Analysis of Hydrolab Profiles For Torch Lake, Lake Bellaire, and Clam Lake in Antrim County, Michigan

By Three Lakes Association
2006 Summer Interns:

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Torch Lake

Clam Lake

Lake Bellaire

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Glossary

1. **Anoxic:** Abnormally low level of oxygen in the water.
2. **Biological Oxygen Demand (BOD):** Oxygen consumed by micoroorganisms in the process of degrading organic substances.
3. **Calibration:** Procedure that standardizes an instrument.
4. **Centigrade:** Metric temperature scale.
5. **Dissolved Oxygen:** Amount of oxygen dissolved in water.
6. **Epilimnion:** Top-most layer in a thermally stratified lake.
7. **Eutrophic:** Classification term that describes a lake with high productivity.
8. **Hydrolab "Quanta":** Field instrument that measures pH, specific conductivity, dissolved oxygen, depth, and temperature.
9. **Hydrolab Profiles:** Plots of measured values a specific depths
10. **Hypolimnion:** Bottom-most layer in a thermally stratified lake.
11. **Mesotrophic:** Classification term that describes a lake with medium productivity
12. **Miligrams per liter:** Units for measuring various parameters. (Parts per million)
13. **Micrograms per liter:** Units for measuring various parameters. (Parts per billion)
14. **Oligotrophic:** Classification term that describes waters with low productivity.
15. **pH:** Scale of 1-14 that measures hydrogen ion concentration.
16. **Predictive water quality model:** A mathematical tool that describes nutrient loading and in conjunction with a land-use model can demonstrate the affects of human activity on water quality.
17. **Sediment Oxygen Demand:** Oxygen consumed by microorganisms in the sediment as they degrade the organic material in the sediment
18. **Specific Conductivity:** A measure of the electric resistance of water. Can also approximate the total dissolved solids (TDS) in a water column. The units are milli-Seimens per centimeter (mS/cm)

Abstract

Three Lakes Association (TLA) summer interns collected water quality data during 2006 for three lakes of the Elk River Chain of Lakes system located in Antrim County, Michigan. These lakes include Lake Bellaire, Clam Lake, and Torch Lake. Our collected data, including information from 2004-2006, allowed us to analyze and compare the water quality of the three lakes. The data include the water quality parameters: pH, specific conductivity, temperature, and dissolved oxygen. The data compiled and analyzed will help complete a nutrient based water quality model for the 500 square mile watershed of the Elk River Chain of Lakes system. This paper explains the different methods and instruments we used to collect the data. We have also compared each lakes data to Lake Onondaga in the New York State to illustrate degrees of water quality. This project has been supported in part by dozens of Three Lake Association volunteers, including summer interns, an $80,000"Clean Michigan Initiative" grant from the Michigan Department of Environmental Quality and $7,000 in matching funds provided by Custer, Kearney, Forest Home, Milton, Helena, Torch Lake, and Clearwater townships.

Introduction

The three major lakes surrounding the village of Bellaire are imperative to its economy as they bring in 50 million dollars through tourism and recreation every year. As the population of Bellaire and the surrounding areas continues to increase, so does the pressure on preserving the community's most important natural resources; Lake Bellaire, Clam Lake and Torch Lake. Population growth requires that city planners and officials have a predictive model to show which decisions will provide a high standard of living while still preserving water quality.

In June 2004, the Three Lakes Association (TLA) was awarded a $62,000 grant by the Michigan Department of Environmental Quality to create a predictive nutrient-based water quality model for Torch Lake. In order for the Torch Lake model to be completely efficient, Lake Bellaire, Clam Lake and the watershed that surrounds all three lakes must be modeled as well. The DEQ awarded TLA a second grant for $80,000 to accomplish this goal. Through a partnership with the Great Lakes Environmental Center of Traverse City (GLEC) TLA has been able to make considerable progress in collecting and analyzing data for the three lake system. In addition, several interns from local high schools have been working to assist TLA in the development of the model. The interns were asked to collect and analyze data and to produce a report that profiles the condition of the lakes for the year 2006. Field work involved measuring stream flow, drilling ground water wells, collecting samples and using the Hydrolab to measure the pH, dissolved oxygen, specific conductivity and temperature of the lakes. This year's report consists of an analysis and comparison of the Hydrolab data for Lake Bellaire, Clam Lake and Torch Lake. This report will be used as a record and a reference of the condition of Lake Bellaire and Clam Lake during 2006.

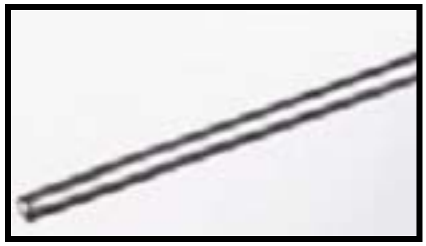
Methodology

(Excerpts from: 2005 Intern Report by Lauren Elbert and Samantha Fox,
Elk Rapids High School and Three Lakes Association Interns)

The instrument used to measure four water quality parameters is called a Hydrolab 'Quanta', manufactured by Hach Inc. A Hydrolab can be used for profiling water quality parameters in lakes at certain locations and depths. The parameters measured using the Hydrolab are temperature, pH, specific conductivity, and dissolved oxygen. The Hydrolab contains a small propeller used to circulate water through the device. The data collected is then sent to a handheld receiving apparatus, which records the information. This can be connected to a computer in order to manipulate the data into graphs.

Hydrolab with receiving apparatus

Temperature variations were easy to interpret, the colder winter months yielded colder water, especially at the shallow depths, less than 5 meters. The study also looked for the depth at which the temperature dropped more rapidly, i.e. thermocline.



Hydrolab temperature sensor

The temperature was measured with a 30 K ohm variable resistance thermometer. Temperature is critical for interpreting other data collected.

Determining how acidic or how basic the water was based on concentration of hydrogen ions in a given liquid and is measured as pH, which can range from very acidic (pH 1) to very basic (pH 14). Higher or lower values relative to neutral pH (pH 7) can help determine the bioavailability of nutrients.

Hyrdrolab pH probe

The pH sensor was a glass bulb with an electrode-detecting device. The glass is impregnated with potassium chloride (KCl) and can only be permeated by hydrogen ions. There is a liquid filled tube in the middle with 3M KCl, and a salt bridge is formed. The bridge allows one to measure the rate of reaction between the KCl and hydrogen ions, which gives the measure of the pH.

Specific conductivity was a measure of ions, e.g. salts, dissolved in water. The more ions in water the more electric current can be conducted. High specific conductivity values mean that more ions are present, such as calcium ions, which is an indicator of water hardness. In many studies, specific conductivity can be used to measure the amount of runoff sediment in tributaries.

Hydrolab Specific Conductivity Sensor

The specific conductivity sensor contains four graphite electrodes in an open cell design, allowing water to pass between the electrodes. The probe measures the current between two of the electrodes. The other two electrodes are simply used to avoid error.

Hydrolab Dissolved Oxygen probe

The fourth parameter measured was the amount of dissolved oxygen (DO) in water. All organisms need oxygen, and plants create it. Animals respire CO_2 and plants need CO_2

for photosynthetic means. If there is not enough DO in the water, aquatic life cannot exist, whether it is plants or animals. Plants may be capable of surviving as long as there is dissolved carbon dioxide (CO_2) in the water if there is enough sunlight to support photosynthesis, which produces oxygen. However animals need the oxygen, and if the oxygen level is too low, they will have a harder time living. The dissolved oxygen is measured by an oxidation-reduction reaction. There is a selective membrane allowing only oxygen to permeate it. The current is then measured from the electrochemical reduction of oxygen.

Results and Discussion

Lake Bellaire-Temperature

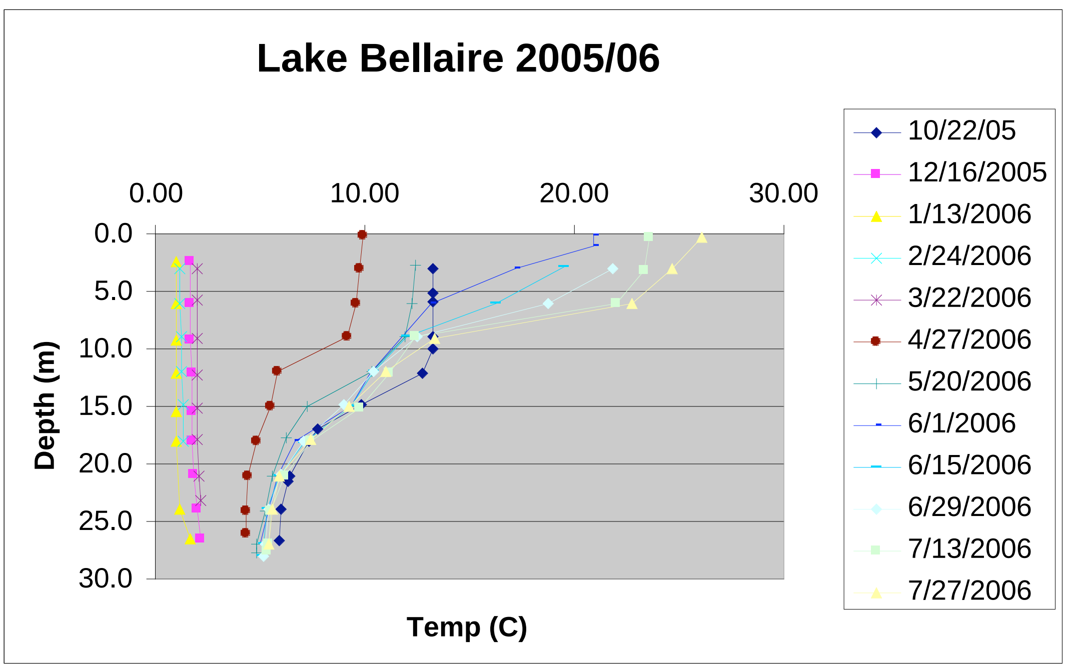


Figure 1

In the winter temperatures from top to bottom are uniform (Fig. 1). This means that there is no thermocline. A thermocline is a layer of water with an abrupt change in temperature that separates the warmer surface water from the colder deep water. This temperature barrier prevents mixing of surface water with bottom water. When the thermocline degenerates in cool weather these layers can mix resulting in a lake turnover. The colder temperatures also allow for more oxygen to enter the lake. By April, there is a noticeable thermocline and throughout May to the end of July we see the highest temperatures.

Lake Bellaire Dissolved Oxygen (DO)

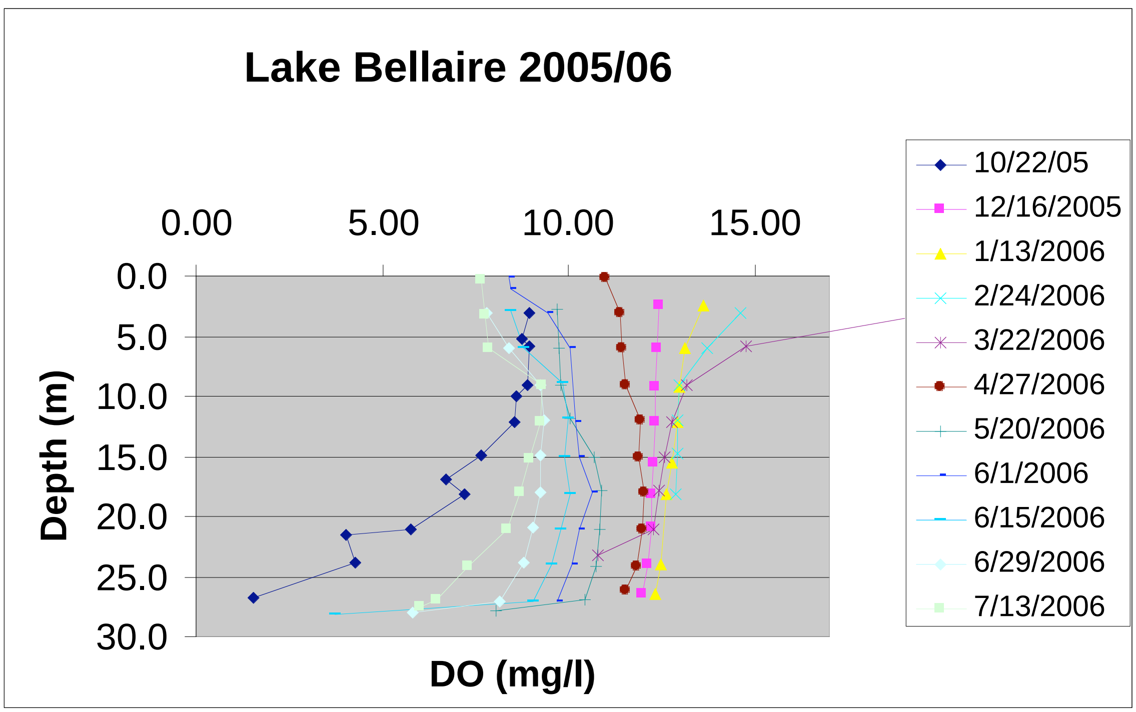


Figure 2

During annual turnover time in November/December, (Fig.2) the lake is destratified and mixing produces a uniform water column. From January to March, temperatures below 20 degrees Centigrade allow the water to hold more than 100% saturation (9 ppm of oxygen.) This represents oxygen supersaturation. From April until July the surface layer has less than 9 ppm of oxygen. This happens because the top layers of water are beginning to warm. We conclude that warm water holds less dissolved oxygen than cold water. During late summer, as the depth increases the level of dissolved oxygen begins to dramatically decrease regardless of lower temperatures. Plotting DO at a constant depth illustrates the seasonality of hypolimnetic anoxia (Fig. 3)

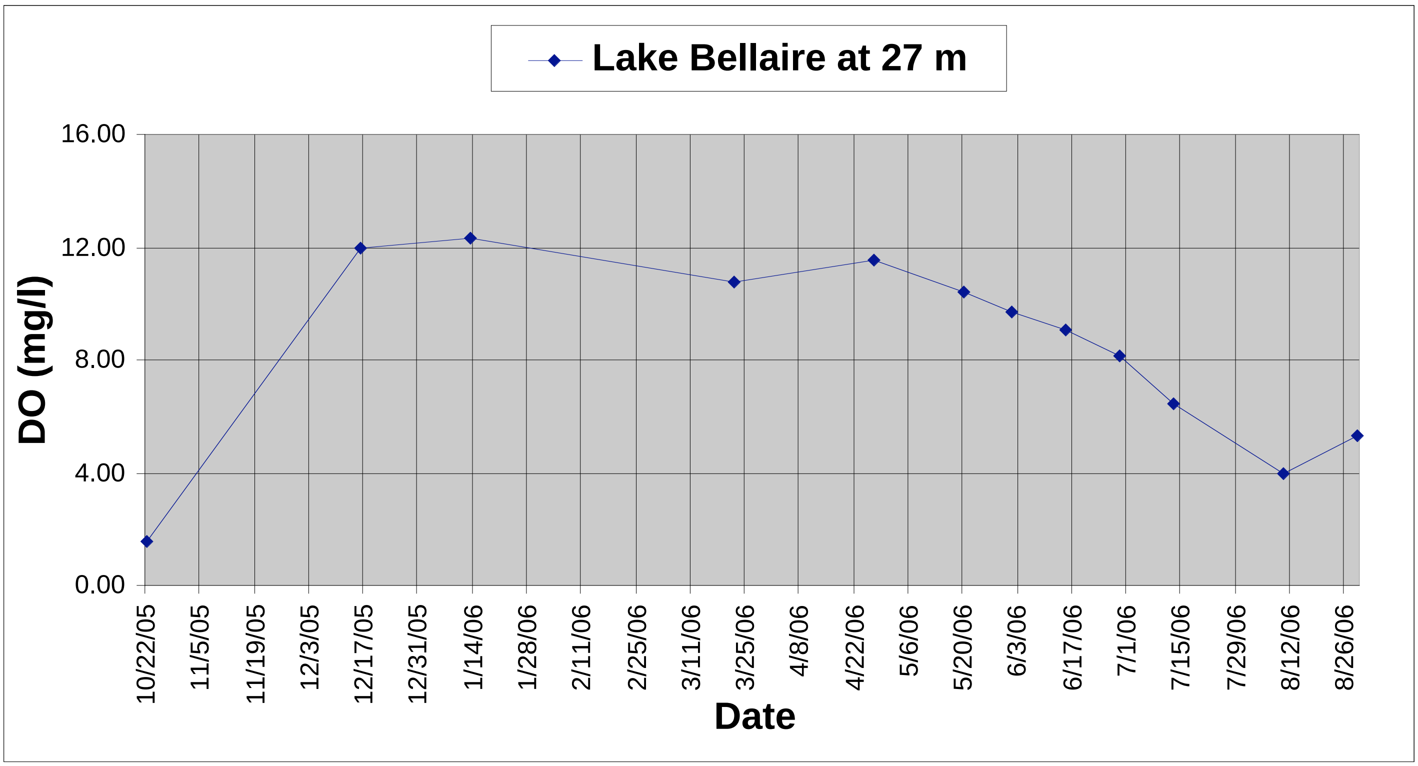


Figure 3

One cause of anoxia is because of bacterial decomposition. Bacteria consume oxygen when decomposing dead plants and animals at the bottom of the lake. During the summer fish have a hard time finding oxygen down near the anoxic hypolimnion due to the biological oxygen demand. This causes them to move toward the epilimnion where oxygen levels are typically higher than the bottom. This is because the oxygen producing process of photosynthesis requires sunlight. Another consequence of low oxygen levels at the deeper depth is the potential for sediments to release phosphorus back into the water column. The turnover process redistributes this nutrient to the epilimnion where it will promote algae growth. A recent study by Homes and McNaught at Central Michigam University (Table 1) measured the phosphorus release rates from sediments in Lake Bellaire and Clam Lake. Although Lake Bellaire is anoxic part of the year the phosphorus release rate is low for unexplained reasons.

<u>Table 1. Phosphorus Release Rates</u> (M. Holmes and S. McNaught, 2005)

	Lake Bellaire	**Clam Lake**
% Organic matter in sediment	16.9%	19.2%
Sediment Oxygen Demand (SOD)	0.54	1.08
Phosphorus release rate: first 4 days of anoxic conditions	282	497 ug/sq. m/day *

*Compared to 1936 ug/sq. m/day for Platte Lake

Lake Bellaire pH

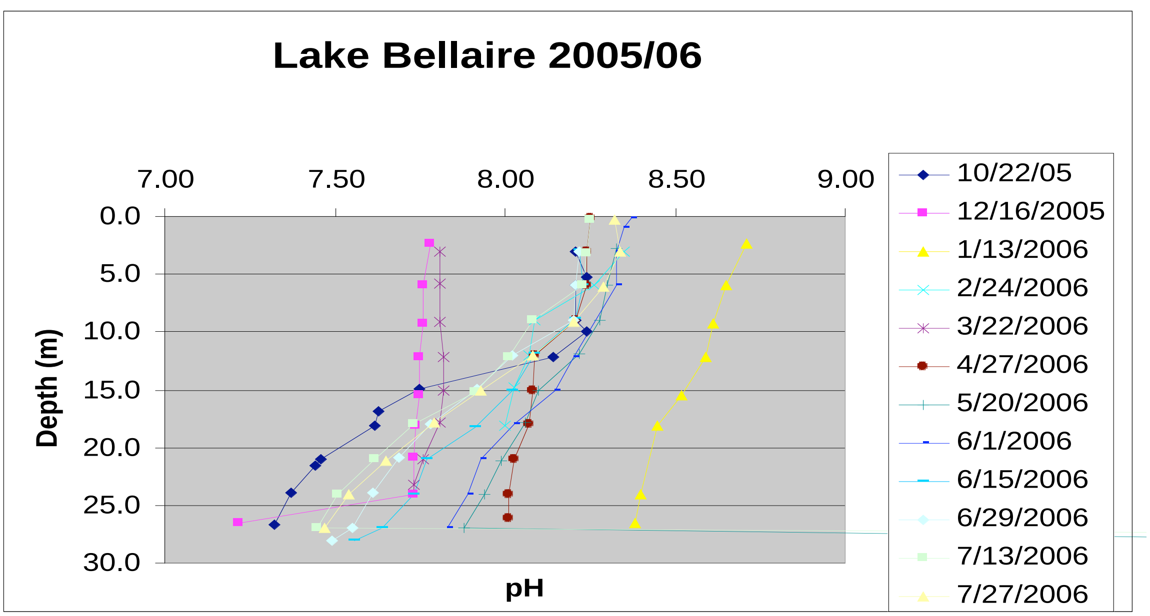


Figure 3

During the winter and early spring (December though April) the pH is more uniform than during the summer months (May through October). The uniformity in pH is most likely due to the lack of plants growing in the lake during these months. Plant growth creates a more basic environment by taking up carbon dioxide dissolved in the epilimnion When there is an absence of plant life in the surface water the pH shifts closer to a neutral pH of 7. During the summer, plants grow in Lake Bellaire's epilimnion and increase the pH by taking up carbon dioxide. This causes the surface waters to become basic while the hypolimnion stays close to neutral.

Lake Bellaire Specific Conductivity (Sp Cond.)

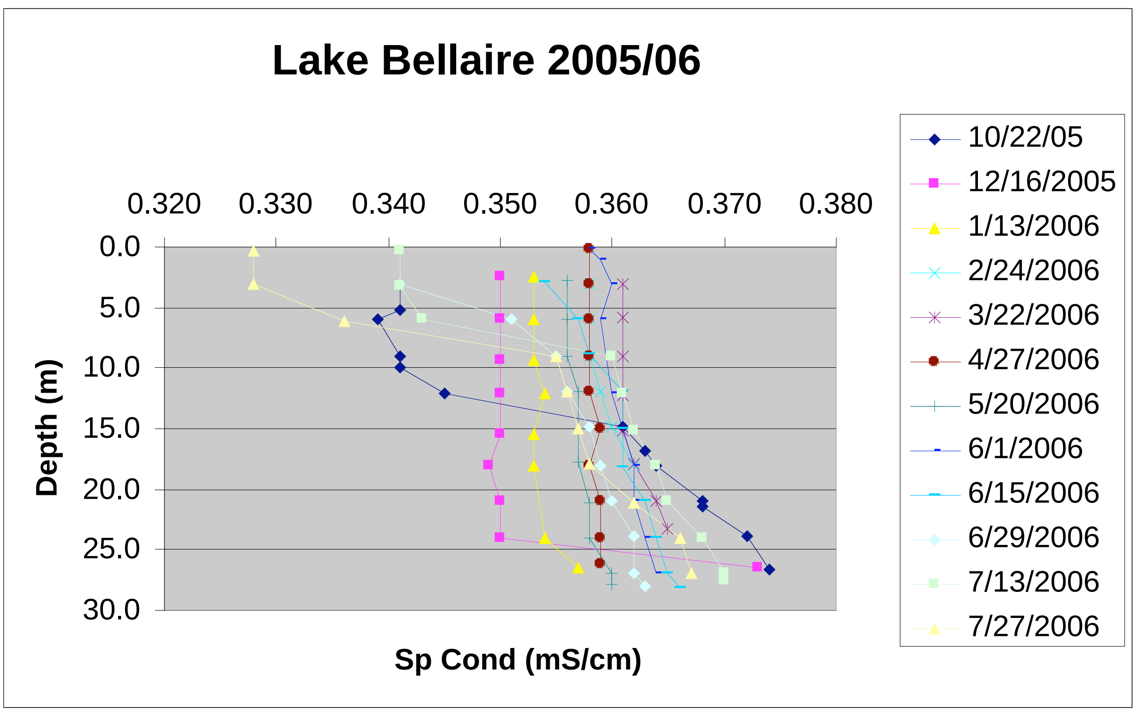


Figure 4

Specific conductivity changes little during winter when the water column is uniform. This is most likely a result of the mixing of lake layers during fall turnover. We can see from the graph of temperature for Lake Bellaire that from December until March there is little or no thermocline. Water from the hypolimnion will mix with the water in the epilimnion creating a more uniform distribution of ions in the lake, hence the more uniform specific conductivity. The decrease in epilimnion conductivity observed in June, July, and October could be the result of improper calibration or some significant rain events. An increase in conductivity is consistently found at the lowest depths. One possible reason is that occasionally the Hydrolab probe drops into the bottom sediments explaining the large increase in conductivity. It is interesting to note that the unusual range of October specific conductivity is inversely correlated to the pH and DO curves. A cause and effect relationship between anoxic conditions at the bottom of the lake and an increase in specific conductivity is speculative and has no current explanation.

Clam Lake Specific Conductivity (Sp Cond.)

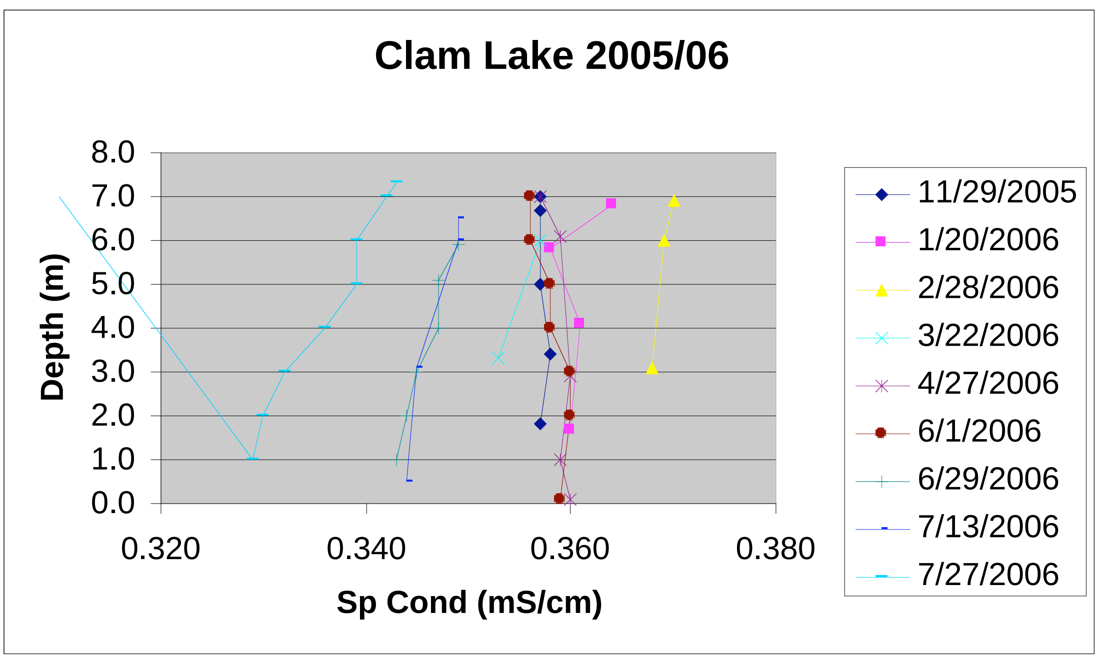


Figure 5

In 2005/06 the typical specific conductivity value was around .350-.360. When the amount of ions in the lake increase the lake becomes more conductive. Pollutants such as road salt, run-off, or precipitation could cause the increase in conductivity. Toward the bottom of the lake the conductivity could be higher because of conductive material such as sediment. We considered a couple months of collected data to be inaccurate. The data didn't seem to match up with other information or fit into a proper graph. The information could have been off for many reasons such as; the probe may have been stuck in the mud, creating higher conductivity. The graph for specific conductivity for Clam Lake seemed to be pretty consistent with an exception of a few months.

Clam Lake pH

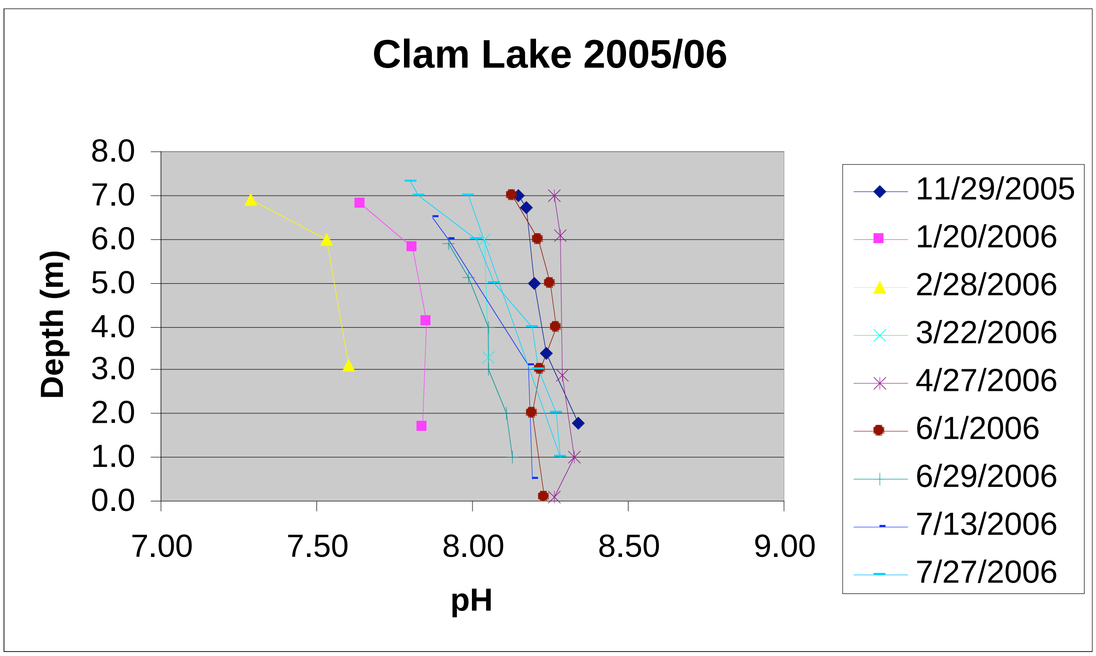


Figure 6

During the winter months the pH level tends to be lower than the warmer months. This could be because during the growing season (the summer months) the pH level is typically higher in lakes because of photosynthesis. Also during the summer there are more people swimming in the lakes creating higher pH levels. During the winter the lake is covered with ice that doesn't allow anything in the lake. As the depth of the lake increases the pH level also decreases. This could be because during the winter there may be an excess of decaying plant life. Throughout the month of April the pH level didn't seem to change. The level typically stayed around 8.30-8.4 all through the month. This could mean that April was the turnover month for pH in Clam Lake.

Clam Lake Temperature

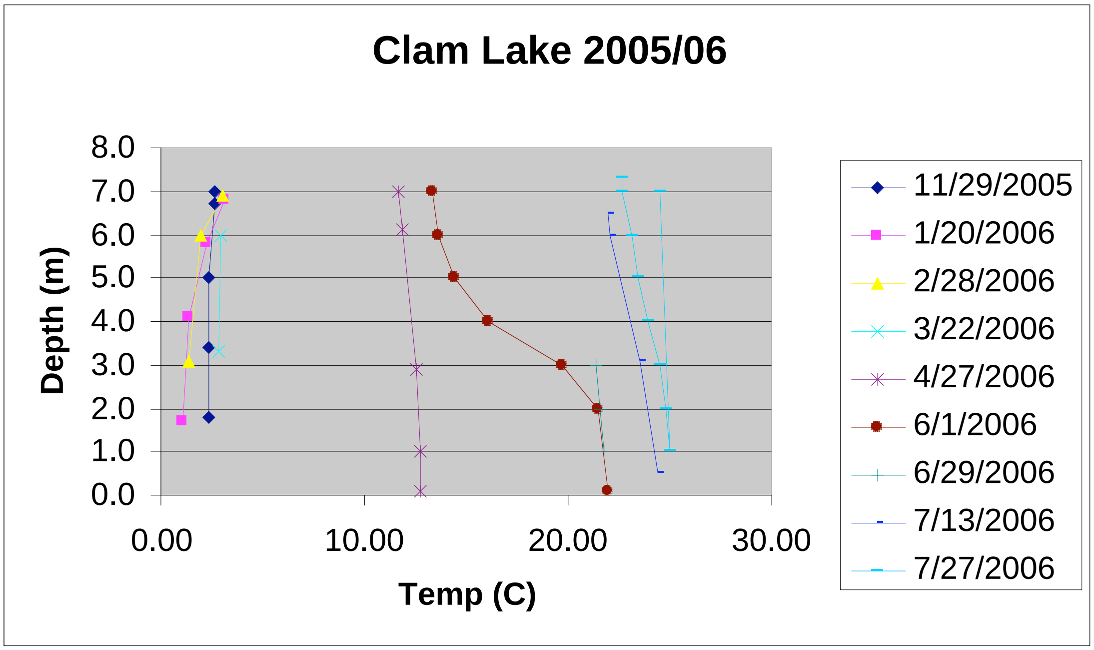


Figure 7

During the months that Northern Michigan had snow cover the temperature of the lake drops dramatically compared to the summer months. During the months of January and February the deeper the water the warmer the temperature was. This could be due to the layers of ice that sits on the surface of the water making it cooler at the surface and warmer toward the bottom. Once the ice sheet melted from the surface the temperature of the lake began to warm up. During April and July the water column is uniform as if turnover occurred twice. Because Clam Lake is such a shallow lake the turnover occurs early because it doesn't take long for the sun to warm up or cool down the lake. For many other lakes such as Lake Bellaire and Torch Lake the turnover months occur around November because of the greater depth. In the month of June the temperature at the surface of Clam Lake was dramatically higher then the temperature toward the bottom due to the sun rays hitting the surface of the water and warming it up. The graph for temperature for Clam Lake shows that the month of June was when the thermocline occurred. During the summer there could be other sources of temperature change in the lake such as people and boats.

Clam Lake Dissolved Oxygen (DO)

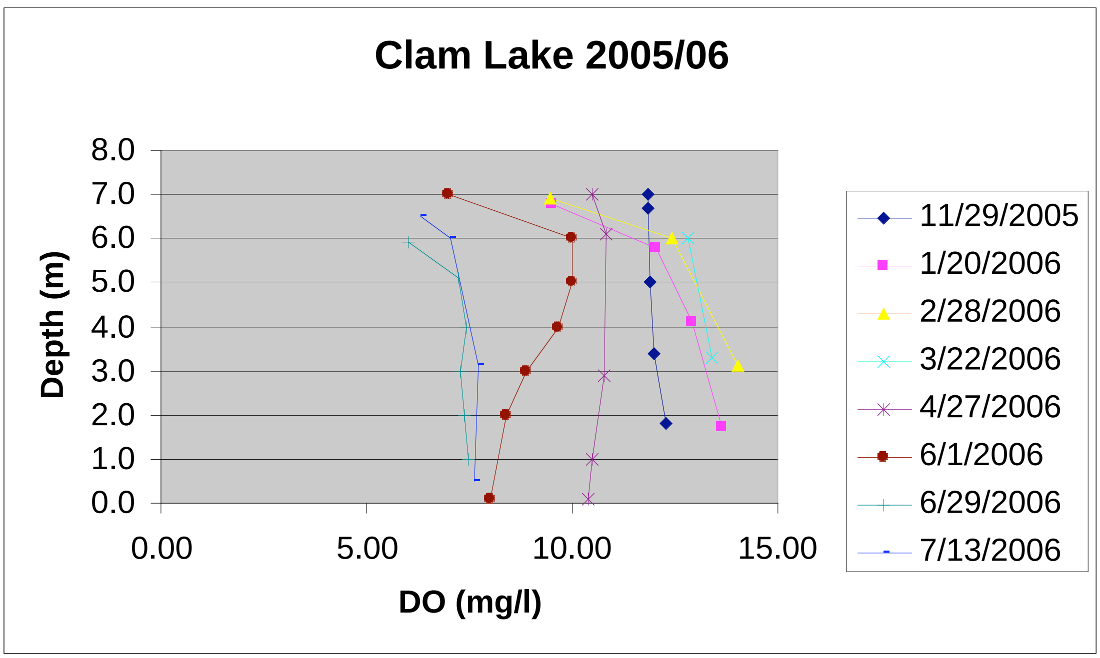


Figure 8

During April dissolved oxygen (DO) is pretty much the same at every depth. This could be because during the winter the sheet of ice covering the lake helps keep out debris and other things that could be decomposed. During the summer months the DO decreases as the depth of the lake decreases. The month of November and April would be the turnover months. The winter months seem to have a higher level of dissolved oxygen, however as the depth increases the level of dissolved oxygen begins to dramatically decrease. One of the reasons this may be is because of decomposition. During the winter layers of ice cover the surface of the lake. Plant life and aquatic life toward the bottom of the lake decomposes and when this occurs dissolved oxygen is consumed. At the surface of the lake the level of DO is typically higher then the bottom because the sunlight causes photosynthesis which produces DO. During the summer fish have a hard time finding oxygen down near the hypolimnion. This causes them to have to stay more toward the epilimnion.

Torch pH

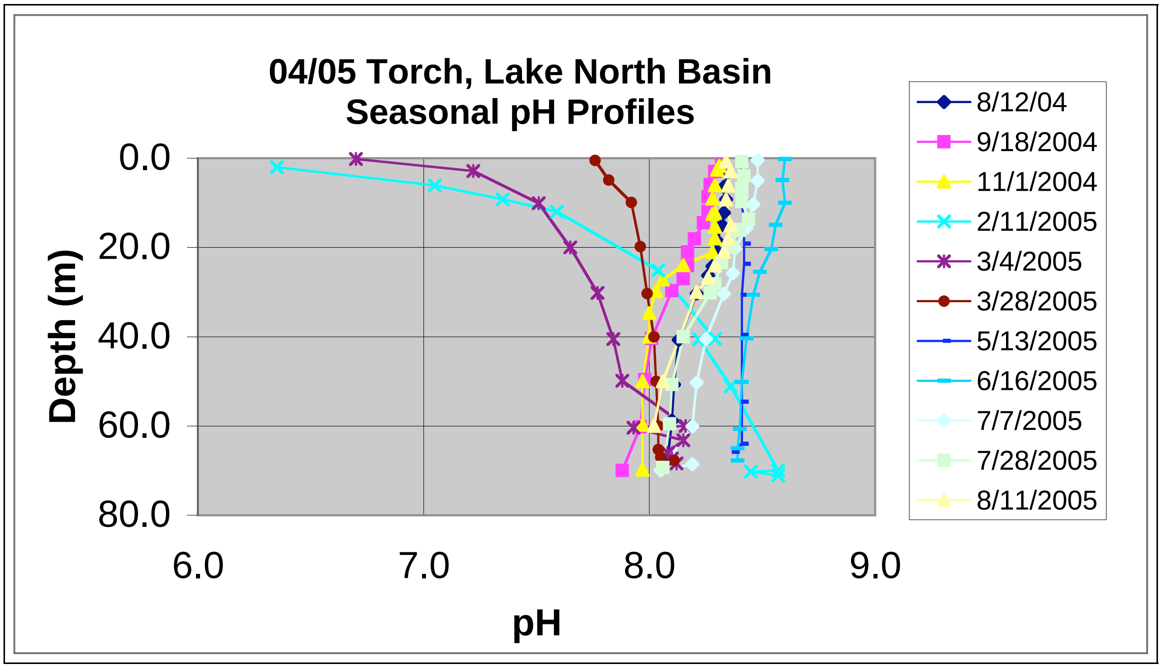


Figure 9

During the summer and fall months the water in Torch Lake is basic due to plant activity and calcium carbonate formation removing carbon dioxide from the water column. Both plants and calcium carbonate appear in the lake during the months when temperatures are higher. In the winter, the epilimnion becomes more acidic due to the absence of aquatic life and calcium carbonate, however; the hypolimnion stays basic because of the carbonate that has settled to the bottom.

Torch Lake Temperature

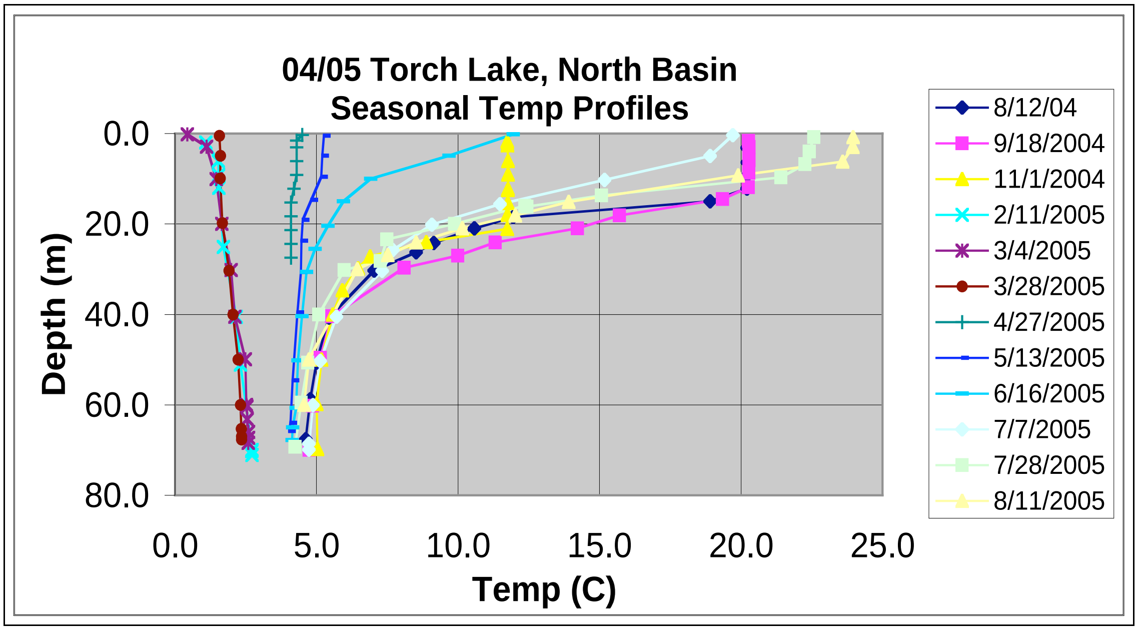


Figure 10

The lake experienced its widest temperature ranges during the summer months. This is due to higher air temperatures during June, July, and August. The epilimnion starts to warm during June, and for the rest of the summer the top of the lake to 20 or 30 meters stays significantly warmer than the lower depths. The thermocline begins to develop in June and is fully developed by July. In November the epilimnion starts to cool and by February the temperature reaches a uniformity throughout all the depths that lasts until mid May. An absence of variation in temperature between depths creates turnover in the lake. Turnover is the mixing of waters from the hypolimnion with the epilimnion. Mixing creates a more uniform distribution of particles throughout the lake. Turnover is especially important in restoring dissolved oxygen to the lowest layers of the lake.

Torch Lake Specific Conductivity

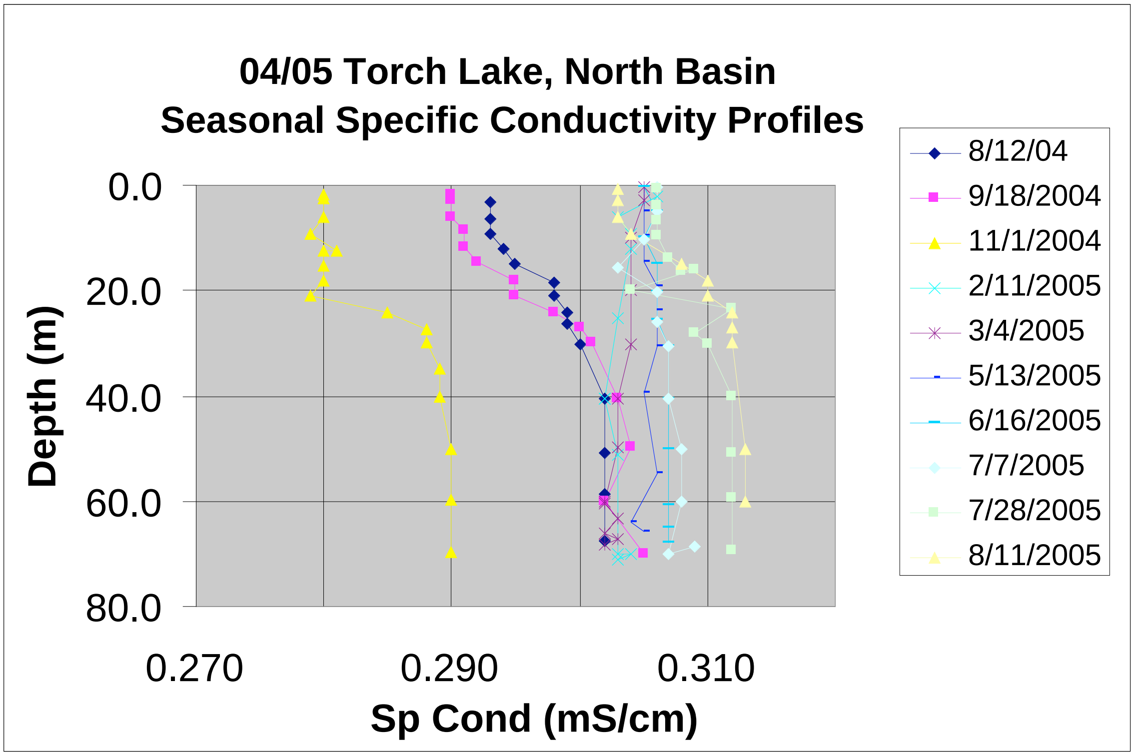


Figure 11

Specific conductivity is a measure of the electrical resistance of the water and depends mainly on impurities found in the lake. The specific conductivity of Torch Lake is most uniform during turnover. Turnover occurs during the winter months when there is little, or no, thermo cline. Turnover in the lake mixes the water, and causes impurities to be distributed more evenly throughout all depths. The unusual November profile may have been due to calibration problems or heavy fall rains.

Torch Lake Dissolved Oxygen

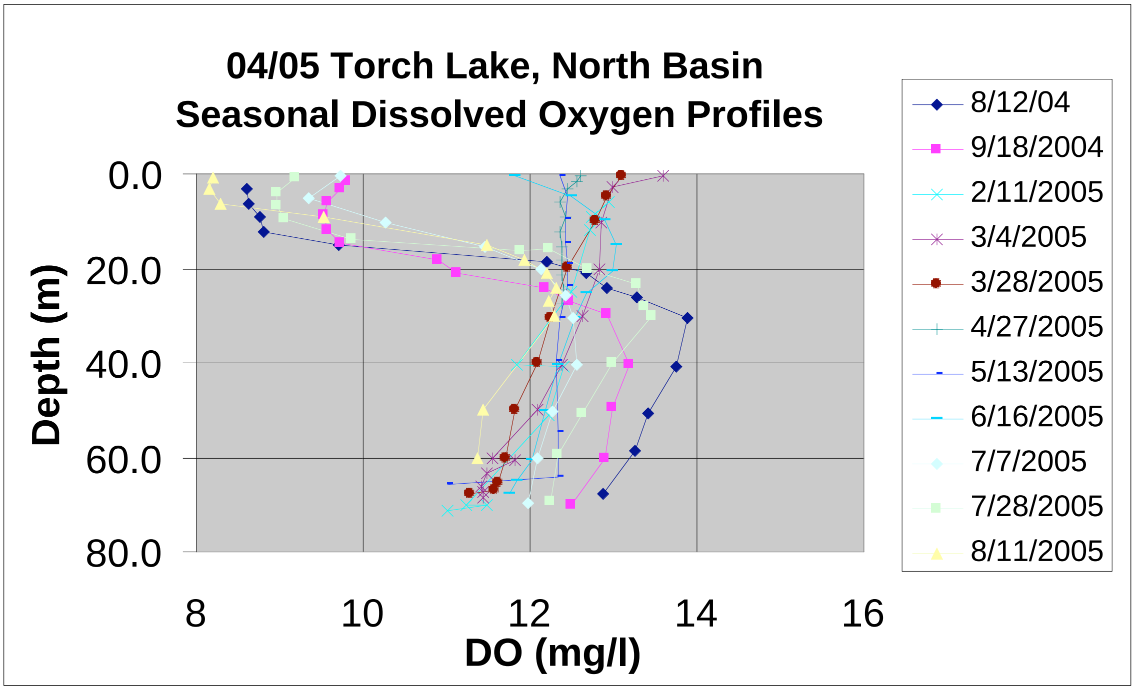


Figure 12

During the summer months there is significantly less dissolved oxygen in the first 30 meters, than during any other season. This phenomenon is due to higher air temperature, and thus higher water temperature, during the summer. Due to the chemical properties of water and oxygen, warm water holds less oxygen than cold water. Torch is a very deep lake, and thus the summer warmth significantly affects only the epilimnion. The hypolimnion stays cold, because sunlight cannot penetrate, and warm, the lower depths of the lake.

<u>Comparisons between Lake Bellaire, Torch Lake, Clam Lake, and Lake Onondaga</u>

For a frame of reference we have chosen to compare the three lakes we studied to one of the most polluted lakes in the United States, Lake Onondaga of New York State.

Lake Onondaga: Size and Depth

The lake covers an area of 4.6 square miles, has an average depth of 35 feet and a maximum depth of 63 feet. Its volume is about 35 billion gallons. It is approximately one mile wide and 4.6 miles long, and receives water form a land area, or drainage basin of 248 square miles located almost entirely within Onondaga County, New York. Lake Bellaire covers an area of 2.7 square miles while Torch covers almost 30 square miles.

Historical Background

The Onondaga Lake area was the center of the Iroquois Confederacy prior to the exploration and settlement by Europeans. The completion of the Erie Canal in the early 1800's led to increased settlement of the area. Many early settlers were attracted to the Syracuse area because of the newly developing slat industry on the Lake's shores. Increased population and the industrialization resulted in pollution that degraded water quality and severely impacted lake use and related industries.

History of Pollution

Onondaga Lake is one of the most polluted lakes in the United States. The lake has a number of domestic and industrial pollution problems relating to population growth and industrialization in Syracuse over the last century. As Syracuse grew in the late 19th and the early 20th century, the lake's western shore became increasingly industrialized. Sewage disposal and industrial discharges into the lake also increased during this period, and as a result, the quality of the water began to suffer. Eventually, people stopped visiting Onondaga Lake for swimming and fishing, primarily because of the lake's degraded water quality. Over time, all of the lake's resorts and beaches closed. By 1940 the lake was mainly being used for the disposal of industrial and domestic wastes.

There were many sources of pollution to Onondaga Lake. For years the city of Syracuse dumped its sewage directly is not the lake. This municipal wastewater released phosphorus, ammonia and nitrite, bacteria and other harmful microorganisms into the lake. Besides these heavy pollutants the lake began to suffer form a reduced oxygen level which seriously impacted the entire ecosystem of the lake.

In 1884 the Solvay Process Company began the production of soda ash on the western shores of Onondaga Lake. The salty wastes, a bi-product of the soda ash production, were deposited in the lake resulting in a drastic increase in chloride, sodium and calcium. It's estimated that 6 million gallons of these wastes were deposited each day. Besides the chemical contamination of the lake, the salinity level rose significantly and dissolved oxygen levels dropped drastically.

Allied Chemical and Dye Company (now Honeywell Corporation) succeeded the Solvay Process Company. It produced chlorine by the mercury cell process. The process dumped mercury waste into the lake. It's estimated that between 1956 and 1970 165,000 pounds of mercury were deposited in the lake form this production process.

Several other companies added to the pollution in the lake. PCBs (polychlorinated biphenyls) and chlorinated benzene were two of the most significant chemicals that came from these other sources. Finally, the lake also suffers from excessive sedimentation, a problem that is indirectly attributed to the actions of solution mining by Allied Chemical Company.

Onondaga's Current Status

Due to many of the projects cited above, the water quality and the overall health of Onondaga Lake is improving. The past several years have seen a dramatic decrease in ammonia levels in the lake. This is directly related to improvements made at the METRO wastewater treatment plant that contributes 90% of the lakes's ammonia. Slightly more than half of the phosphorus entering the lake comes from the METRO plant; the other half is contributed by runoff from urban and agricultural areas. Phosphorus levels in the lake are declining as well, but they still remain above the guidance value of 20 micrograms per liter. Dissolved oxygen level and water clarity in Onondaga Lake are improving, in part due to the reduction in phosphorus levels in the lake. Bacteria levels in the lake are still unacceptable for water contact recreation. Thus, continuous improvements in reducing the number of combined sewer overflows (CSOs) are needed. The concentration of chloride, the most important component of salinity to Onondaga

Lake has decreased form 1600 milligrams per liter to less than 400 milligrams per liter since the closure of he Allied soda ash facility. The Lake's entire bottom sediments and related sites are on the federal Superfund list. A plan for cleaning up the lake bottom can be found at the Department of Environmental Conservation's website http://www.dec.state.ny.us/index.html

	Hypolimnion Dissolved Oxygen (DO) mg/l	**Secchi Depth (ft)**	**Phosphorus ug/l**	**Specific Conductivity mS/cm**	**Bacteria Count C/100ml**	**Ammonia mgN/l**
Torch Lake	11	23	2.6	0.31	0	0
Clam Lake	7	18	5	0.36	0	0
Lake Bellaire	0	15	5	0.36	0	0
Lake Onondaga	0	5	>20	2.2	>200	>1.5

Table 2: Water quality comparison for August '04 –'06

The dissolved oxygen values for Clam Lake, Lake Bellaire and Torch Lake range from 0 to 11. The three lakes appear to have a very healthy amount of dissolved oxygen at the surface but Lake Bellaire drops to zero at the end of summer. Lake Onondaga, however, has a healthy amount of oxygen for only the first 7 meters. The bottom half of the lake has anoxic conditions, with a dissolved oxygen value of less than 1mg/L. These values indicate that there is an excessive amount of oxygen demanding biological activity in the hypolimnion. Anoxic conditions signify a severely unhealthy environment.

Compared to Lake Onondaga in New York State, Lake Bellaire, Torch Lake and Clam Lake are all very healthy. None of the lakes in Antrim County experience as severe anoxic conditions or have the high measurements of specific conductivity that are found in Lake Onondaga.

Secchi depth measures water clarity. Lake Onondaga has massive algae blooms resulting from high phosphorus levels and the result is a decrease in Secchi depth. Lake Bellaire has had algae blooms in the past due to the Village of Bellaire's sewage lagoons but that problem has been resolved. The presence of Zebra mussels in all three lakes contributes to improved water clarity.

Phosphorus levels in our three lakes are very low. Levels below 10 ppb are considered an indication of excellent water quality. Lake Onondaga has an excess of 20 ppb which explains the repeated algal blooms.

Lake Bellaire, Clam Lake, and Torch Lake, all have an average specific conductivity for the month of August 2006 between .30-.36 mS/cm. However, Lake Onondaga has an unusually high specific conductivity of about 1.75 mS/cm toward the surface of the water and about 2 mS/cm at the bottom of the water. At a depth of about 10 feet the specific conductivity drastically changes from approximately 1.9-2 mS/cm up to 2.5 mS/cm and rapidly declines after about 10 feet until it reaches roughly 2 mS/cm. Lake Onondaga's high specific conductivity could be due to higher concentrations of impurities, which indicates a lower quality of water.

The bacterial count for Lake Onondaga exceeds the limit for bathing and explains why the NY State Health Department has regularly closed public beaches. A 2003 study of the Torch Lake Sand Bar revealed zero bacteria during the summer, including samples taken immediately after the Fourth of July holiday.

Ammonia is toxic to living things. We have not measured ammonia levels in our three lakes because there is not a source we are aware of. Lake Onondaga has significantly high levels due to the sewage treatment facility at the south end of the lake. Ammonia will kill plankton and fish making the lake undesirable.

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Acknowledgements

- Norton Bretz, Ph.D. Three Lakes Technical Advisor.
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