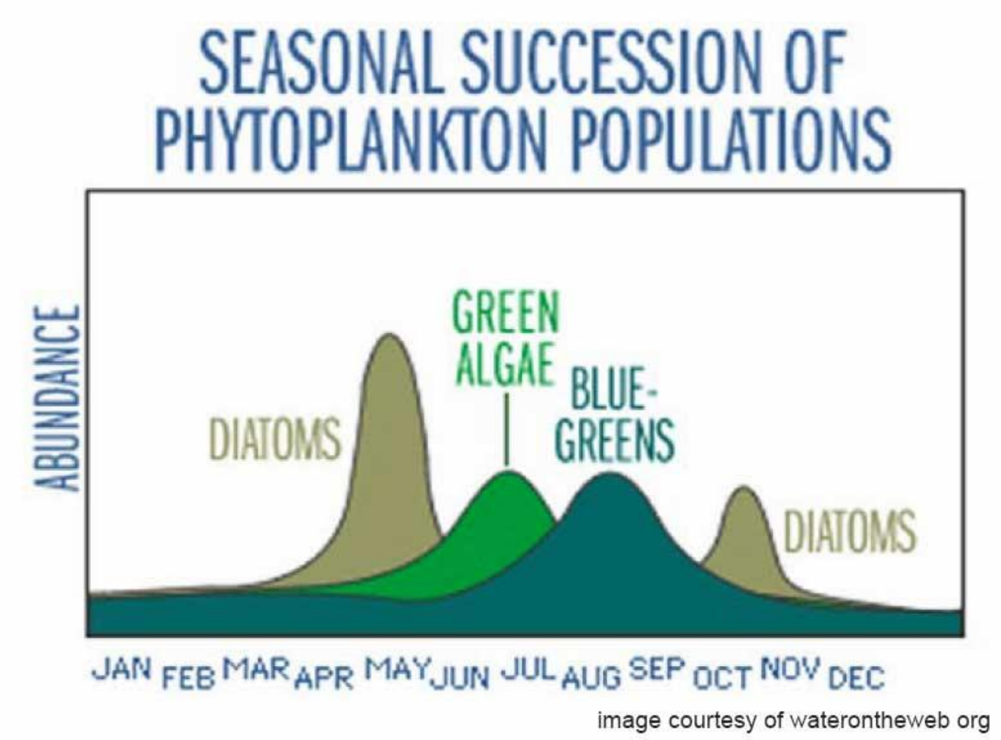


image courtesy of waterontheweb org

Many Secchi transparency readings are needed over a period of years in order to confidently detect and track trends in lake water quality. The natural variability of water clarity and other indicators of lake quality complicates the detection of trends, which is why many complete seasons of data are generally needed in order to be able to recognize a true change in water quality. Thus volunteers are asked to collect complete seasons of data from May through September—or later—each year.

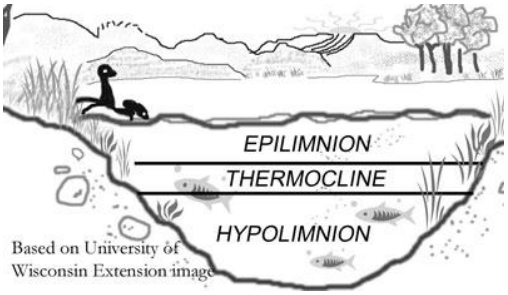
Monitoring Dissolved Oxygen and Lake Water Temperature

Another critical indicator of the health and quality of lakes and ponds is the concentration of oxygen that is dissolved in the water. Dissolved oxygen (DO) levels in lake water are influenced by many factors, including water temperature, the concentration of algae and other plants in the water, and the amount of nutrients and organic matter that flow into the water body from the watershed. Oxygen is produced through plant metabolism (photosynthesis), and it is consumed during respiration and decomposition. Oxygen in lake water is also influenced by wind and wave action through weather events and the exposure of surface water to atmospheric sources.

An adequate supply of dissolved oxygen in lake water is essential to fish and other aquatic life forms. DO is also a sensitive indicator of change in water quality, and of the ability of a water body to support aquatic life. The loss, over time, of DO in the deep areas of a lake, especially during summer months, may indicate that the ecosystem is stressed and changing.

Thermal Stratification

As lake water is warmed in the summer the water in deeper lakes forms three distinct temperature layers:



Based on University of Wisconsin Extension image

- warmer (less dense) epilimnion layer at the surface
- the thin thermocline (transition) layer
- the cold and deep hypolimnion layer

Biological activity peaks in lakes and ponds during the warm weather months. It is also at this time that the phenomenon of thermal stratification (see Thermal Stratification at right) occurs. The combined influence of the two processes has a pronounced effect on water chemistry, and in particular on dissolved oxygen levels. The physical isolation of deep, cold water at the bottom of a lake from the surface water during summer stratification prevents the oxygen supply in the deeper water from being replenished. The period of isolation varies from one body of water to another, and depends on depth, and the influences of weather. Stratification may last from several weeks to a few months and it may exist only during warm, calm periods in shallower waterbodies.

Some oxygen loss occurs naturally during the summer months as water temperatures rise, because the solubility of oxygen in water is inversely proportional to the water temperature. In other words, cold water is able to contain more oxygen than warm water (all other factors being held equal.) However, as lakes become more biologically productive, and organic matter accumulates in the system, the potential increases for oxygen levels to decline as the organic matter decomposes in deep, stratified areas. Oxygen depression or depletion can stress fish and other aquatic biota, and under certain circumstances, it can cause an acceleration in the decline of water quality.

Volunteer monitors are trained to measure oxygen concentrations in the water using inexpensive chemical kits and a simple sampling device. This method is accurate and reliable, although somewhat time-consuming. The temperature of the water must also be recorded for each oxygen reading. A more costly, but time-saving alternative involves the use of a probe that is attached to an oxygen meter via a cable. The probe and meter simultaneously measure dissolved oxygen and water temperature, and the information is displayed on the meter.

Oxygen concentrations and water temperature are generally recorded throughout the summer stratification period, from early spring through late summer and early fall, when DO levels are likely to be lowest in Maine lakes and ponds. Readings are generally taken from the water surface to the bottom of the deepest area of a lake, at one-meter intervals (depending on the individual water body.) Dissolved oxygen is measured in milligrams per liter (mg/L) or parts per million (ppm).

Monitoring Total Phosphorus Concentrations in Lakes

Total Phosphorus Long-term Data Distribution

Volunteer monitors are trained to collect total phosphorus samples from their lakes, using a simple process of obtaining a sample from a few inches below the water surface at the designated monitoring station. Total phosphorus analysis includes both organic and inorganic forms of the element that may be present in the water, in solution or in particulate form.

Phosphorus is the nutrient that most influences the growth of algae in lakes. An increase in the concentration of total phosphorus in lake water generally indicates a potential increase in biological productivity (trophic state) of the system. Tracking in-lake phosphorus levels over time is another way of monitoring changes in lake water quality. Combined with Secchi transparency readings, TP data provides additional information about lake ecosystem dynamics.

Ideally, phosphorus samples should be taken from early summer through the end of the sampling season in September or October. However, the sample analysis involves laboratory fees, and volunteers are often limited to taking one or two samples during the late summer (about mid-August), when biological activity is at a peak. The LSM arranges to provide volunteer monitors with special sampling and laboratory mailing containers to facilitate the collection of phosphorus data.

As is the case with most indicators of lake water quality, the concentration of phosphorus in lake water varies within individual seasons, and from one year to the next. Therefore it is important to collect multiple samples during the monitoring season, when possible.

Chemical Lake Data

Accurate lake water quality characterization requires that periodic “baseline” data be collected for all of the lakes in the LSM. Maine DEP and LSM staff strive to collect additional water quality data for all lakes in the program, and for other lakes and ponds with special concerns. This is done on a rotating basis, and as financial resources allow. Baseline sampling of program lakes occurs approximately every three to five years during the late summer. Volunteers who wish to assist in obtaining advanced baseline samples from their lakes may participate in special workshops offered by LSM and DEP staff. This additional information adds considerable value to data collected by volunteer monitors. Baseline data are gathered for the following indicators of lake water quality:

– Total Phosphorus Long-term Distribution
– Chlorophyll a Long-term Distribution
– Color Long-term Distribution
– Conductivity Long-term Distribution
– pH Long-term Distribution
– Total Alkalinity Long-term Distribution
– Phytoplankton
– Anions and Cations
– Zooplankton

Appendix II Distribution of Water Quality Data in Maine Lakes

The data illustrated here are based on the long-term means (average of all the historical annual averages) for each parameter measured in Maine lakes. Every effort has been made to ensure that the data are representative. This may be compared with information in the body of this report.

Data Source: LSM and Maine DEP

This page contains histograms (a graph that shows how the data are distributed for a particular variable) of the indicators of lake water quality for the lakes that have been included in each data set. The number of lakes sampled (N) varies for each lake quality indicator. The range of means, the statewide mean, and the number of lakes sampled are shown with each graph.

As you view this information, please be aware that lake water quality varies from year to year. However, the distribution of data in these graphs shows little change from year to year, because of the cumulative nature of the information being illustrated. Water quality indicators for individual lakes may show substantial annual variation.

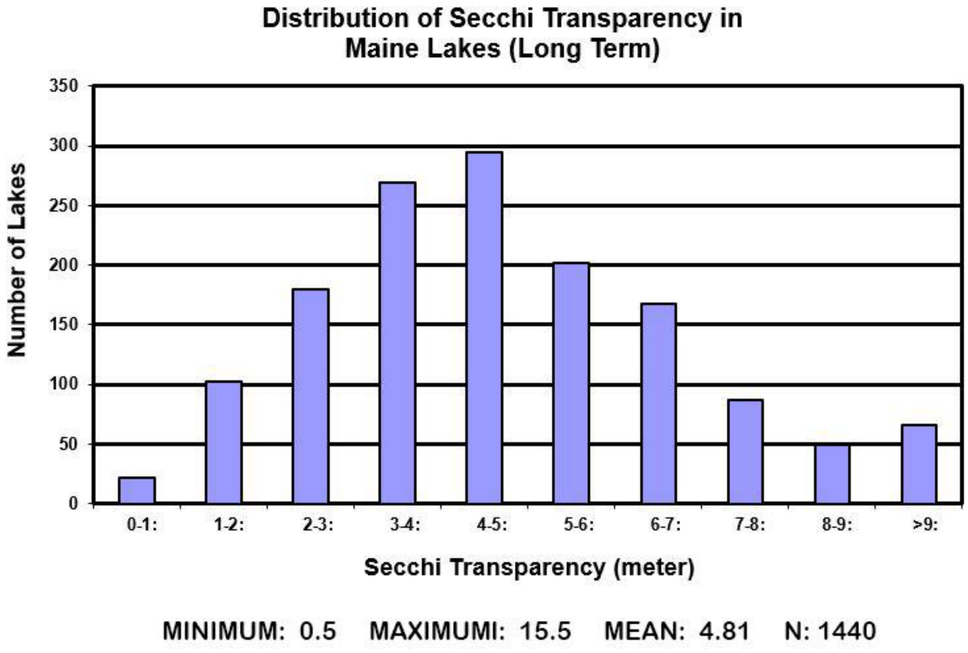
Secchi Disk Transparency

A measure of water clarity; the distance one can see down into the water column (Figure 1).

Factors that affect transparency include algal growth, zooplankton, natural water color, and suspended silt particles. Because algae are the most abundant particles in most lakes, transparency indirectly measures algal growth. Transparency values vary widely in Maine lakes. Unless a lake is highly colored or turbid from suspended sediment, transparency readings of 2 meters or less generally indicates a severe algal bloom.

Figure 1

Distribution of Secchi Disk Transparency in Maine Lakes



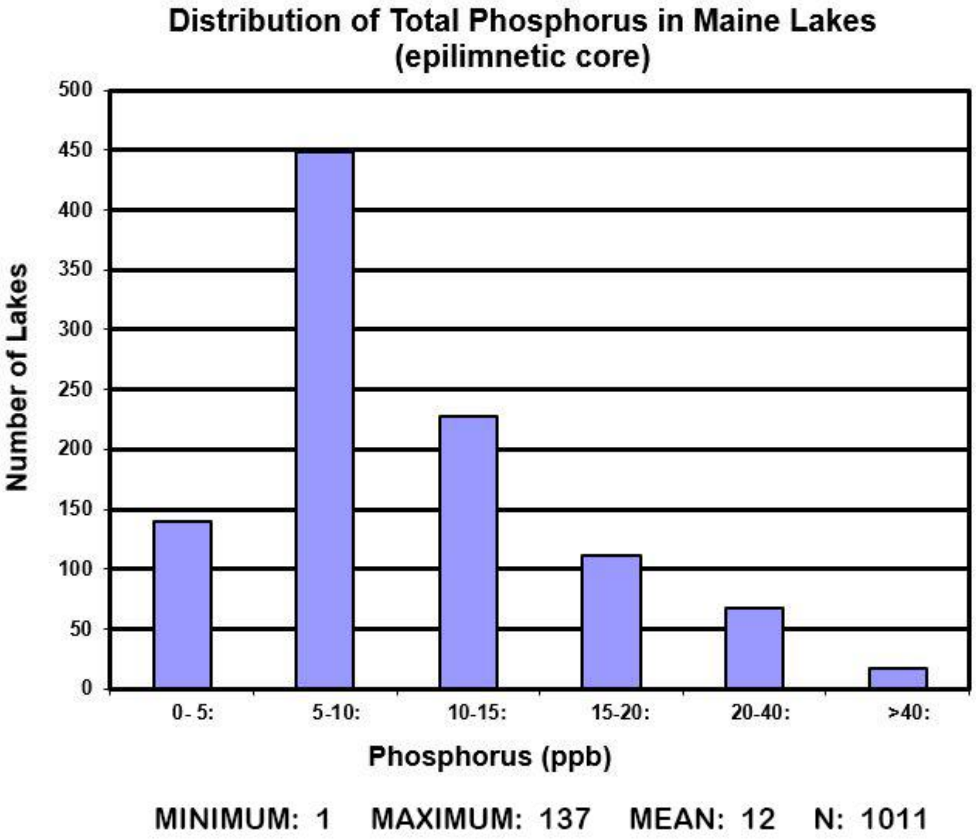
Total Phosphorus

A measure of all forms of phosphorus (organic and inorganic) in the water (Figure 2).

Phosphorus is one of the major nutrients needed for plant growth. Because it's natural occurrence in lakes is very small, phosphorus "limits" the growth of algae in lake ecosystems. Small increases in phosphorus in lake water can cause substantial increases in algal growth. Phosphorus is measured in parts per billion (ppb). Phosphorus concentrations may be based on samples taken from the surface of the lake or from discrete samples taken at specific depths, or from an integrated water column (epilimnetic core) sample.

Figure 2

Distribution of Total Phosphorus in Maine Lakes (epilimnetic core)

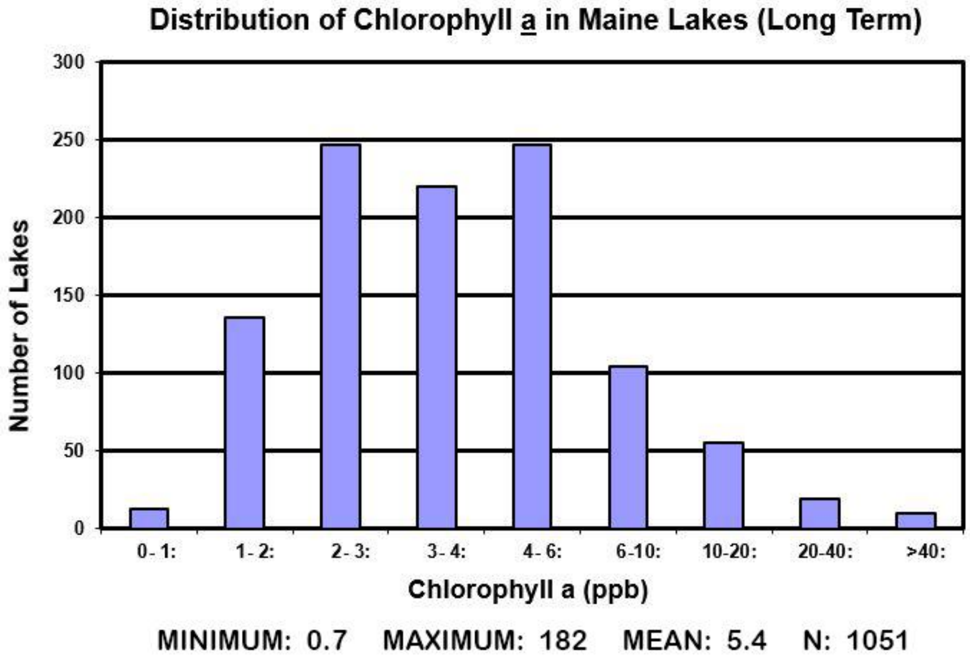


Chlorophyll a (CHL a)
A pigment found in algae and other plants used to estimate biological productivity of lake ecosystems. (Figure 3)

By measuring the concentration of CHL a in lake water, the algae population can be estimated. CHL a is measured in parts per billion (ppb). Figure 3 illustrates the distribution of Chlorophyll a in Maine lakes.

Chlorophyll a samples are generally obtained from an integrated water column sample because the greatest concentration of algal growth typically occurs from the surface of the lake to the bottom of the epilimnion or the top of the thermocline.

Figure 3
Distribution of Chlorophyll a in Maine Lakes



Transparency, total phosphorus, and chlorophyll a are sometimes referred to as "trophic state" indicators, or indicators of biological productivity in the lake ecosystem. Table 1 equates general levels of productivity for Maine lakes with levels or concentrations of the three trophic state indicators.

Table 1

Level of Productivity	Transparency (Meters)	Total Phosphorus (parts per billion)	Chlorophyll a (parts per billion)
Low	>8.0	<4.5	<1.5
Medium	4.0 – 8.0	4.5 – 20	1.5 – 7.0
High	<4.0	>20	>7.0

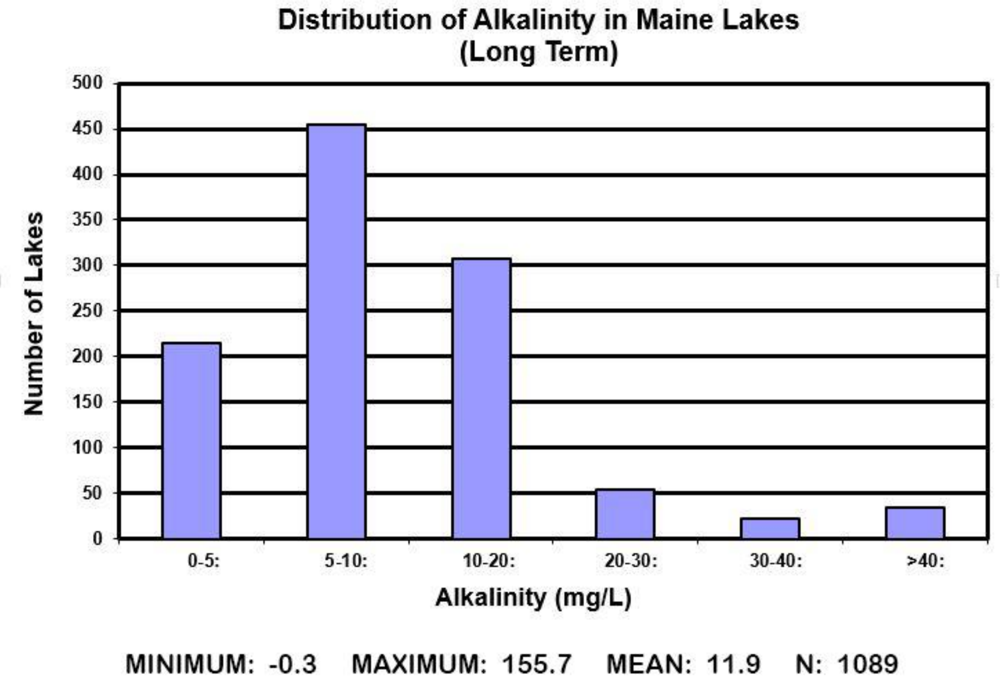
Alkalinity

A measure of the capacity of water to neutralize acids, or buffer against changes in pH. (Figure 4)

Alkalinity is also referred to as "buffering capacity." It is a measure primarily of naturally available bicarbonate, carbonate, and hydroxide ions in the water. Alkalinity is measured in milligrams per liter (mg/l). Figure 4 illustrates the distribution of alkalinity in Maine lakes.

Figure 4

Distribution of Total Alkalinity in Maine Lakes



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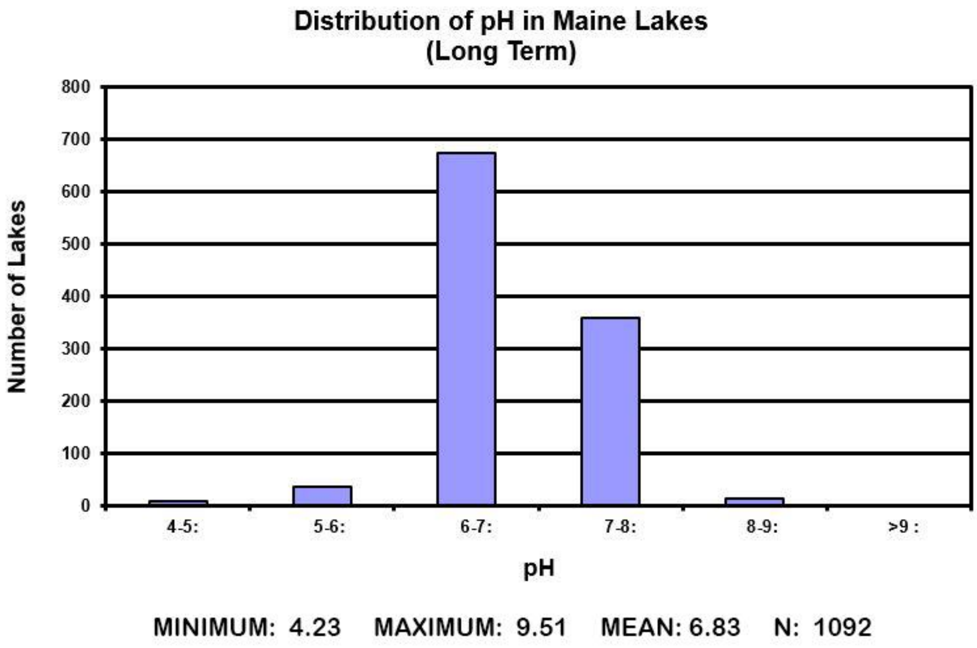
pH

A measure of the relative acid-base status of lake water. *(Figure 5)*

pH helps determine which plant and animal species can live in the lake, and it governs biochemical processes that take place. The pH scale ranges from 0-14, with 7 being neutral. Water is increasingly acidic below 7, and increasingly alkaline above 7. A one unit change in pH represents a tenfold change in acidity or alkalinity. The pH scale is the inverse log of the hydrogen ion concentration. Figure 5 illustrates the distribution of pH in Maine lakes.

Figure 5

Distribution of pH in Maine Lakes

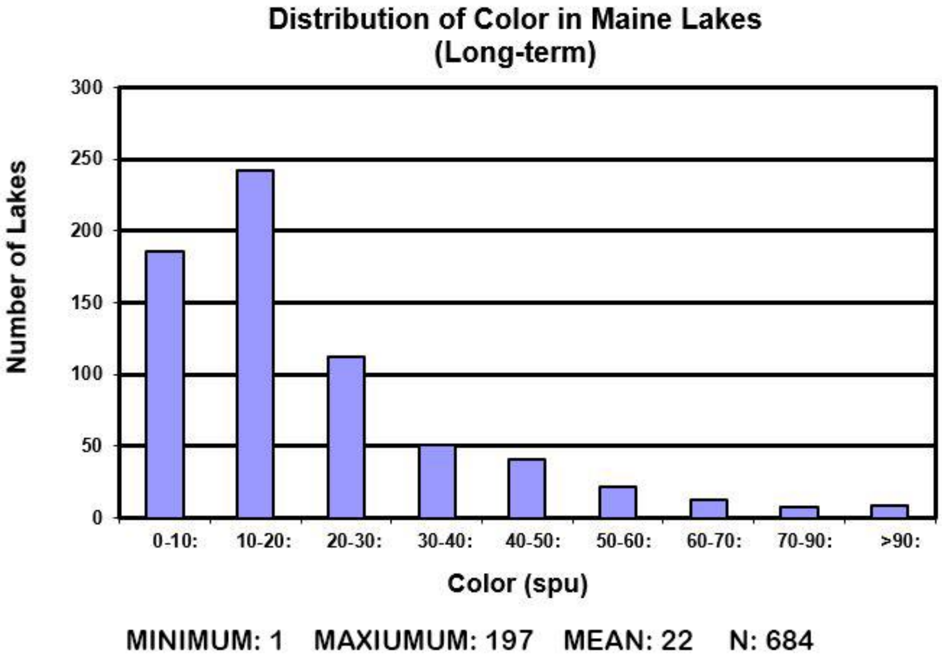


Apparent Color

The concentration of natural, dissolved, humic acids in lake water. (Figure 6)

Organic "Humic" acids leach from vegetation in the lake watershed. Color is measured in Standard Platinum Units (SPU). Lakes with color levels greater than 25 SPU are considered to be colored. This can cause transparency to be reduced, and phosphorus levels to be elevated. The water in highly colored lakes often has the appearance of tea. When lakes are highly colored, the best indicator of algal growth is Chlorophyll a. Figure 6 illustrates the distribution of color in Maine lakes.

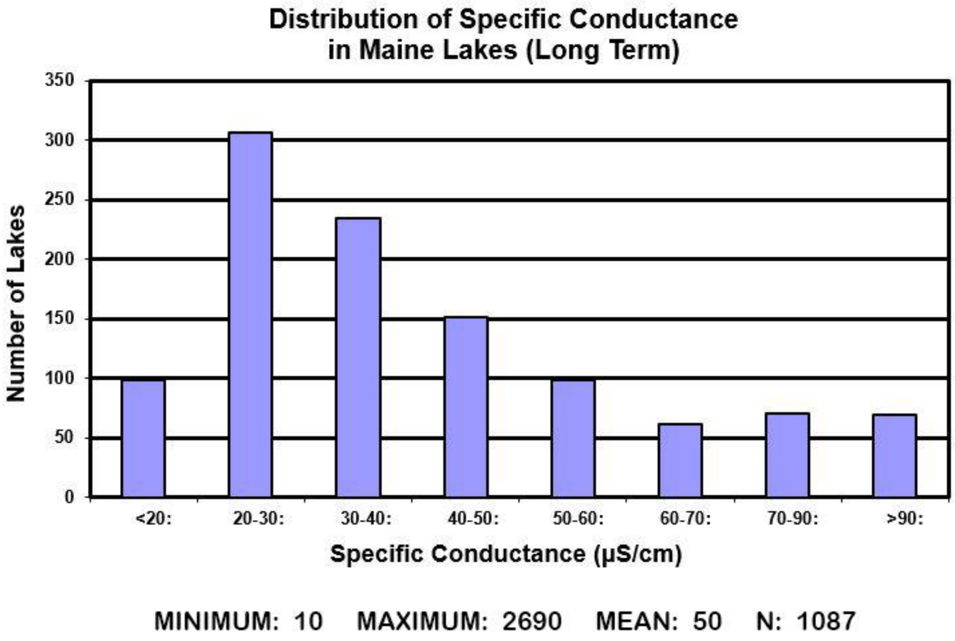
Figure 6
Distribution of Apparent Color in Maine Lakes



Specific Conductance
A measure of the ability of water to carry an electrical current. (Figure 7)

Conductivity is directly related to the level of dissolved ions in the water. Conductivity levels will generally increase if there is an increase in the concentration of pollutants in the water. Conductivity is measured in micro-siemens per centimeter (µS/cm). Figure 7 illustrates the distribution of specific conductance in Maine lakes.

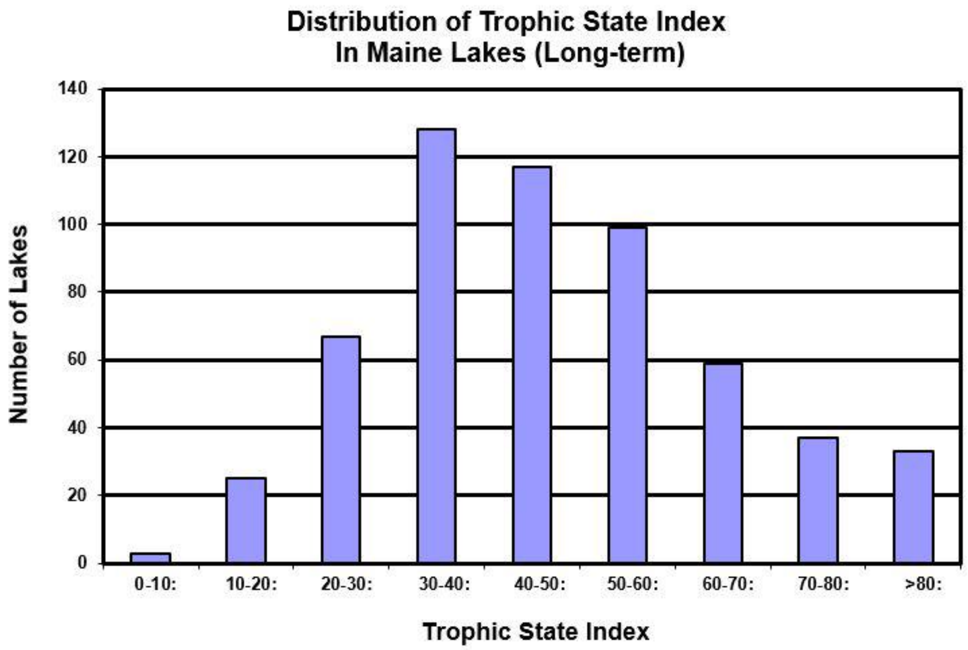
Figure 7
Distribution of Specific Conductance in Maine Lakes



Trophic State Index
A simplified index of biological productivity in lakes. (Figure 8)

The Trophic State Index (TSI) was developed in 1977 by Robert Carlson as a means to be used for establishing a simple numerical scale for each of the three indicators of lake water quality that are commonly used to measure (directly or indirectly) lake productivity. Because the units of measurement and scale for Secchi disk transparency, total phosphorus and chlorophyll a differ, the TSI provides a convenient means by which the three indicators can be compared. The TSI converts raw data from each of the three indicators to standard numerical scales that range from 0 to over 100, with higher numbers representing increasing productivity, and typically poorer water quality. The TSI models developed by Carlson have been modified for Maine lakes, based on historical data for each indicator. Figure 8 illustrates the TSI distribution of Maine lakes from transparency data.

Figure 8
Distribution of Trophic State Index in Maine Lakes from Transparency Data



MINIMUM: 8 MAXIMUM: 163 MEAN: 48 N: 568

Appendix III--Dissolved Oxygen and Lake Turnover

Courtesy of Water on the Web

Dissolved Oxygen

Biological activity peaks during the spring and summer when photosynthetic activity is driven by high solar radiation. Furthermore, during the summer most lakes in temperate climates are stratified. The combination of thermal stratification and biological activity causes characteristic patterns in water chemistry. Figure 9 shows the typical seasonal changes in dissolved oxygen (DO) and temperature. The top scale in each graph is oxygen levels in mg O_2/L. The bottom scale is temperature in °C. In the spring and fall, both oligotrophic and eutrophic lakes tend to have uniform, well-mixed conditions throughout the water column. During summer stratification, the conditions in each layer diverge.

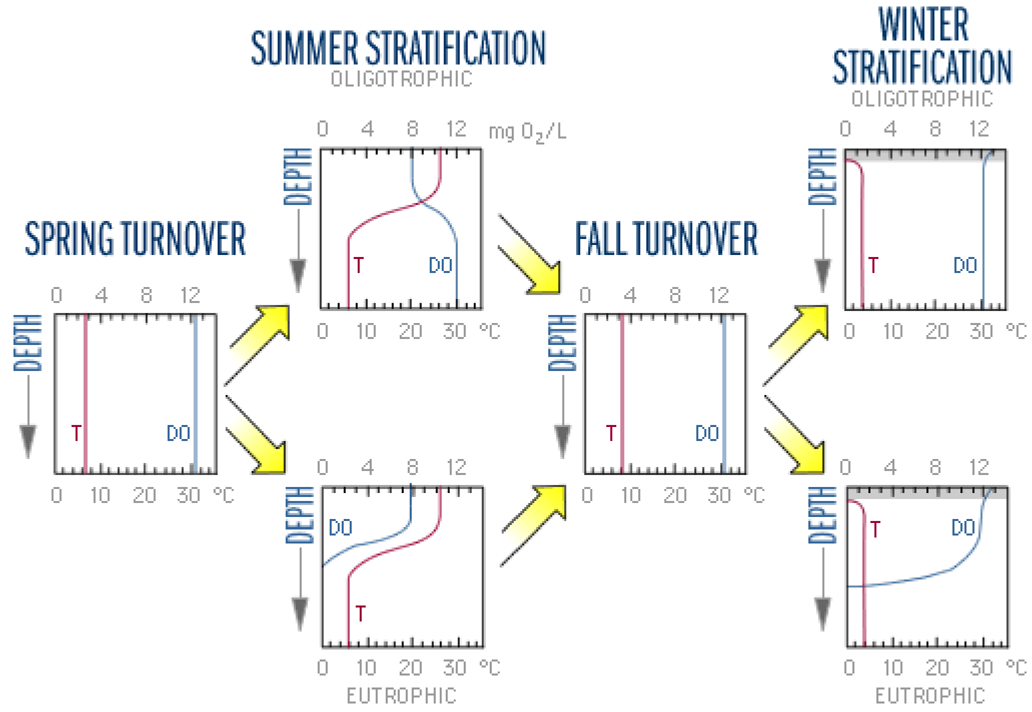


Figure 9. (adapted from Figure 8-1 in Wetzel, R.G. 1975. Limnology. W.B.Saunders Company)

The DO concentration in the epilimnion remains high throughout the summer because of photosynthesis and diffusion from the atmosphere. However, conditions in the hypolimnion vary with trophic status. In eutrophic (more productive) lakes, hypolimnetic DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and consume oxygen. The bottom layer of the lake and even the entire hypolimnion may eventually become anoxic, that is, totally devoid of oxygen. In oligotrophic lakes, low algal biomass allows deeper light penetration and less decomposition. Algae are able to grow relatively deeper in the water column and less oxygen is consumed by decomposition. The DO concentrations may therefore increase with depth below the thermocline where colder water is "carrying" higher DO leftover from spring mixing (recall that oxygen is more soluble in colder water). In extremely deep, unproductive lakes such as Crater Lake, OR, Lake Tahoe, CA/NV, and Lake Superior, DO may persist at high concentrations, near 100% saturation, throughout the water column all year. These differences between eutrophic and oligotrophic lakes tend to disappear with fall turnover (Figure 9).

In the winter, oligotrophic lakes generally have uniform conditions. Ice-covered eutrophic lakes, however, may develop a winter stratification of dissolved oxygen. If there is little or no snow cover to block sunlight, phytoplankton and some macrophytes may continue to photosynthesize, resulting in a small increase in DO just below the ice. But as microorganisms continue to decompose material in the lower water column and in the sediments, they consume oxygen, and the DO is depleted. No oxygen input from the air occurs because of the ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. This condition can cause high fish mortality during the winter, known as "winter kill." Low DO in the water overlying the sediments can exacerbate water quality deterioration, because when the DO level drops below 1 mg O_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus from the sediments into the water. When a lake mixes in the spring, this new phosphorus and ammonium that has built up in the bottom water fuels increased algal growth.

Nutrients

Aquatic organisms influence (and are influenced by) the chemistry of the surrounding environment. For example, phytoplankton extract nutrients from the water and zooplankton feed on phytoplankton. Nutrients are redistributed from the upper water to the lake bottom as the dead plankton gradually sink to lower depths and decompose. The redistribution is partially offset by the active vertical migration of the plankton.

In contrast to DO, essential nutrients such as the bioavailable forms of phosphorus and nitrogen (dissolved phosphate, nitrate, and ammonium) typically increase in the spring from snowmelt runoff and from the mixing of accumulated nutrients from the bottom during spring turnover. Concentrations typically decrease in the epilimnion during summer stratification as nutrients are taken up by algae and eventually transported to the hypolimnion when the algae die and settle out. During this period, any "new" input of nutrients into the upper water may trigger a "bloom" of algae. Such inputs may be from upstream tributaries after rainstorms, from die-offs of aquatic plants, from pulses of urban stormwater, direct runoff of lawn fertilizer, or from leaky lakeshore septic systems. In the absence of rain or snowmelt, an injection of nutrients may occur simply from high winds that mix a portion of the nutrient-enriched upper waters of the hypolimnion into the epilimnion. In less productive systems, such as those in Northeastern Minnesota, significant amounts of available nitrogen may be deposited during rainfall or snowfall events (wet deposition) and during the less obvious deposition of aerosols and dust particles (dry deposition). For instance, Lake Superior has been enriched by as much as 300 µg/L during this century, presumably due to air pollution. Nitrogen and phosphorus in dry fallout and wet precipitation may also come from dust, fine soil particles, and fertilizer from agricultural fields.