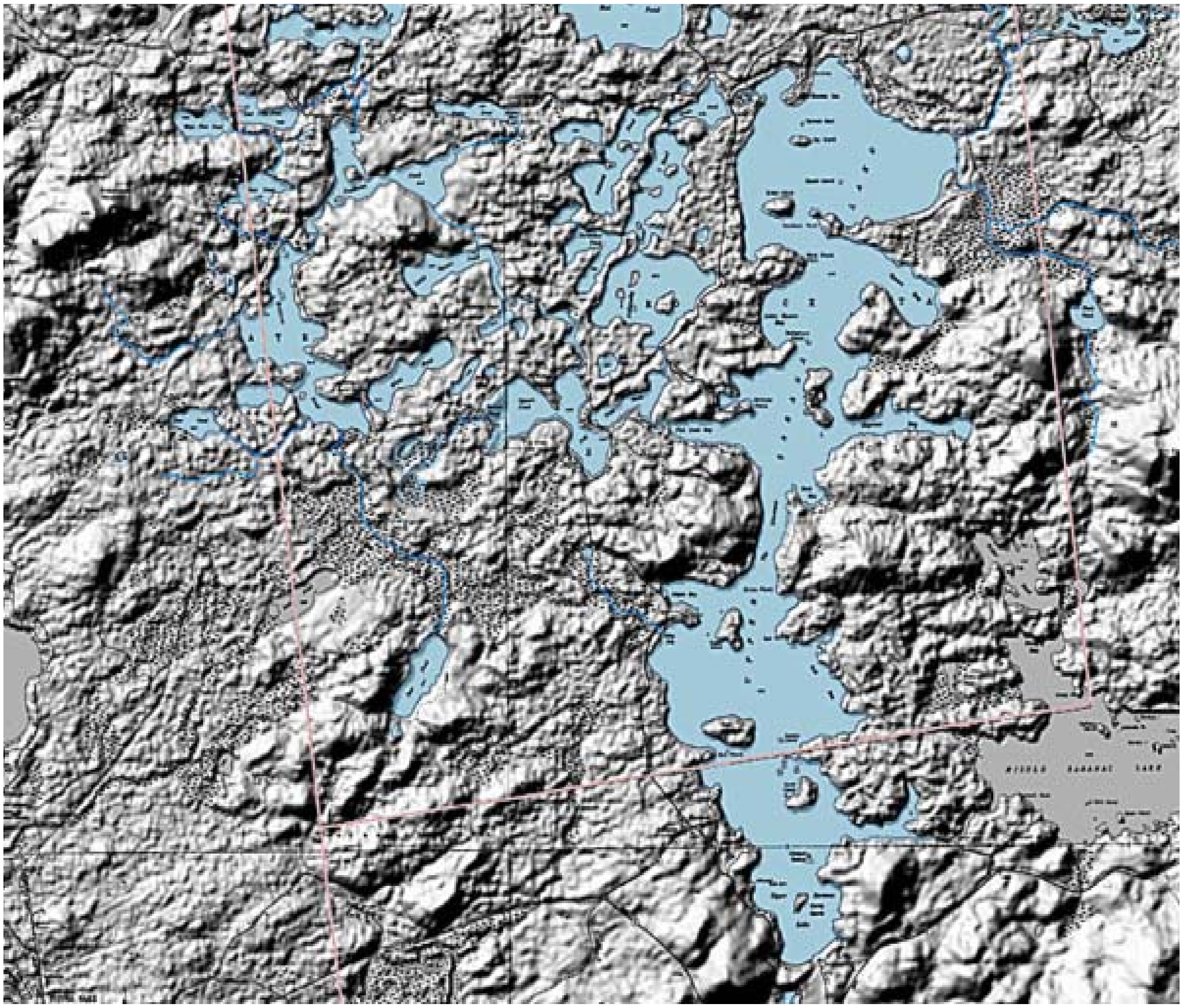
Report on the Water Quality Status and Long Term Water Quality Trends for Upper Saranac Lake

2005 Monitoring Season



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Report on the Water Quality Status and Long Term Water Quality Trends for Upper Saranac Lake

2005 Monitoring Season

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Executive Summary

Introduction

This report presents the findings of the 2005 monitoring season of Upper Saranac Lake and its major tributaries, along with an examination of long-term water quality trends in Upper Saranac Lake. Sample collection, data analysis, and report writing were conducted by Michael R. Martin, Certified Lake Manager and President of Cedar Eden Environmental, LLC in Saranac Lake NY. Sample analysis was conducted by F. X. Browne, Inc.'s EPA-certified water quality laboratory in Marshalls Creek, PA. All sample collection and analysis followed established protocol.

A glossary of lake and watershed terms is provided in Appendix A. All water quality data are presented in Appendix B. Dissolved oxygen and temperature profile data are presented in Appendix C.

Lake Water Quality

Water quality in Upper Saranac Lake continued to improve in 2005 following the widespread algae blooms of 2003, although water quality still has not returned to levels that were observed prior to 2003. However, both basins continued to experience periods of time during the summer when oxygen levels throughout the cold deep waters were too low to support cold water fish species. Phosphorus continued to be released from the north basin sediments during the summer months due to the lack of oxygen. As in previous years, this phosphorus accumulated to high concentrations that were released into the lake system in mid-September during turnover and possibly contributed to algae growth in the upper waters during the summer months as well.

Tributary Water Quality

Little Clear Pond Outlet continued to exhibit the influence of the fish hatchery discharge, having higher phosphorus and higher nitrogen concentrations than the other monitored tributaries. These higher nutrient levels could pose an issue with excessive growth of plants and algae.

Recommendations

The recommendations are discussed in detail at the end of this report and presented here in summary.

Water Quality Monitoring

1. It is recommended that the long-term water quality monitoring program at Upper Saranac Lake be continued, as it is crucial to understanding water quality trends in the lake.
2. It is recommended that the Spider Creek station be continued, since it provides a tributary that receives little influence from development.
3. It is recommended that the nitrogen series analysis continues (ammonia, TKN, and nitrate) to provide a better understanding of this nutrient in the lake and its tributaries.

Lake Restoration Activities

1. It is recommended that a study of the mass balance of phosphorus release and migration within the north basin water column be conducted to determine how much phosphorus is released from the sediments and how much, if any, migrates into the surface waters during the summer when it can cause algae blooms (proposal is being prepared for USLF consideration).
2. It is recommended that a feasibility study of phosphorus inactivation using alum be conducted to determine dosage rates and costs.

Watershed Restoration Activities

1. Construction Site/Land Clearing: Work with local governments to establish strict land clearance regulations to ensure the protection of water quality. Ensure existing rules and regulations such as SPDES Stormwater Regulations for Disturbed Areas over 1 Acre are enforced.
2. Watershed Logging: Work with DEC Forestry to ensure that silviculture BMPs are used whenever logging is undertaken within the watershed.
3. Land Use Regulations: Work with local governments to establish stricter land development guidelines to ensure protection of Upper Saranac Lake from tiered development. There are numerous issues to address, including development along slopes, land clearance, development densities near shores, depth to water table/depth to ledge for septic systems.
4. Phosphorus Reductions: Work with lake residents to reduce phosphorus from all sources by promoting Homeowner Stewardship Practices. Encourage the replacement of old standard/sub-standard septic systems with alternate technologies (composting/incinerating toilet w/grey water system).
5. Consider the establishment of protective district around the lakeshore. This would make it easier to implement protective land use measures.

Introduction

This report presents the findings of the 2005 monitoring season of Upper Saranac Lake and its major tributaries, along with an examination of long-term water quality trends in Upper Saranac Lake. Sample collection, data analysis, and report writing were conducted by Michael R. Martin, CLM of Cedar Eden Environmental, LLC. Sample analysis was conducted by the F. X. Browne, Inc. water quality laboratory in Marshalls Creek, PA (EPA ID # PA00181).

A glossary of lake and watershed terms is provided in Appendix A. All water quality data are presented in Appendix B. Dissolved oxygen profiles, temperature profiles, dissolved oxygen isopleths, and temperature isopleths are presented in Appendix C.

Water Quality Methodology

Upper Saranac Lake was sampled once per month from May through October 2005 at the deep stations established in the north and south basins. On each sampling date, samples were collected within the epilimnion (1½ meters below the surface) and hypolimnion (approximately 1½ meters above the bottom) at each station. These samples were analyzed for total phosphorus, nitrate/nitrite nitrogen, pH, and alkalinity. Additional composite samples of the upper two meters of the water column were collected for chlorophyll *a* determinations. Temperature and dissolved oxygen profiles and Secchi disk transparencies were measured in the field at each station using an air calibrated YSI Model 85 digital dissolved oxygen meter and a standard limnological Secchi disk. Specific conductance was also measured in the field using the YSI Model 85.

The Upper Saranac Lake outlet and major tributaries (Lake Clear Outlet, Little Clear Outlet, Spider Creek, and Fish Creek) were sampled once or twice per month from May through October 2005 at historically established stations. On each sampling date, flow measurements were taken with a Marsh-McBirney Flo-Mate 2000 electromagnetic flow meter and/or gage heights were noted. Samples were collected and analyzed for total phosphorus, nitrate/nitrite nitrogen, pH, and alkalinity. Temperature, dissolved oxygen, and specific conductivity was measured in the field using a YSI Model 85 meter.

Once collected, samples were placed in a cooler with ice packs, transported to Cedar Eden Environmental, processed, preserved where appropriate, and either frozen for later shipment or shipped on the date of collection. Frozen and/or fresh samples were shipped via overnight carrier to the water quality laboratory for analysis. All analyses were completed using Standard Methods for the Examination of Water and Wastewater 19th Edition. All water quality data are provided in Appendix B.

Weather Conditions

The 2005 monitoring season could be described as hot and humid spells, interspersed with periods of heavy rain. The monitoring season was unseasonably warm, with a total of 39 days above 80° F between May 1 and September 30[*]. More significantly, there were 14 days above 80° F in June, including two five day period, and 14 days above 80° F in July including a 7 day period. As a result, water temperatures in the lake (and presumably in the streams, although this was the first year measuring stream temperature) were exceedingly high – reaching a higher temperature earlier in the season and reaching a higher overall temperature than typical for a season.

Precipitation was light in May, slightly less than an inch. June received a total of 4.4 inches of rain, including three storm events of ½ inch or greater: June 9 - 0.53"; June 13-18 - 2.25" (peak June 16 - 0.91" and June 17 - 0.65"); June 28-29 – 1.24". A total of 5.29 inches of rain were received in July, including three storm events of ½ inch or greater: July 5 - 1.92"; July 8-9 - 0.89"; July 26-27 - 1.32". In August, a total of 4.51 inches of rain fell, with one storm on August 31 contributing 2.54 inches to that total. In September, 5.13 inches of rain fell, including 3 storms of ½ inch or greater: Sept. 3 - 0.54"; Sept. 16-17 - 1.95"; Sept. 26 - 0.89".

Lake Water Quality Results

Throughout this report, the terms epilimnion and epilimnetic refer to the upper waters of the lake and samples collected within the epilimnion, while the terms hypolimnion and hypolimnetic refer to the bottom waters of the lake and samples collected within the hypolimnion. Water quality results are often presented as concentrations in milligrams per liter (mg/L) or its equivalent of parts per million (ppm) and micrograms per liter (µg/L) or its equivalent of parts per billion (ppb). The relationship between these units is shown below:

1 mg/L = 1 ppm; 1 µg/L = 1 ppb, 1 ppm = 1,000 ppb
example: 0.020 mg/L (ppm) = 20 µg/L (ppb)

Dissolved Oxygen and Temperature

Vertical mixing within the water column of a lake is a function of the water's temperature dependent density gradient. Cold water is denser than warm water. In the spring and fall lakes generally become isothermal (entirely the same temperature) and lake water circulates freely from top to bottom. As the surface water heats up in late spring/early summer, this water becomes less dense. When a lake is deep enough, and/or sheltered from the wind, the water at the bottom of the lake remains cold throughout the summer and does not mix with the warm, low density surface water. The lake is then essentially divided into three different compartments. The cold bottom waters make up the hypolimnion, and the warm surface water is called the epilimnion. The transition zone

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[*] Source: Paul Smith's College Weather Station

where temperatures change rapidly with depth is termed the metalimnion. The thermocline lies within the metalimnion and is the horizontal plane where the maximum change in temperature with depth occurs.

The amount of oxygen dissolved in a lake plays an important part in its ecosystem. EPA guidelines for dissolved oxygen concentrations for adult life stages of fish are 5.0 mg/L for warmwater species and 6.5 mg/L for coldwater species (US EPA 1986). EPA also established minimum dissolved oxygen concentrations at different levels of fish impairment. The levels of production impairment for adult salmonids (cold-water fish) are: none at 8 mg/L, slight at 6 mg/L, moderate at 5 mg/L, severe at 4 mg/L, and acute mortality at 3 mg/L. Lakes receive most of their oxygen from the atmosphere through gas exchange at the water's surface. In deeper lakes that stratify, the colder bottom water (hypolimnion) is isolated from the oxygen entering the upper water (epilimnion). If the lake sediments are rich in organic matter, bacterial decomposition uses up the oxygen in the bottom waters and the hypolimnion becomes hypoxic (less than 2.0 mg/L of oxygen) or anoxic (without oxygen). If this occurs, cold water fish habitat is lost, and phosphorus within the sediments may be released into the overlying water.

Dissolved oxygen (DO) and temperature profiles and isopleths are presented in Appendix C. Upper Saranac Lake was just showing the signs of developing stratification on June 1. By July 29, stratification was well defined and the upper waters were much warmer than normal, approaching 24° C in both the north and south basins of the lake. By August 19, oxygen depletion was evident in the north basin. In August, mid-thermocline depths (separation between epilimnion and hypolimnion) were about 6.0 meters to 8.0 meters (20 - 25 feet) in the north and south basins. Both basins remained stratified through September. However, by September 28, the thermocline in the north basin had moved downward, a sign of approaching destratification. The thermocline depth in the south basin was relatively unchanged by September 28, but the hypolimnion exhibited dissolved oxygen levels that were 3 mg/L or less. By October 20, the north basin was destratified, well oxygenated and with uniform temperatures from the surface to the lake bottom. The south basin was still stratified on October 20, but the thermocline depth had moved to about 15 meters (50 feet).

Lake stratification shows well in the color temperature isopleth graphs in Appendix C, with the warm upper waters being orange to red and the cold bottom waters being blue. The lake water can mix top to bottom when the temperature (colors) are similar top to bottom. The color dissolved oxygen isopleth graphs in Appendix C show oxygen concentrations in the lake. Hypoxic conditions (< 2 mg/L DO) existed at the sediment-water interface in the north basin hypolimnion from at least the beginning of June to late October and in the south basin from mid-June through at mid-October. Anoxic conditions (< 1 mg/L DO) existed at the sediment-water interface in the north basin hypolimnion from late-June through early-October and in the south basin from early-June through at least late-September. The extent of oxygen depletion in the bottom waters was significantly greater in the north basin and slightly less in the south basin in 2005 compared to 2004.

pH and Alkalinity

The acidity of water (concentration of hydrogen ions) is measured as pH and reported in standard units on a logarithmic scale that ranges from one to fourteen. On the pH scale, seven is neutral, lower numbers are more acidic, and higher numbers are more basic. In general, pH values between 6.0 and 8.0 are considered optimal for the maintenance of a healthy lake ecosystem. Many species of fish and amphibians have difficulty with growth and reproduction when pH levels fall below 5.5 standard units. Alkalinity (or acid neutralizing capacity) is a measure of the buffering capacity of water, the ability of a lake to absorb or withstand acidic inputs. In the northeastern United States, many lakes have low alkalinities, which mean that they are sensitive to the effects of acidic precipitation. This is a particular concern during the spring when large amounts of low pH snowmelt run into lakes with little or no contact with the soil's natural buffering agents. Typical summer levels of alkalinity in northeastern lakes are around 10 milligrams per liter (mg/L).

Levels of pH and alkalinity in Upper Saranac Lake are shown graphically in Figures 1 and 2. Upper Saranac Lake remained relatively well buffered with a stable epilimnetic pH of 7.1 to 8.3 and epilimnetic alkalinity of 12 mg/L to 16 mg/L. Higher epilimnetic pH values occurred earlier in the season during periods of higher algal growth. Within the hypolimnion, hypoxic (low oxygen) and anoxic (without oxygen) conditions resulted in lower pH values and higher alkalinities. Alkalinity within the hypolimnion increased throughout the monitoring season as the bottom waters became increasingly anoxic.

Conductivity

Conductivity (or specific conductance) is a measure of the ability of water to conduct electric current, and is related to the amount of dissolved ions within the water. Higher conductivity values are indicative of pollution by road salt or septic systems and more eutrophic conditions in a lake. Conductivities may be naturally high in stained water that drains from swamps and marshes. Clean, clear-water lakes in the Adirondack region typically have conductivities of around 20 to 30 micro-mhos per centimeter (µmhos/cm).

Levels of conductivity in Upper Saranac Lake are shown in Figure 3. The values were moderate. Conductivities increased slightly throughout the monitoring season. Conductivity increased markedly within the north basin hypolimnion due to its strong oxygen depletion. The drop in hypolimnetic conductivity in the north basin on the last date is due to lake turnover and mixing, causing both a dilution effect and a reoxygenation of water above the sediments.

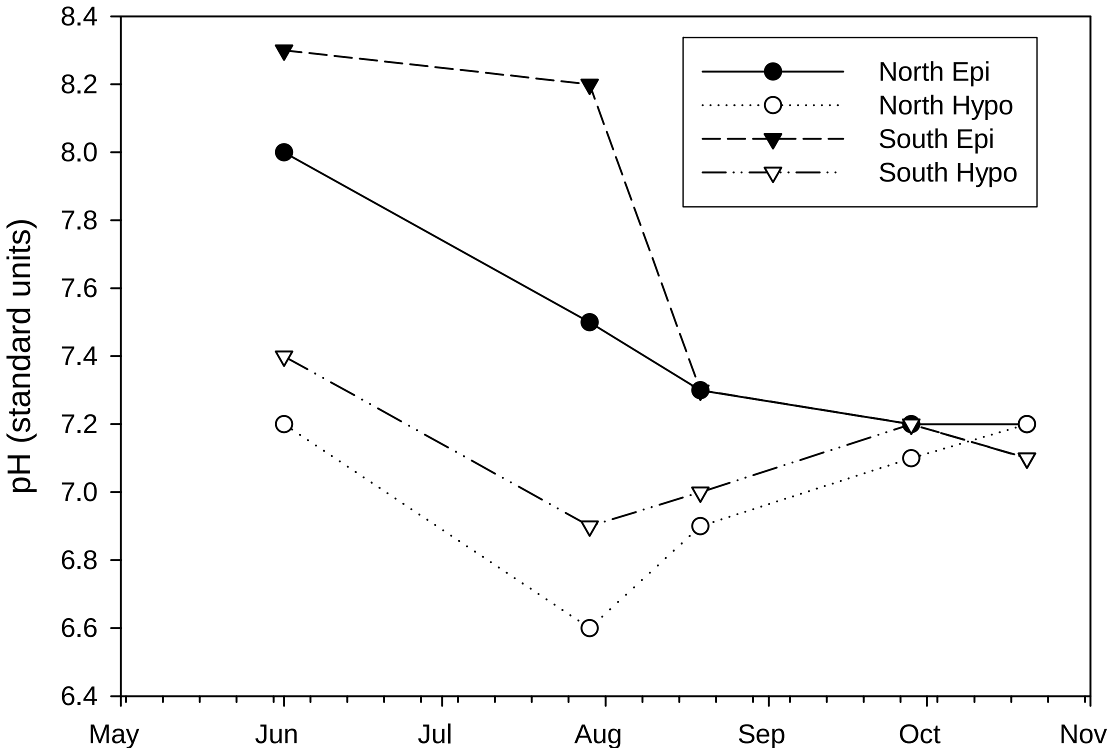

Figure 1 Levels of pH in Upper Saranac Lake during 2005

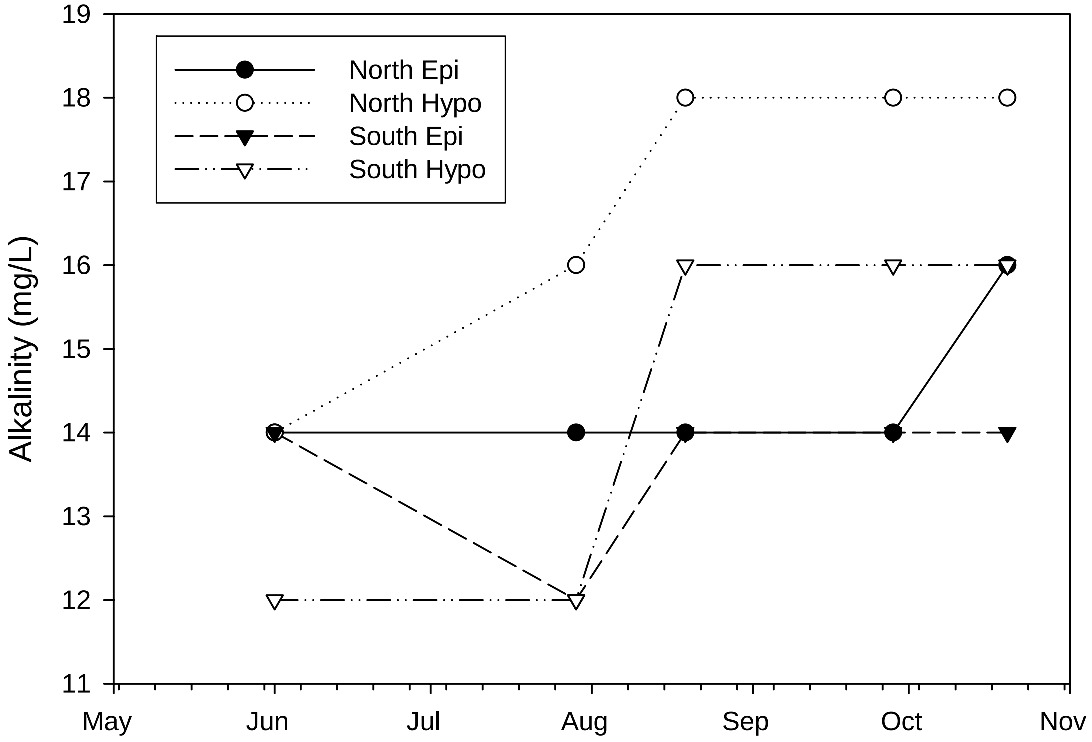

Figure 2 Levels of alkalinity in Upper Saranac Lake during 2005

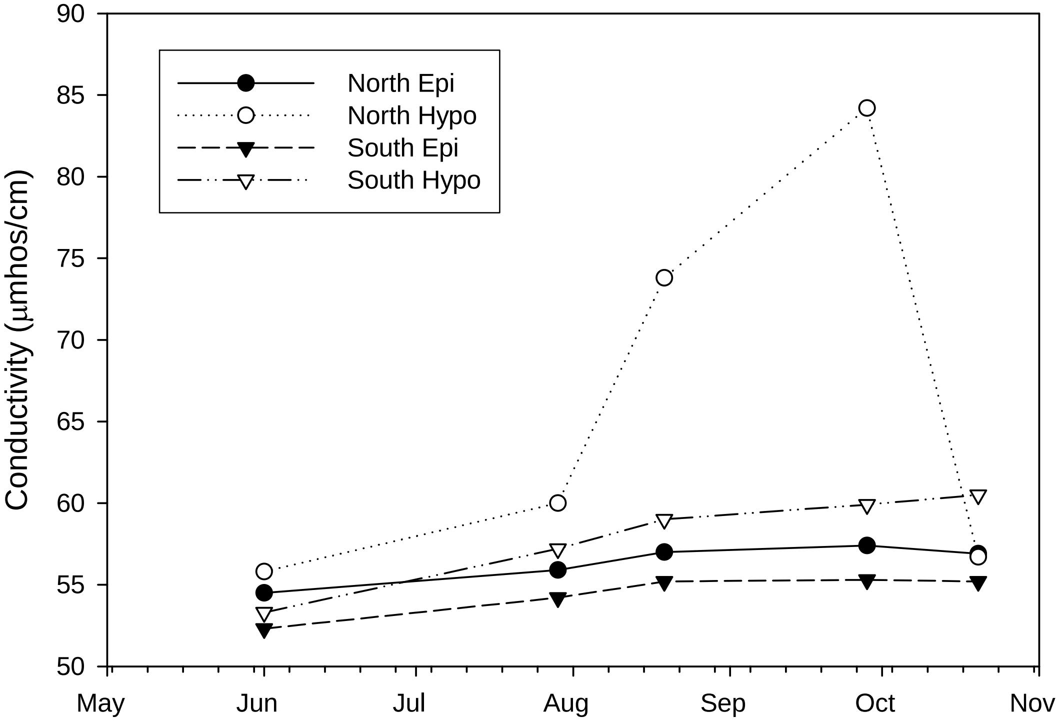

Figure 3 Levels of conductivity in Upper Saranac Lake during 2005

Phosphorus

Phosphorus is the nutrient that most often controls algal productivity (growth) in lakes. Total phosphorus is a measure of all forms of phosphorus, both organic and inorganic. Total phosphorus concentrations are directly related to the trophic condition of a lake. Epilimnetic (surface) total phosphorus concentrations less than 0.010 mg/L are associated with oligotrophic conditions and concentrations greater than 0.025 mg/L are associated with eutrophic conditions (DEC & FOLA 1990).

Total phosphorus concentrations in Upper Saranac Lake are shown in Figure 4 and Figure 5. Figure 4 compares phosphorus concentrations at both stations and in both the epilimnion and hypolimnion. Figure 5 shows the phosphorus concentrations in the epilimnion only. Epilimnetic concentrations ranged from 0.009 mg/L to 0.026 mg/L in the north basin (0.013 mg/L summer average) and 0.009 mg/L to 0.027 mg/L in the south basin (0.011 mg/L summer average). Within the epilimnion, total phosphorus concentrations were highest in late summer/early fall. This may be due to a possible mixing event where higher concentrations of phosphorus in the north and south basin hypolimnia were mixed into the epilimnion. There is evidence of a reduction in hypolimnetic phosphorus concentrations and a corresponding increase in epilimnetic phosphorus concentrations in the south basin. This also corresponds to the time when the north basin epilimnion had moved down into the hypolimnion near the onset of fall turnover, allowing the migration of accumulated hypolimnetic phosphorus to reach the lake's surface waters. There is a corresponding increase in chlorophyll *a* concentrations in the north basin at this time, showing that algae were able to capitalize on this extra phosphorus.

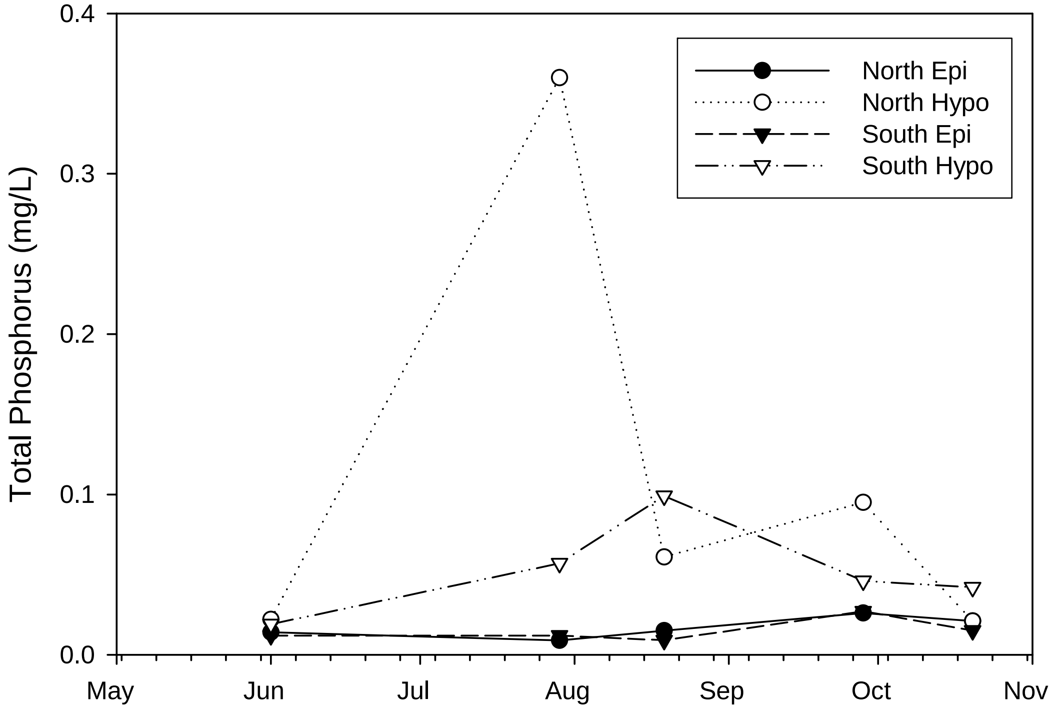

Figure 4 Total phosphorus levels in Upper Saranac Lake during 2005

Hypolimnetic phosphorus concentrations ranged from 0.021 mg/L to 0.095* mg/L in the north basin and from 0.015 mg/L to 0.061 mg/L in the south basin. Hypolimnetic phosphorus concentrations were similar in the north and south basins.

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* ignoring 0.360 mg/L outlier in July likely outlier or sample contamination

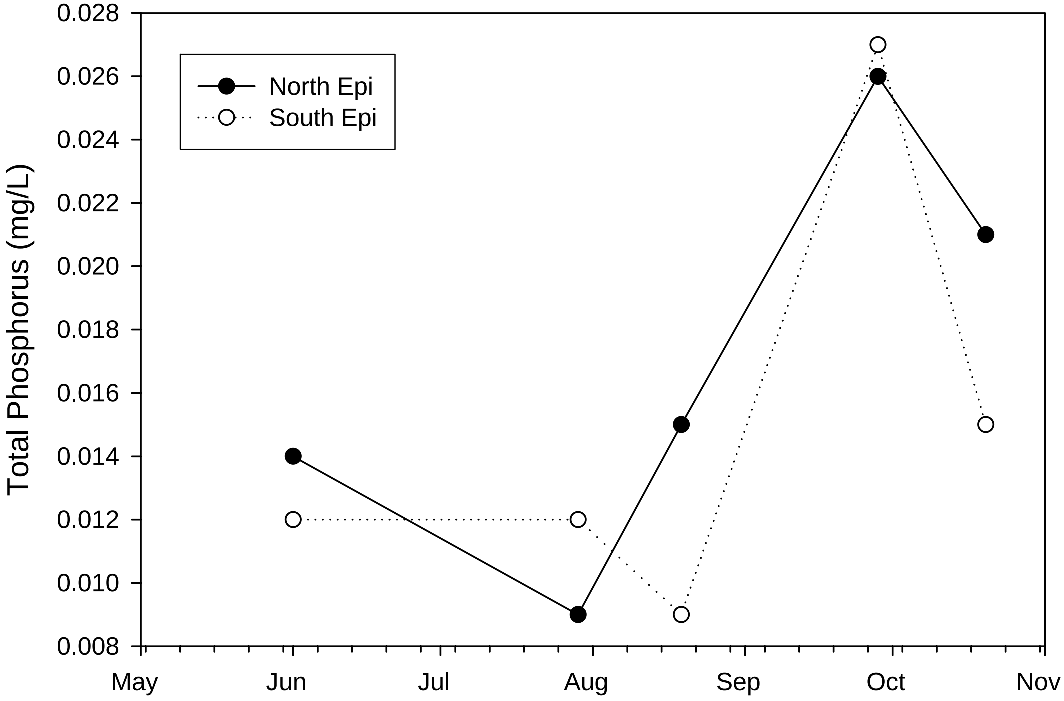

Figure 5 Total phosphorus in the epilimnion of Upper Saranac Lake during 2005

Nitrogen

Nitrogen is one of the three main nutrients of life, along with phosphorus and carbon. Nitrate is an inorganic form of nitrogen that occurs naturally. It is a component of atmospheric pollution and elevated concentrations in lakes and ponds may be associated with acidification. Total nitrogen is a measure of all forms of nitrogen, including both organic (ammonia) and inorganic (nitrate) forms. Elevated concentrations of nitrogen may also be indicative of wastewater pollution. Excessive nitrogen is often associated with agricultural activities and wastewater influence.

Because nitrogen is so readily converted from one form to another depending on environmental conditions, identifying sources of nitrogen from analyses of different forms at a single monitoring station is difficult. However, nitrogen from specific sources enters the hydrologic cycle in characteristic forms. Sources of Total Kjeldahl nitrogen (TKN, or ammonia plus organic nitrogen) include the decay of organic material such as plant material and animal wastes and disposal of sewage and organic waste. Large amounts of ammonia and organic nitrogen are applied to cropland as fertilizer. Both ammonia and organic nitrogen are relatively immobile in soils and ground water because of adsorption on soil surfaces and particulate filtering, but are susceptible to nitrification (conversion to nitrate nitrogen by addition of oxygen) under aerobic conditions.

Nitrate/Nitrite Nitrogen

Nitrate/nitrite (nitrate plus nitrite) nitrogen can be derived from nitrification of TKN, and thus shares all the potential sources of TKN. Nitrate/nitrite concentrations can exceed 10 mg/L in rivers affected by fertilizer application and animal wastes. Unlike ammonium ions and organic nitrogen, nitrate is highly mobile in ground water; nitrate derived from agricultural fertilizer, animal waste, or decaying plant material can infiltrate ground water, which in turn can discharge to streams. Nitrogen oxides discharged to the atmosphere by plants and the burning of fossil fuels are transformed to nitrate that is present in rain water; ammonium ions also are present in rain water. Important changes in concentration for nitrate/nitrite nitrogen in streams occur through incorporation into organic matter and denitrification.

Nitrate/nitrite nitrogen concentrations for Upper Saranac Lake are shown in Figure 6. With one exception, epilimnetic nitrate/nitrite concentrations were at or below the detection limit of 0.01 mg/L. The south basin hypolimnion again exhibited measurable levels of nitrate/nitrite throughout the monitoring period. The levels were low and are likely due to conversion of ammonia to nitrate/nitrite that would occur in the oxygenated south basin hypolimnion but not the anoxic north basin hypolimnion. This conclusion is supported by the observation that some nitrate/nitrite is present in the north basin hypolimnion early in the season but disappears later, when the entire hypolimnion is anoxic.

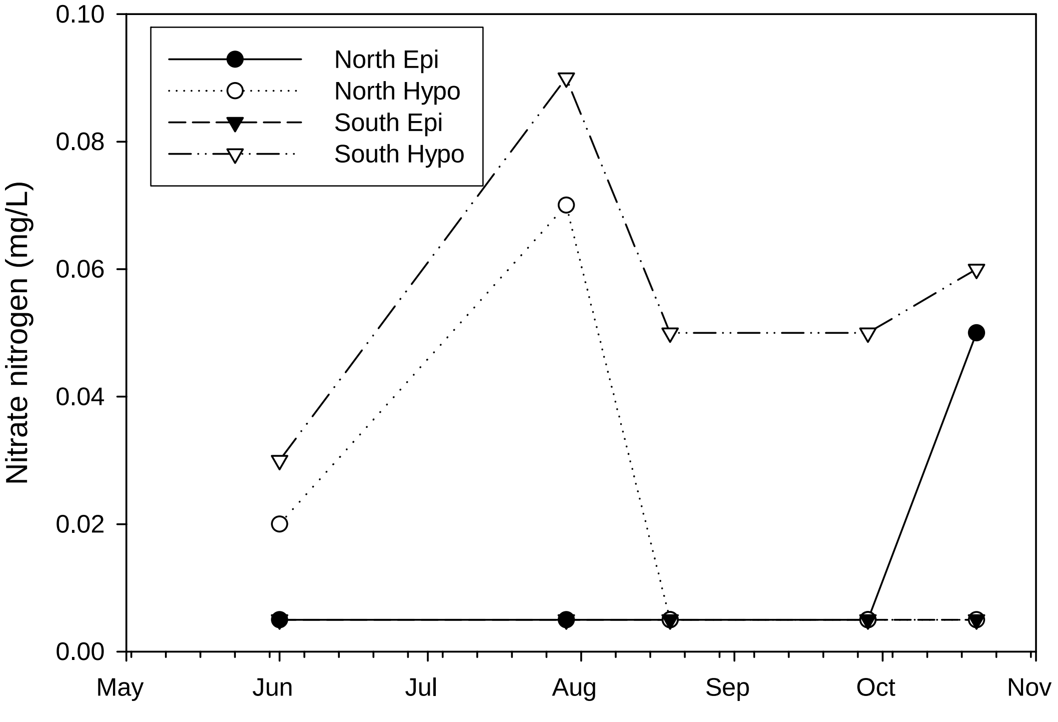

Figure 6 Nitrate/nitrite nitrogen values in Upper Saranac Lake during 2005

Ammonia Nitrogen

Ammonia is found naturally in the environment as an initial by-product from the decomposition of nitrogen rich compounds found in organic material. Ammonia is also a major, potentially harmful constituent of municipal wastewater effluents and agricultural runoff. The environment has a certain capacity to convert ammonia to other compounds and the rate depends on temperature, pH, and other nutrient species present. Through normal bacterial activity, the environment produces plant nourishing nitrates from ammonia.

Ammonia is generally not problematic with respect to the eutrophication of lakes that are typically limited by phosphorus. The ecological impact of ammonia in aquatic ecosystems is likely to occur through chronic toxicity to fish and benthic invertebrate populations as a result of reduced reproductive capacity and reduced growth of young. These are subtle impacts that will likely not be noticed for some distance below an outfall or impact zone. The zone of impact varies greatly with discharge conditions, river flow rate, temperature and pH.

Ammonia nitrogen concentrations for Upper Saranac Lake are shown in Figure 7. Ammonia levels in Upper Saranac Lake were low or below the detection limits throughout the season (detection limit of 0.10 mg/L logged as ½ detection limit or 0.05 mg/L). This is as expected in a non-agricultural watershed with no major wastewater treatment plants or industrial discharges. Ammonia was only detectable within the hypolimnion, where anoxic conditions prevented its oxidation into the nitrate form of nitrogen. Concentrations were highest during periods of greatest anoxia.

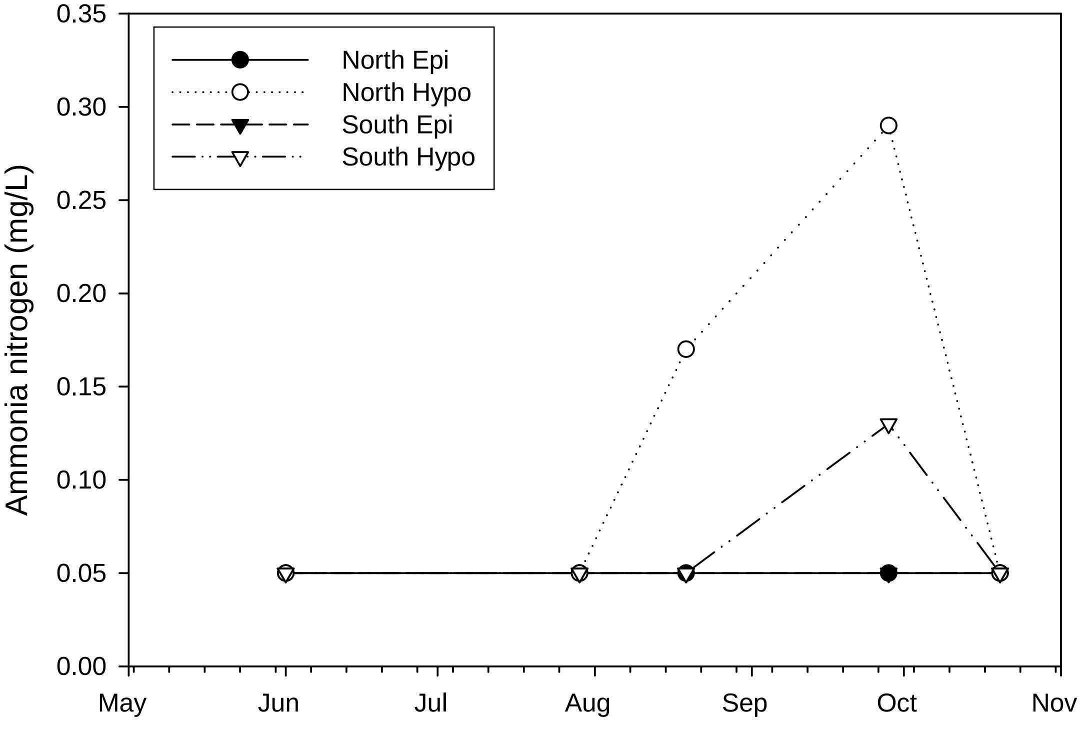

Figure 7 Ammonia nitrogen values in Upper Saranac Lake during 2005

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen is the sum of organic nitrogen and ammonia in a water body. The Kjeldahl technique is a laboratory test for measuring the amount of organic nitrogen contained in water. The organic nitrogen concentration is actually the total Kjeldahl nitrogen concentration minus the ammonia concentration. Organic nitrogen may be either dissolved or suspended particulate matter in water. High levels of organic nitrogen in water may indicate excessive production or organic pollution from the watershed. Animal and human waste, decaying organic matter, and live organic material like tiny algae cells can causes organic nitrogen enrichment of lake water.

Total Kjeldahl nitrogen (TKN) concentrations for Upper Saranac Lake are shown in Figure 8. TKN was low in Upper Saranac Lake but exhibited a definite increasing trend throughout the season starting in late July within the epilimnia and hypolimnia at both stations. Since ammonia was for the most part below detection limits, TKN represents organic nitrogen in Upper Saranac Lake. The trend does not correspond with algae concentrations in the lake. A potential source for an increase in TKN that starts in August and continues into fall is septic system leachate, since it would take some period of occupancy for loading to reach the lake.

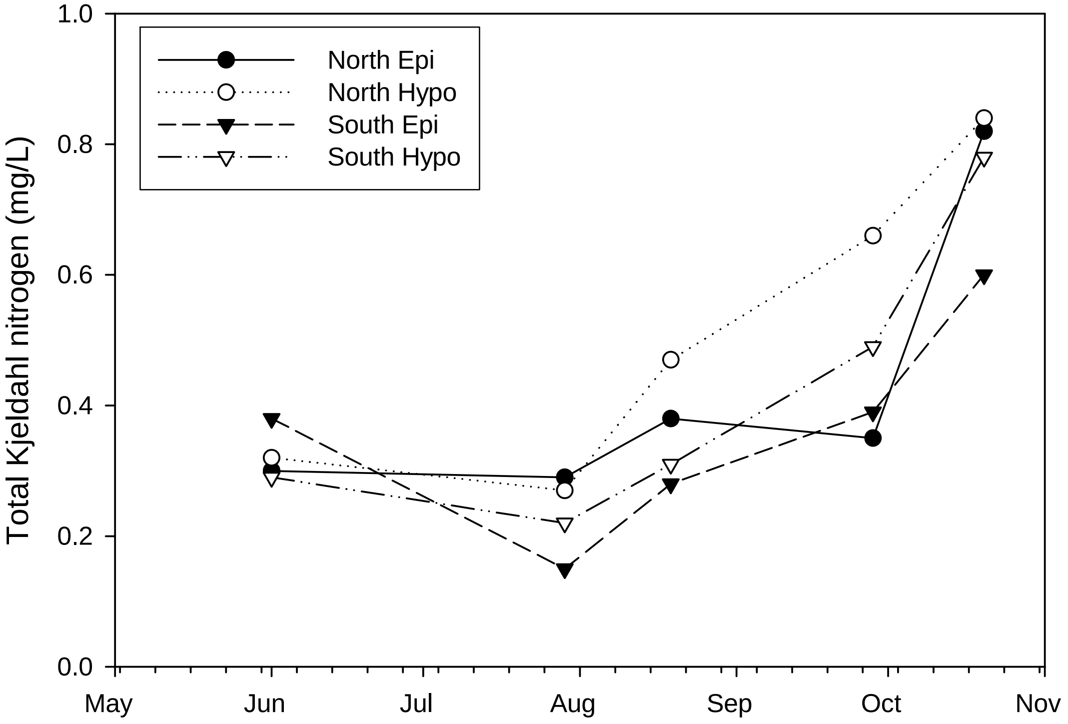

Figure 8 Total Kjeldahl nitrogen values in Upper Saranac Lake in 2005

Total Nitrogen

Total nitrogen is a measure of all the various forms of nitrogen that are found in a water sample. Nitrogen is a necessary nutrient for the growth of aquatic plants and algae. Not all forms of nitrogen can be readily used by aquatic plants and algae, especially nitrogen that is bound with dissolved or particulate organic matter. Total nitrogen consists of inorganic and organic forms. Inorganic forms include nitrate (NO_3^-), nitrite (NO_2^-), unionized ammonia (NH_4), ionized ammonia (NH_3^+), and nitrogen gas (N_2). Amino acids and proteins are naturally-occurring organic forms of nitrogen. All forms of nitrogen are harmless to aquatic organisms except un-ionized ammonia and nitrite, which can be toxic to fish. Nitrite is usually not a problem in waterbodies, however, because (if there is enough oxygen available in the water for it to be oxidized) nitrite will be readily converted to nitrate. Total nitrogen can be determined analytically as the sum of Total Kjeldahl Nitrogen and Nitrate/Nitrate Nitrogen.

Total nitrogen concentrations for Upper Saranac Lake are shown in Figure 9. Since both ammonia and nitrate nitrogen were low or below detection limits, most of the total nitrogen consisted of organic nitrogen. Therefore, the total nitrogen results are similar to the total Kjeldahl nitrogen results, exhibiting a steady increase from late July to the end of the monitoring period at both depths in both the north and south basins.

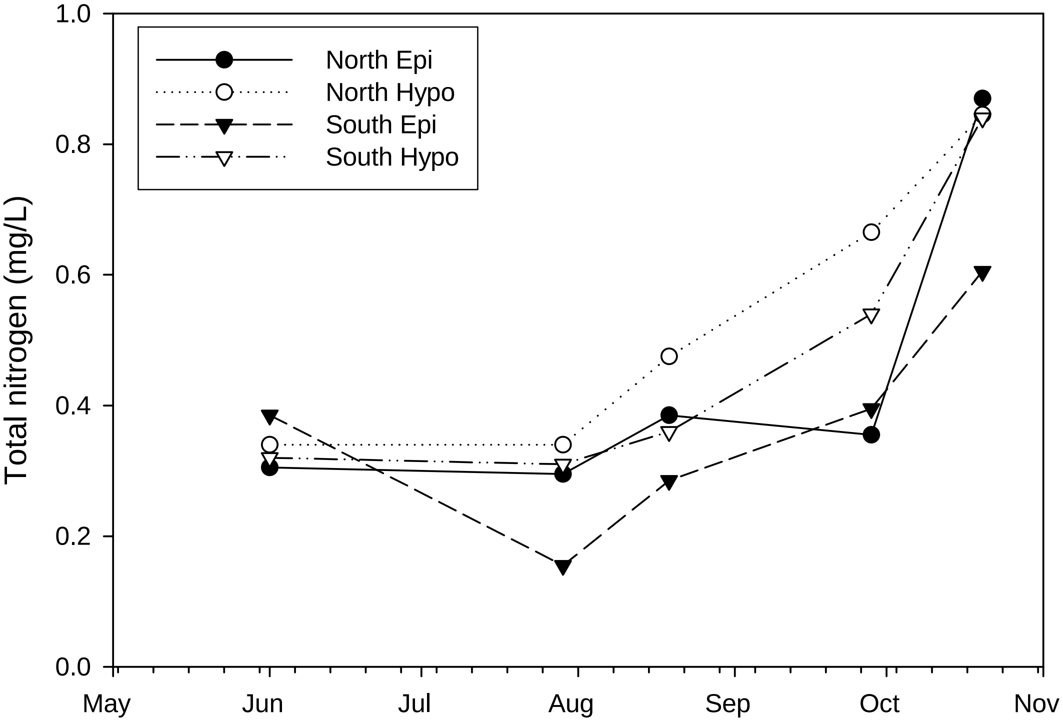

Figure 9 Total nitrogen values in Upper Saranac Lake in 2005

Transparency

Transparency is a measure of water clarity in lakes and ponds. It is determined by lowering a 20 cm black and white disk (Secchi disk) into a lake to the depth where it is no longer visible from the surface. Since algae are the main determinant of water clarity in non-stained lakes that lack excessive amounts of inorganic turbidity (suspended silt), transparency is used as an indicator of lake trophic state. Transparencies greater than 4.6 meters are associated with oligotrophic conditions, while transparencies less than 2 meters are associated with eutrophic conditions (DEC & FOLA 1990).

Transparency values for Upper Saranac Lake are presented in Figure 10. Transparency ranged from 3.0 m to 4.7 m (mean = 4.1 m) in the north basin and from 4.1 m to 5.5 m (mean = 4.8 m) in the south basin. Both basins exhibited a drop in transparencies in mid-August, followed by an improvement. The north basin exhibited a much lower transparency in late October when the basin had turned over, mixing murkier bottom waters and phosphorus throughout the water column.

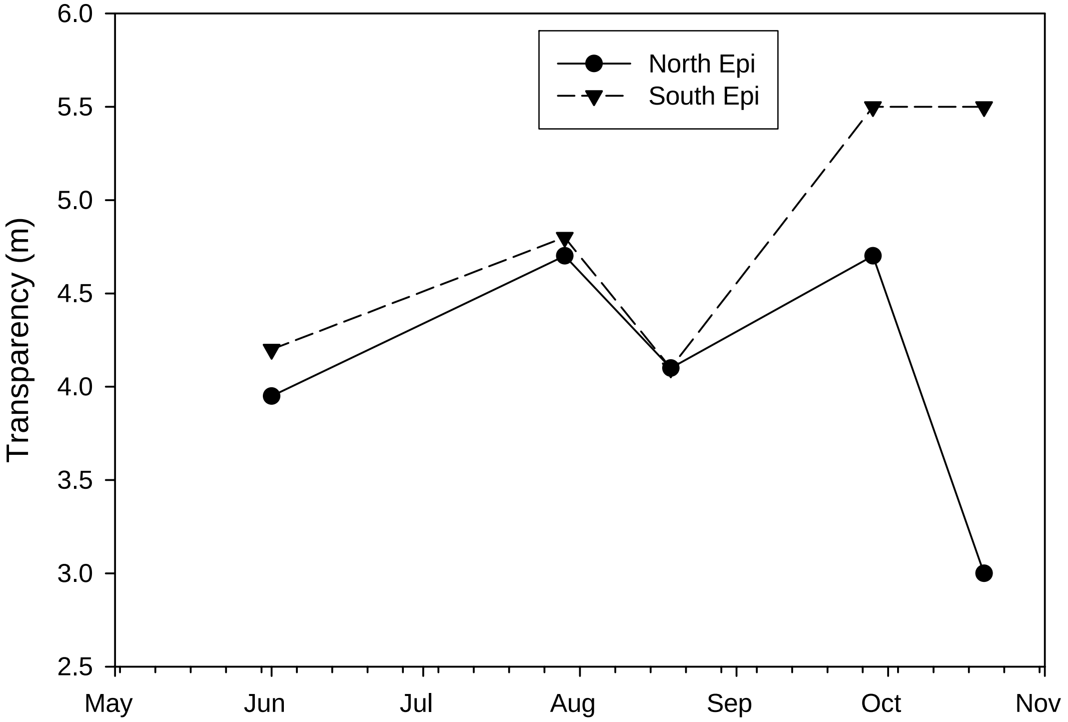

Figure 10 Transparency in Upper Saranac Lake during 2005

Chlorophyll *a*

Chlorophyll *a* is a green pigment used by plants in photosynthesis. The measurement of chlorophyll *a* provides an indication of the amount of phytoplankton growing in a lake and therefore can be used to classify lake trophic state. Chlorophyll *a* concentrations less than 2 micrograms per liter (µg/L) are associated with oligotrophic conditions, while concentrations greater than 8 µg/L are associated with eutrophic conditions (DEC & FOLA 1990).

Chlorophyll *a* concentrations for Upper Saranac Lake are presented in Figure 11. Chlorophyll *a* was generally higher in the north basin throughout the monitoring period. Chlorophyll *a* levels exhibited a spring peak in both basins, and a fall peak in the north basin. North basin chlorophyll *a* peaked at 6.7 µg/L in early June and at 3.9 µg/L in late-September. South basin chlorophyll a peaked at 4.6 µg/L in early June.

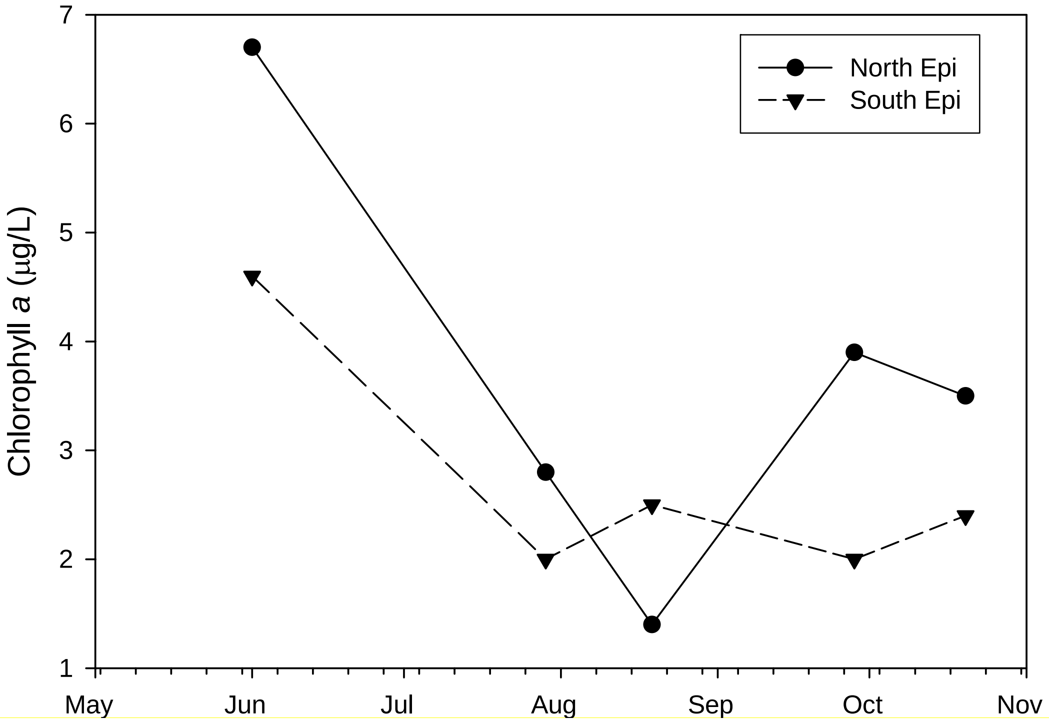

Figure 11 Chlorophyll *a* levels in Upper Saranac Lake during 2005

Trophic State

Trophic state is a term used in limnology to describe the amount of algae and macrophytes (aquatic plants) found in a lake. Oligotrophic lakes have few algae and macrophytes and appear clean and clear, while eutrophic lakes show an overabundance of growth and often have a pronounced green color due to algae. Eutrophication is a natural process whereby lakes increase in trophic state over long periods of time. However, the process of eutrophication can be greatly accelerated by human activities (such as watershed development and sewage disposal) which introduce additional nutrients, organic matter and silt into the lake system. This cultural eutrophication can be reversed by controlling human inputs, but in many cases additional in-lake treatments are required in order to accelerate this rehabilitation process.

The Carlson (1977) Trophic State Index (TSI) is an extremely valuable tool for the evaluation of lakes. This index can be calculated using summer averages for total phosphorus, chlorophyll a, and/or transparency (Secchi depth) data. To calculate this index each seasonal average is logarithmically converted to a scale of relative trophic state ranging from 1 to 100. This index was constructed such that an increase in ten units represents a doubling in algal biomass. For example, a lake with a chlorophyll TSI of 40 has twice as much algae as a lake with a TSI value of 30. Generally, TSI values less than 38 are considered oligotrophic, while TSI values greater than 51 are considered eutrophic (DEC & FOLA 1990).

The Carlson's TSI values for Upper Saranac Lake are presented in Figure 12. TSI values for all parameters were within the mesotrophic range. In both basins, the chlorophyll TSI values were slightly higher than the total phosphorus and transparency values.

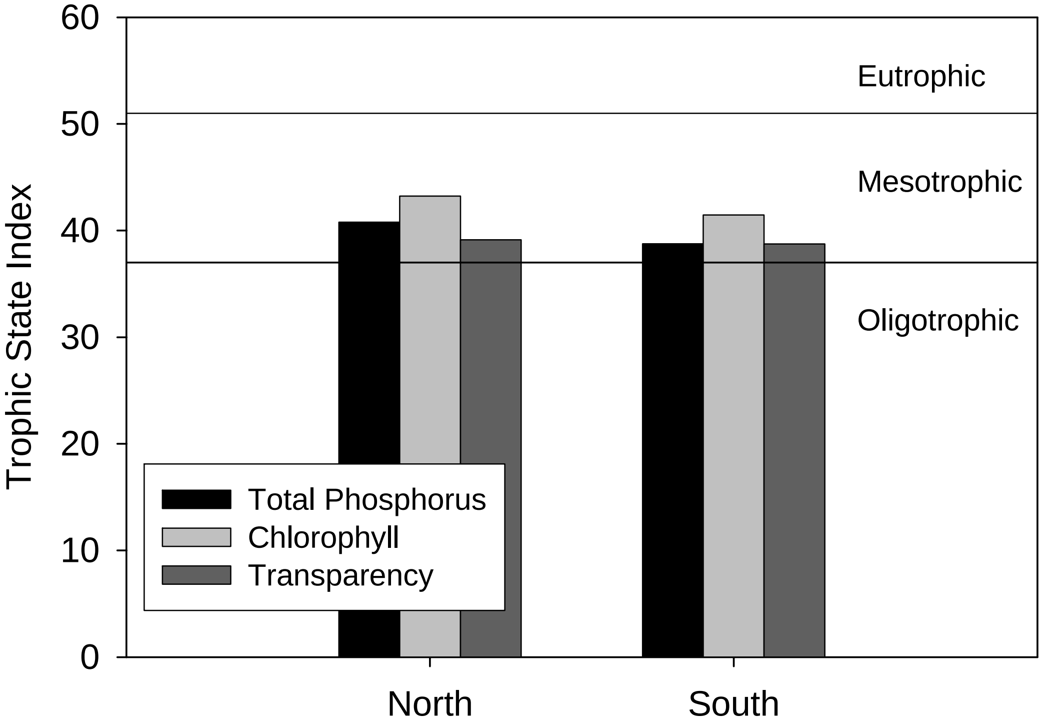

Figure 12 Trophic State Index values for Upper Saranac Lake during 2005

Limiting Nutrient (TN:TP Ratio)

A limiting nutrient is a chemical necessary for plant growth, but available in quantities smaller than needed for algae and macrophytes to increase their abundance. Once the limiting nutrient in a waterbody is exhausted, algae stop growing. If more of the limiting nutrient is added, larger algal populations will result until their growth is again limited by nutrients or by limiting environmental factors. In lake management, we often think that if a lake has a limiting nutrient, we can improve water quality by reducing that nutrient. While this is true to some degree – water quality in a phosphorus-limited lake might be improved by reducing phosphorus loading – this does not always hold true. In the case of phosphorus limitation, a lake might have already reached a maximum achievable water quality threshold. With nitrogen limitation, not often seen in fresh waters, you have many blue-green algae (cyanobacteria) that can fix their own nitrogen, so controlling phosphorus is still the primary objective. A lake that is neither nitrogen or phosphorus limited would still benefit from nutrient reduction, particularly if lake concentrations are low so that small changes are readily observable or if the lake is balanced on a threshold where small nutrient increases might trigger algae blooms.

Phosphorus and nitrogen are both essential nutrients for all plants, including aquatic plants and algae. In some cases, the low concentration of total nitrogen or total phosphorus in waterbodies has been found to limit the growth of free-floating algae (i.e., phytoplankton). If total nitrogen is in short supply and phosphorus is abundant, it is called nitrogen limitation. Nitrogen limitation occurs most commonly when the ratio of total nitrogen to total phosphorus is less than 10 (in other words, the TN concentration divided by the TP concentration is less than 10 or TN/TP < 10). If total phosphorus is in short supply and total nitrogen is abundant, it is called phosphorus limitation. Phosphorus limitation occurs most commonly when the ratio of total nitrogen to total phosphorus is more than 33 (TN concentration divided by TP concentration is greater than 33 or TN/TP > 33).

The TN:TP Ratios for Upper Saranac Lake are shown in Figure 13. Upper Saranac Lake was neither phosphorus or nitrogen limited throughout the growing period, although at times the lake was at the phosphorus limited boundary (P-limited, for all intents and purposes). The lake was definitively P-limited in the fall, when accumulated nutrients from the hypolimnion, both N and P, are mixed throughout the lake.

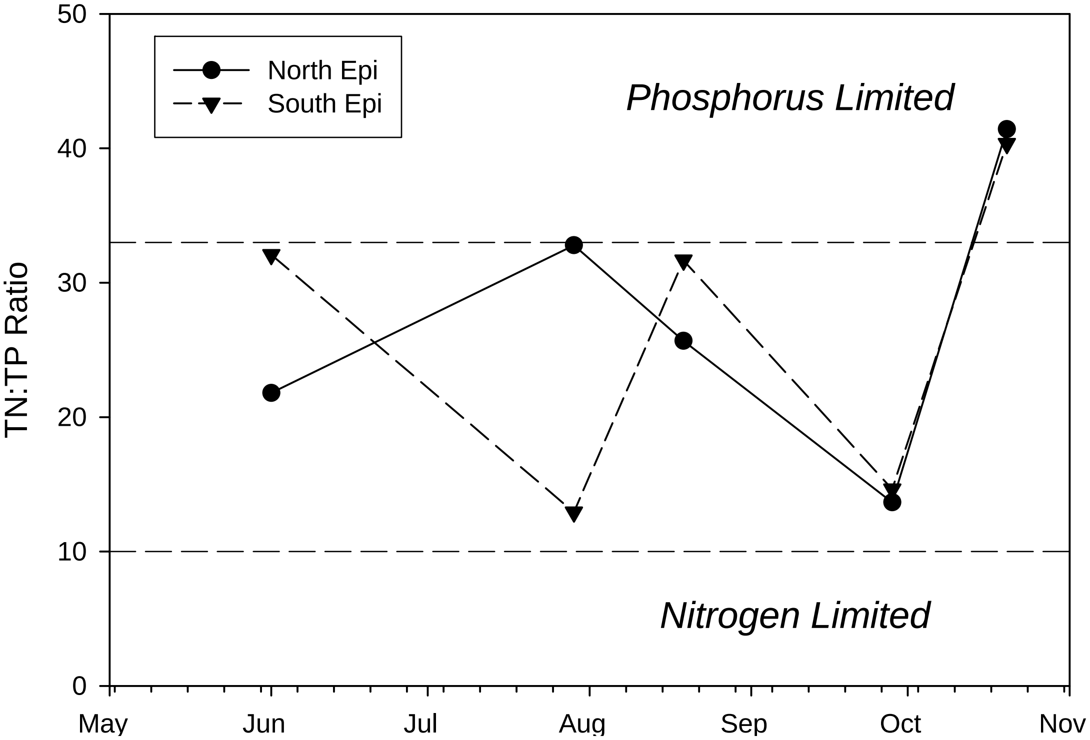

Figure 13 TN:TP Ratio in Upper Saranac Lake during 2005

Tributary Water Quality Results

pH and Alkalinity

The pH and alkalinity in the tributaries and outlet of Upper Saranac Lake are presented in Figure 14 and Figure 15. Fish Creek, Little Clear, and Lake Clear Outlet followed a similar trend of pH throughout the monitoring season, with no clear differences between each station. Spider Creek and Upper Saranac Lake Outlet varied from that trend. Tributary pH was generally higher in the spring and reached a stable point in mid-summer. With regard to alkalinity, Little Clear Pond Outlet and Spider Creek exhibited higher alkalinities and similar trends to each other. Alkalinity increased in Fish Creek, Lake Clear, and Upper Saranac Lake Outlet from mid-August to the end of the season, possibly due to the influence of septic systems and/or the release of solutes from stream sediments during low-flow periods (much as happens in lake hypolimnia during anoxic periods).

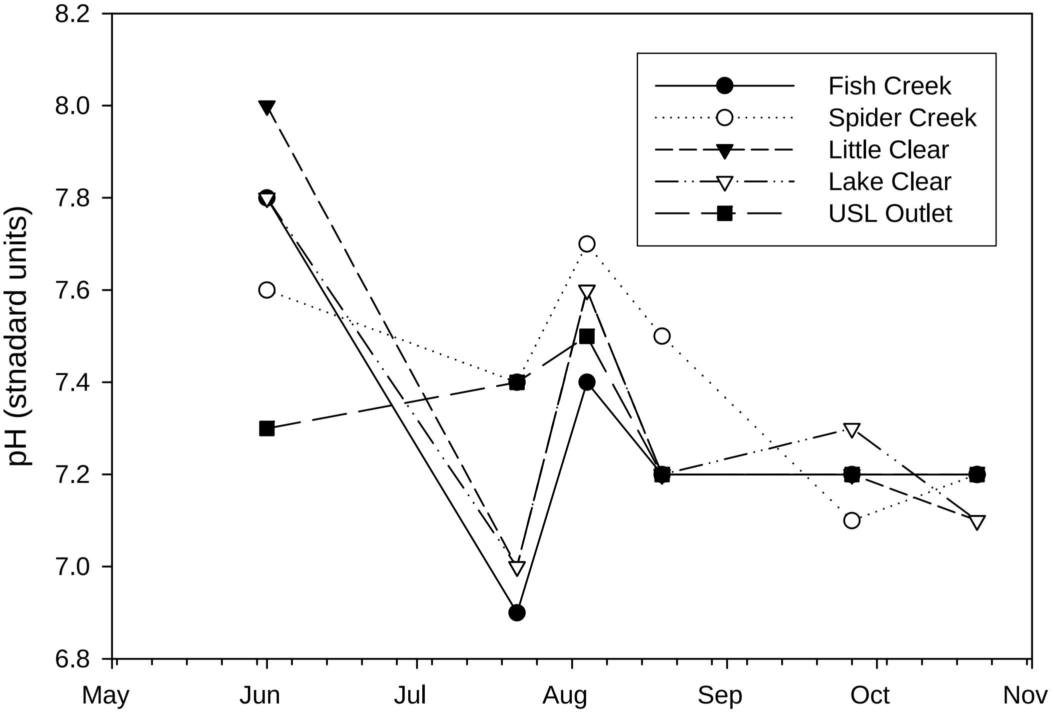

Figure 14 pH values in Upper Saranac Lake tributaries during 2005

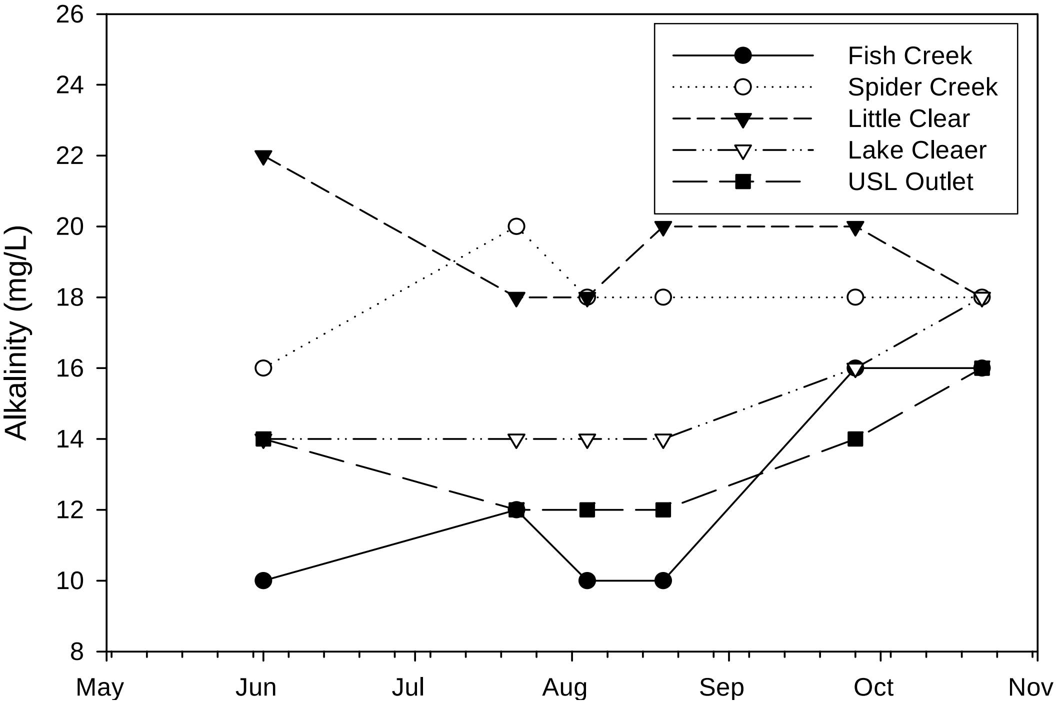

Figure 15 Alkalinity in Upper Saranac Lake tributaries during 2005

Conductivity

Conductivity in the tributaries and outlet of Upper Saranac Lake are presented in Figure 16. Conductivity was highest in Lake Clear Pond Outlet, followed closely by Little Clear Pond Outlet, with the lowest conductivities in Fish Creek. Little Clear Outlet receives the outfall from the Adirondack Fish Culture Station, while Lake Clear Outlet receives both wetland drainage and septic influences. All of these are sources for increased conductivity. The extreme high value in Little Clear measured in July may be due to instrument error. No seasonal increase in conductivity was observed this year in Lake Clear Outlet that might be attributable to septic loading.

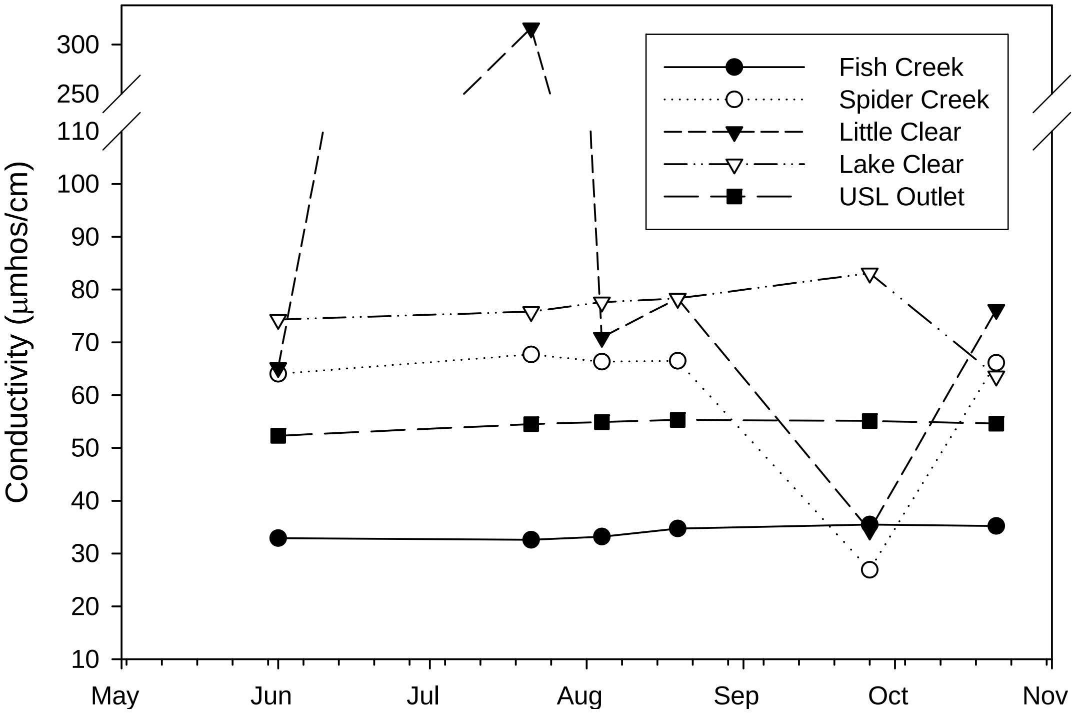

Figure 16 Conductivity in Upper Saranac Lake tributaries during 2005

Phosphorus

Figure 17 presents the total phosphorus concentrations in each tributary for each sampling date, while Figure 18 presents a comparison of average total phosphorus for each tributary for the monitoring season. Overall, phosphorus concentrations were highest in Little Clear Pond Outlet, and lowest in Fish Creek, Spider Creek and Upper Saranac Lake outlet. Little Clear Pond Outlet is influenced by the fish hatchery discharge. No seasonal increase in concentrations were observed this year in Lake Clear Outlet that might be attributable to septic loading. Average total phosphorus was significantly higher in Little Clear Outlet than any other station, and significantly higher at Lake Clear Outlet than at Fish Creek, Spider Creek and Upper Saranac Lake Outlet, as seen in Figure 18.

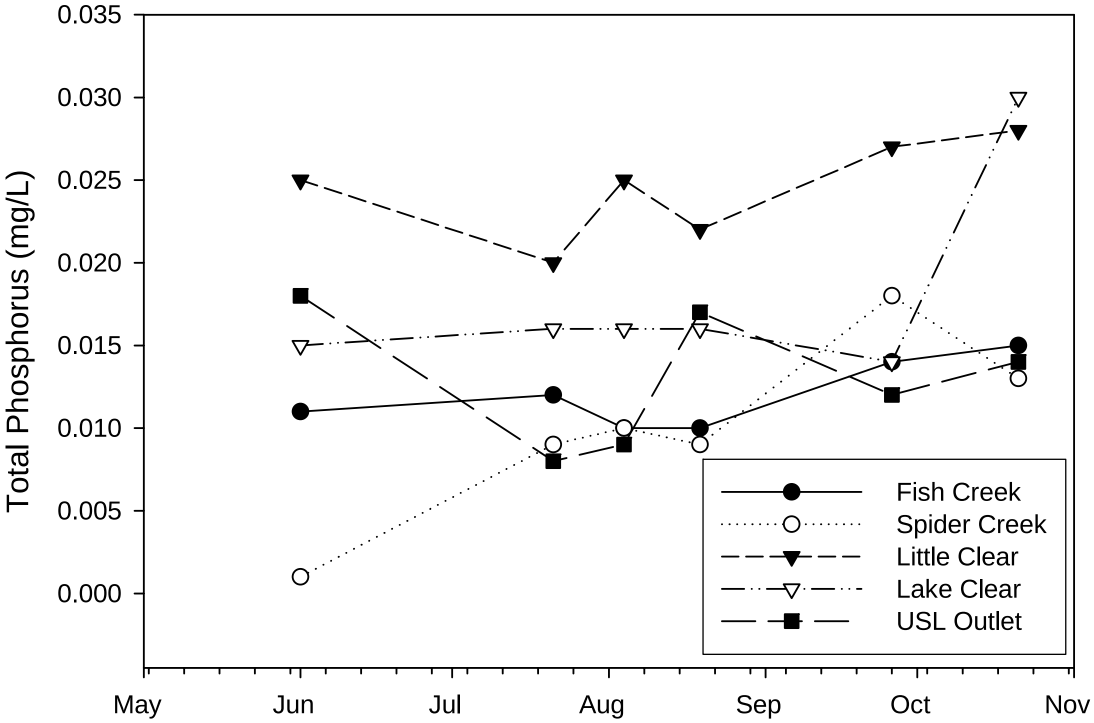

Figure 17 Total phosphorus levels in Upper Saranac Lake tributaries during 2005

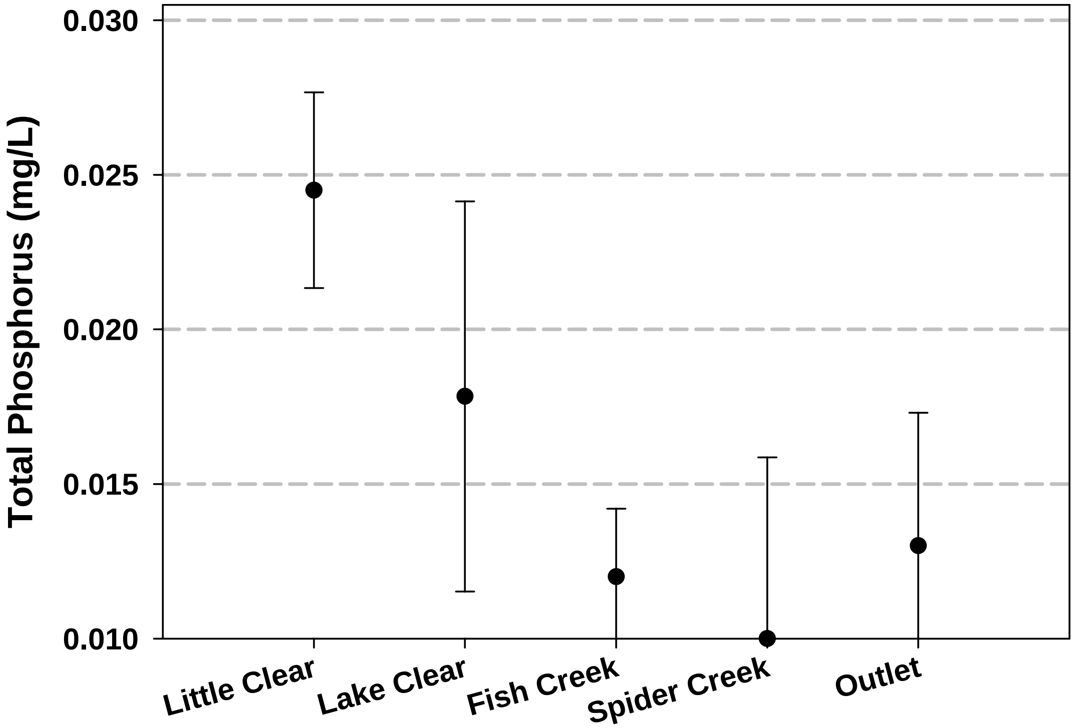

Figure 18 Average total phosphorus in Upper Saranac Lake tributaries during 2005. Error bars are 95% confidence intervals

Nitrogen

Nitrate/Nitrite Nitrogen

Figure 19 presents the nitrate nitrogen concentrations in each tributary for each sampling date, while Figure 20 presents a comparison of average nitrate nitrogen for each tributary for the monitoring season. Nitrate nitrogen was at or near the analytical detection limit at each station on nearly every sampling date, with the exception of Little Clear Outlet. Nitrate nitrogen levels were elevated in Little Clear Outlet from mid-June through October due to the influence of the fish hatchery discharge. As with phosphorus, excess nitrogen can spur the growth of aquatic plants and algae. Summer values of nitrate nitrogen in Little Clear Outlet are much higher than is typical for an Adirondack stream, and significantly higher than the other monitored stations in the watershed (Figure 20).

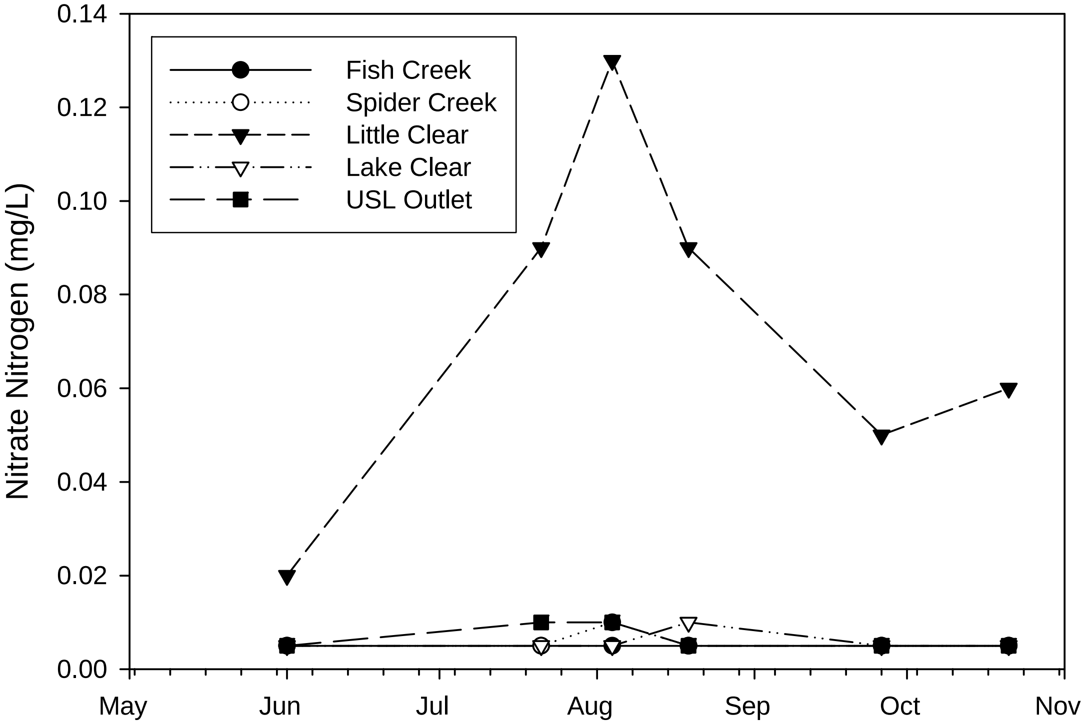

Figure 19 Nitrate nitrogen in Upper Saranac Lake tributaries during 2005

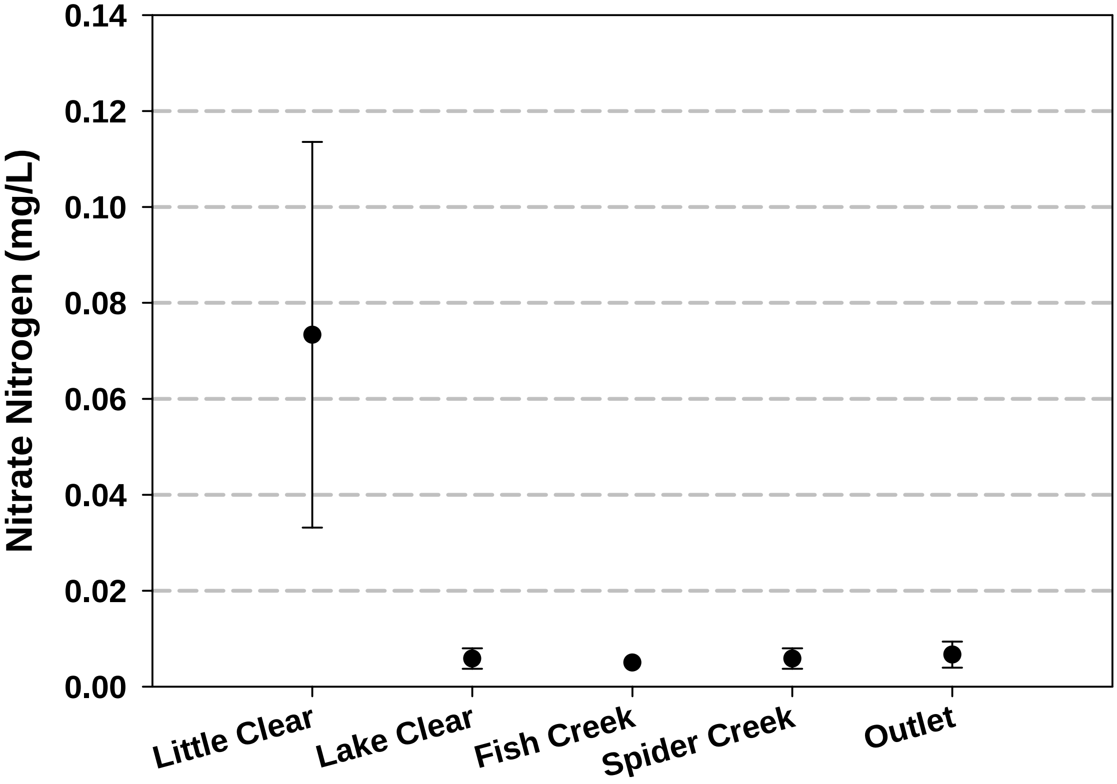

Figure 20 Average nitrate nitrogen in Upper Saranac Lake tributaries during 2005. Error bars are 95% confidence intervals

Ammonia Nitrogen

Ammonia nitrogen concentrations for Upper Saranac Lake tributaries are shown in Figure 21. With the exception of one sample date in Little Clear Outlet, ammonia was at or below the detection limit within the tributaries throughout the monitoring season. This is to be expected in a relatively unimpacted watershed, but it should be noted that at some times the fish hatchery is causing detectable levels of potentially harmful ammonia to occur below its outfall.

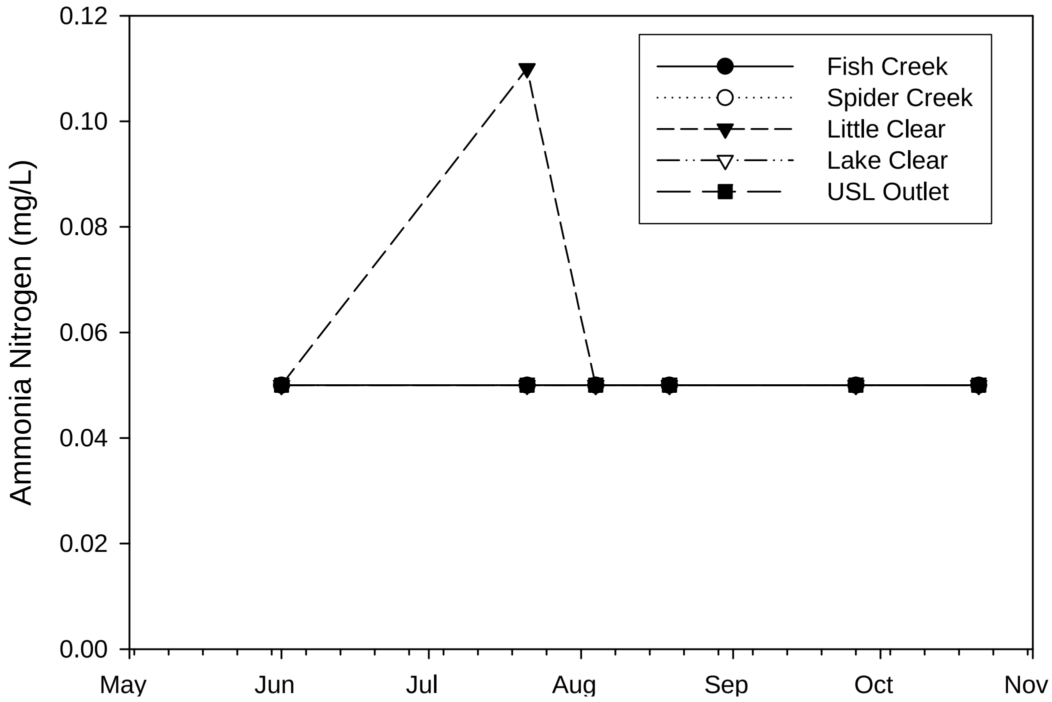

Figure 21 Ammonia nitrogen values in Upper Saranac Lake tributaries during 2005

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen concentrations for Upper Saranac Lake tributaries are shown in Figure 22. As in the lake, TKN in the tributaries represents primarily organic nitrogen, since ammonia was mainly undetected in the streams. TKN in the tributaries exhibited a trend similar to the lake, with concentrations showing a steady increase from early August through the end of the monitoring period in late October. This trend occurred at all stream stations to more or less the same degree, suggesting that the mechanism, though not known at this time, is natural rather than human-induced. In contrast to the lakes, the tributaries exhibited much more variability in concentrations earlier in the season.

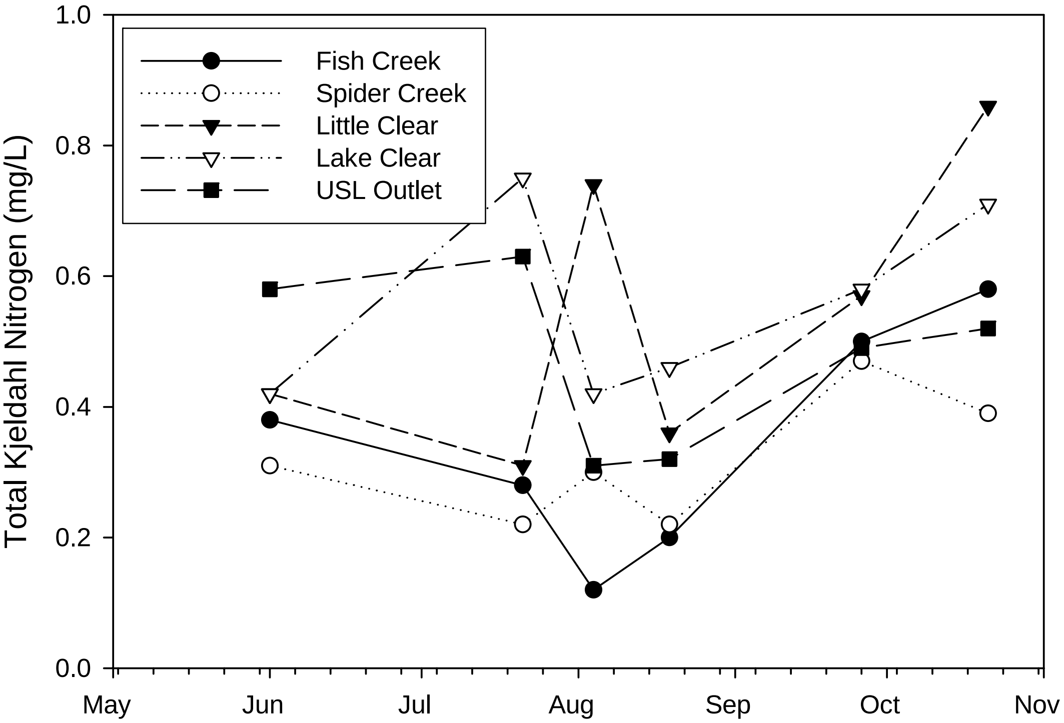

Figure 22 Total Kjeldahl nitrogen values in Upper Saranac Lake tributaries during 2005

Total Nitrogen

Figure 23 presents the total nitrogen concentrations in each tributary for each sampling date, while Figure 24 presents a comparison of average total nitrogen for each tributary for the monitoring season. The total nitrogen trend was almost identical to the TKN trend, since TKN accounts for the majority of the total nitrogen measured in the system (ie., very little of the measured nitrogen was in the forms of ammonia or nitrate/ nitrite). The seasonal average total nitrogen values in Little Clear Outlet and Lake Clear Outlet were significantly higher than the seasonal average values in Fish Creek and Spider Creek. The difference between these two grouping of stations again being level of development, with Little Clear and Lake Clear outlets receiving cultural impact from the fish hatchery and septic systems, respectively. It is interesting to note that the large campground facilities in the Fish Creek system do not appear to have a major impact on the water quality of Fish Creek.

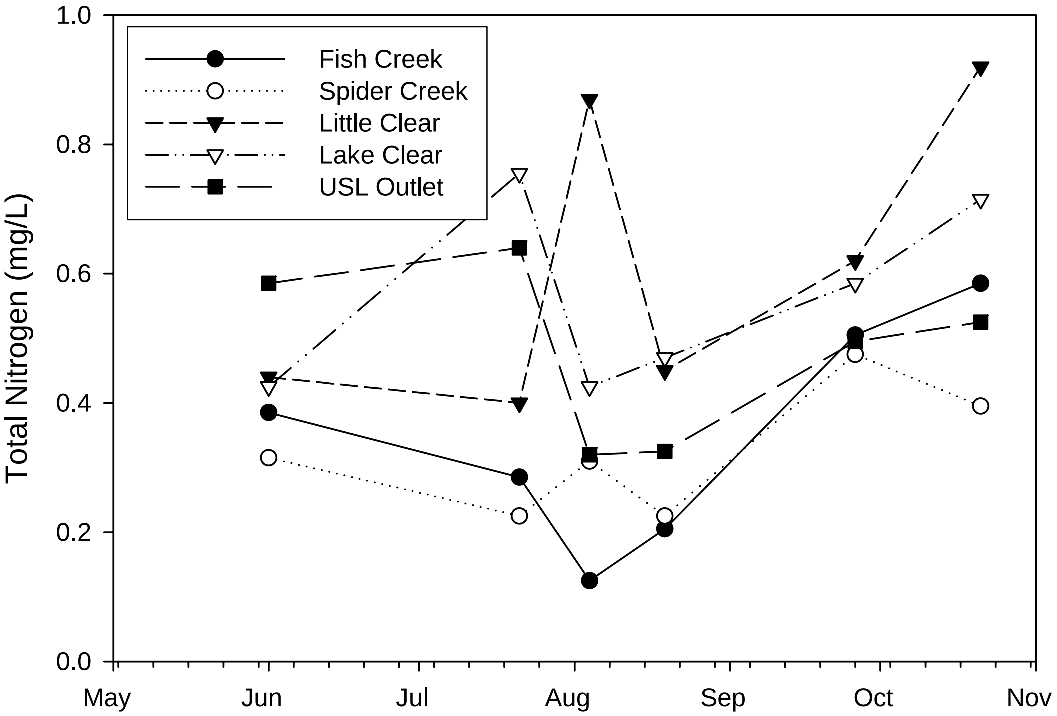

Figure 23 Total nitrogen values in Upper Saranac Lake tributaries during 2005

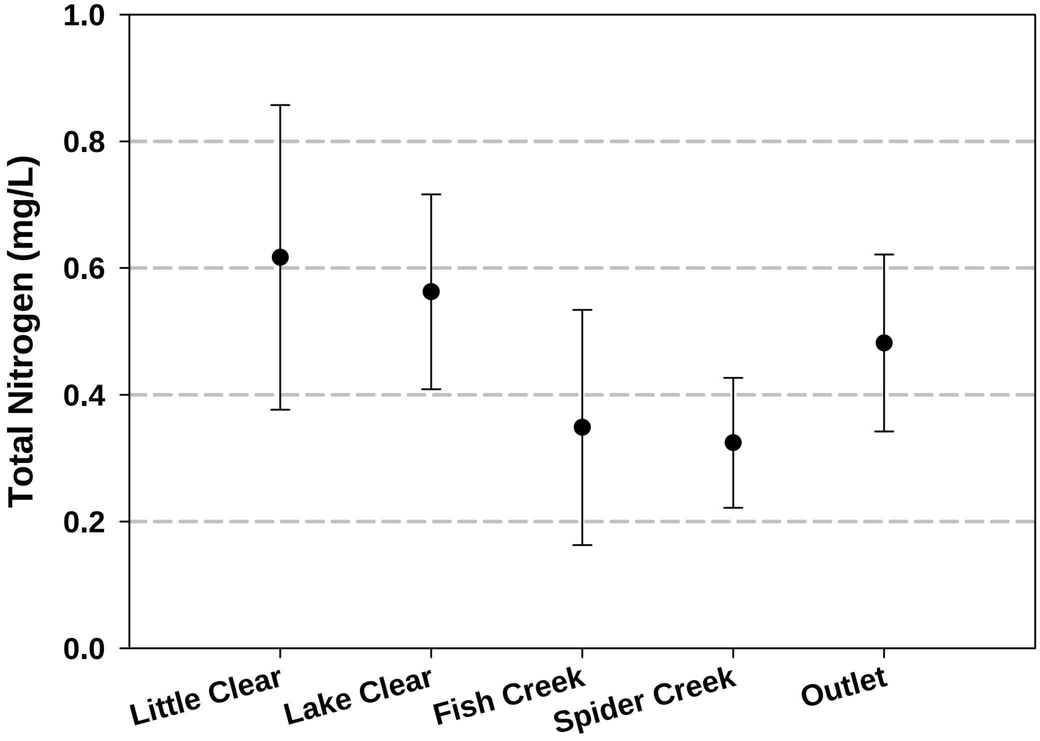

Figure 24 Average total nitrogen values in Upper Saranac Lake tributaries during 2005. Error bars are 95% confidence intervals

Lake Water Quality Trends

Water quality within a lake will show natural variability due to seasonal and annual differences in climate and biological processes. While many lakes are continuously undergoing natural eutrophication as they age, this process is very slow. For lakes as large as Upper Saranac Lake significant changes in water quality would likely take many generations, if only non-catastrophic natural processes were at work. However, human activity within Upper Saranac Lake's watershed has greatly accelerate the eutrophication process, particularly those activities that result in an increased amount of phosphorus being delivered to the lake. Overall, it is extremely important to take natural variability into account while making determinations as to whether human impacts are affecting water quality.

In the accompanying figures the dark circles represent summertime (June - August) mean values (averages). The error bars (vertical lines above and below each data point) each represent 95 percent confidence intervals. Wider error bars indicate greater differences in water quality between sampling dates in a given year. Data points without error bars result when there was only one value for a particular year or when all the results in a particular year were nearly identical. Trends for the entire period of record are shown, as well as post-bloom trends to better examine water quality changes that have been occurring since the blooms of 1989 and 1990.

Phosphorus

Phosphorus is the nutrient that most often controls algal productivity (growth) in lakes. Total phosphorus is a measure of all forms of phosphorus, both organic and inorganic. Total phosphorus concentrations are directly related to the trophic condition of a lake. Epilimnetic (surface) total phosphorus concentrations less than 0.010 mg/L are associated with oligotrophic conditions and concentrations greater than 0.025 mg/L are associated with eutrophic conditions (DEC & FOLA 1990).

Summer total phosphorus trends in the north basin and south basin for the entire period of record are presented in Figures 25 and 26, respectively. Post-bloom trends for the north and south basin are presented in Figure 27. Total phosphorus levels in 2005 continue to improve following the widespread bloom conditions of 2003. Statistically speaking, total phosphorus concentrations within the lake have returned to pre-2003 total phosphorus concentrations.

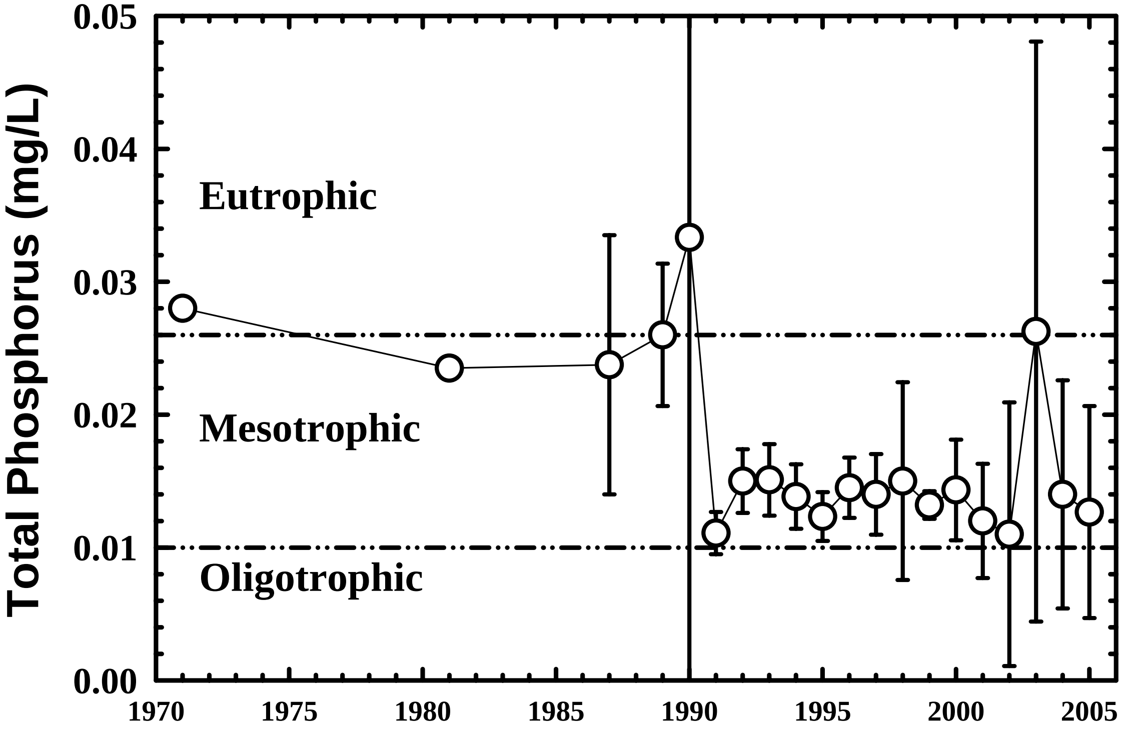

Figure 25 Average summer total phosphorus concentrations Upper Saranac Lake north basin

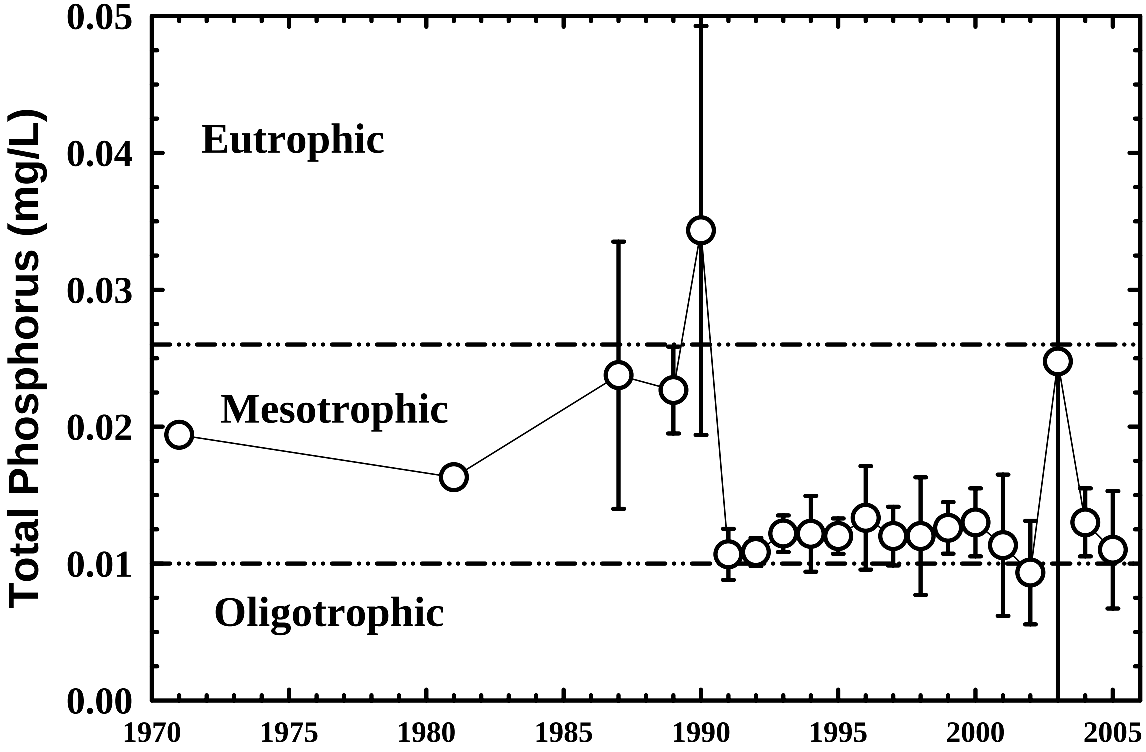

Figure 26 Average summer total phosphorus concentrations in Upper Saranac Lake south basin

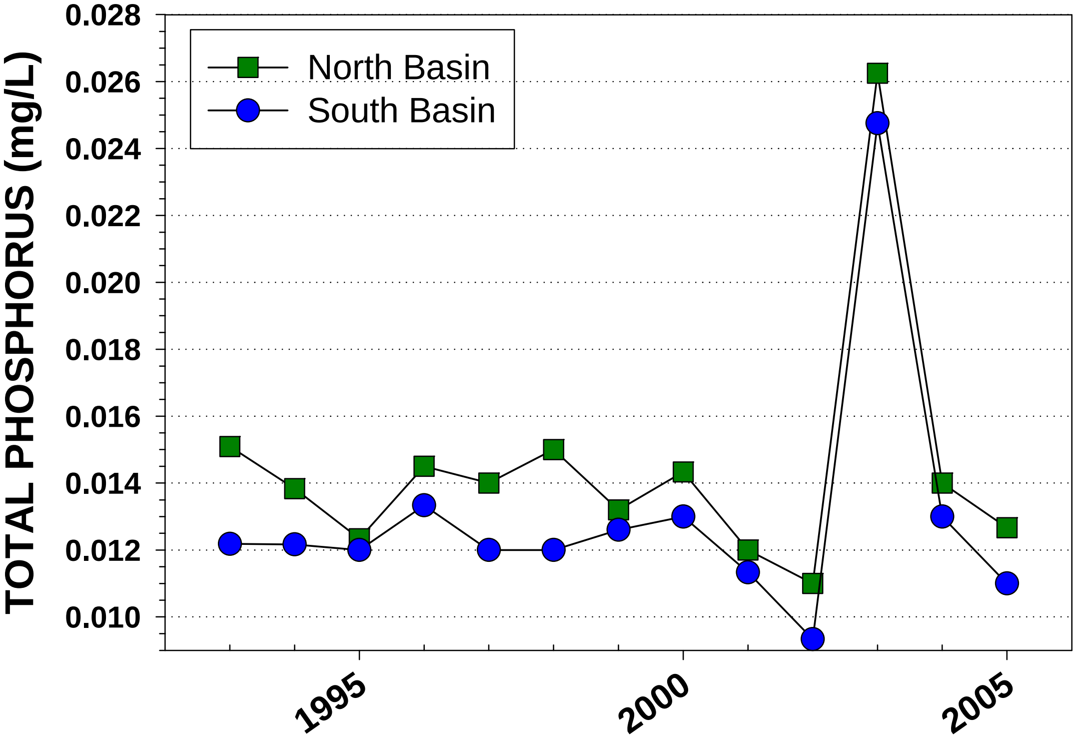

Figure 27 Average post-bloom summer total phosphorus concentrations in Upper Saranac Lake

Chlorophyll *a*

Chlorophyll *a* is a green pigment used by plants in photosynthesis. The measurement of chlorophyll *a* provides an indication of the amount of phytoplankton growing in a lake and therefore can be used to classify lake trophic state. Chlorophyll *a* concentrations less than 2 micrograms per liter (µg/L) are associated with oligotrophic conditions, while concentrations greater than 8 µg/L are associated with eutrophic conditions (DEC & FOLA 1990).

Summer chlorophyll *a* trends in the north basin and south basin for the entire period of record are presented in Figures 28 and 29, respectively. Post-bloom trends for the north and south basin are presented in Figure 30. Average summer chlorophyll *a* concentrations in 2005 continued the decreasing trend observed over the past two to three years and were again as low as have been measured since 1990 in both the north and south basin.

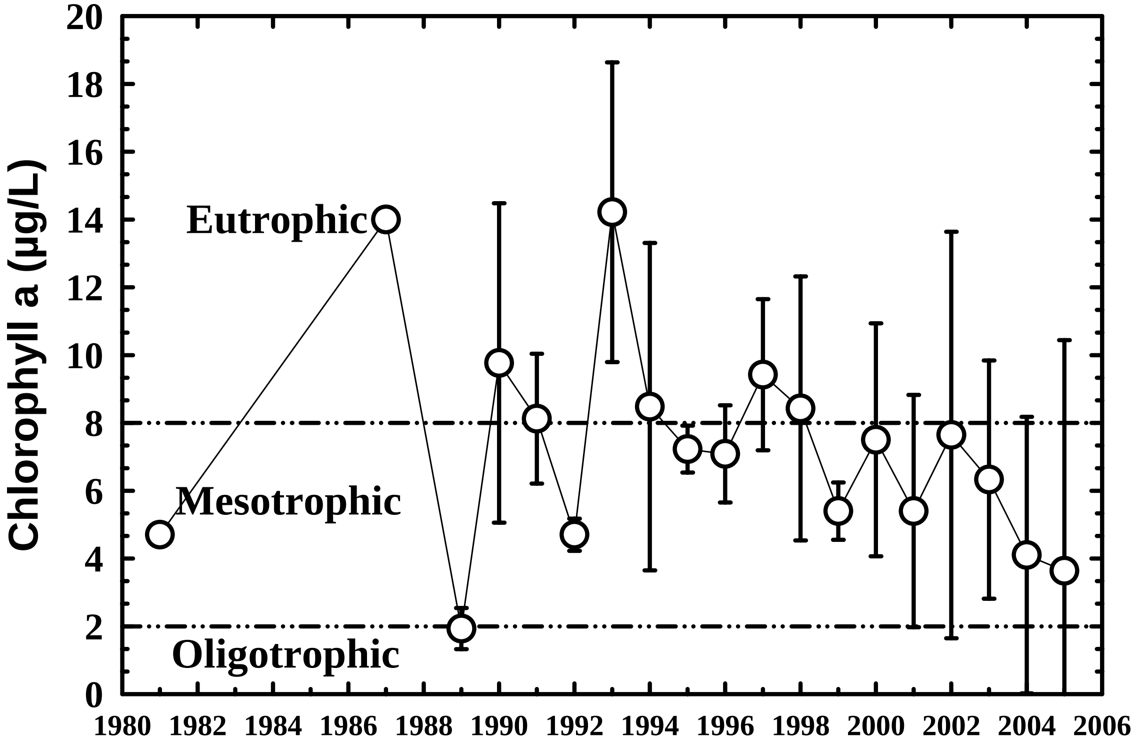

Figure 28 Average summer chlorophyll *a* concentrations in Upper Saranac Lake north basin

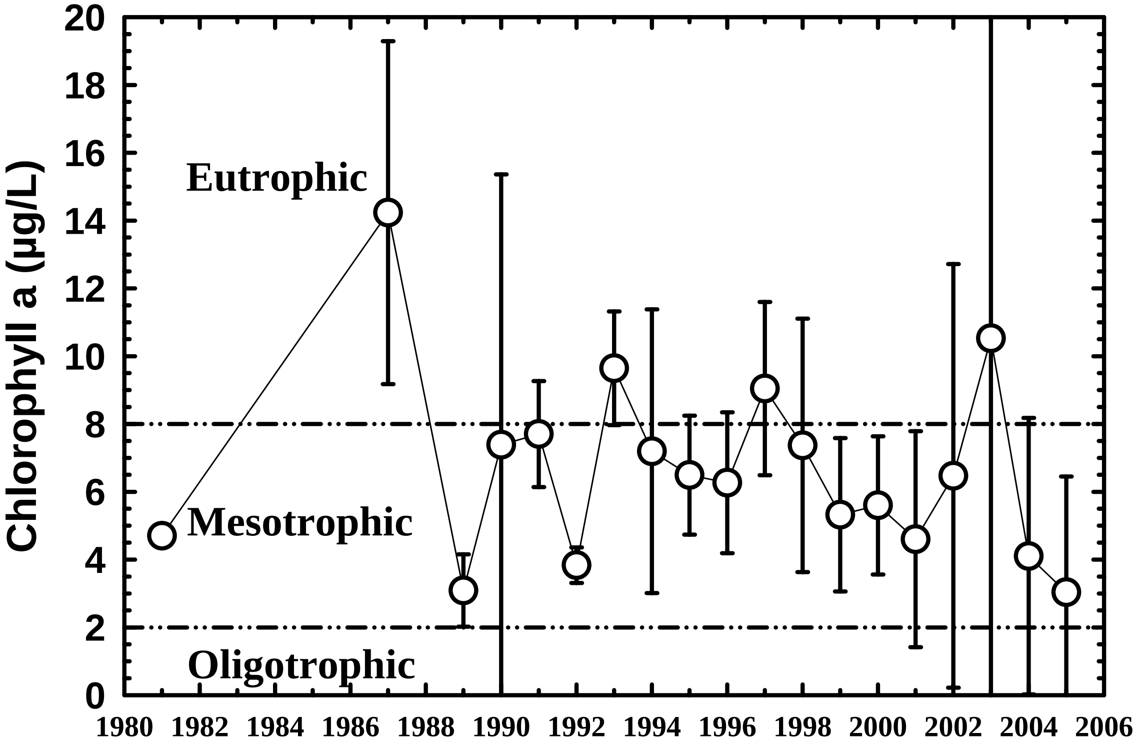

Figure 29 Average summer chlorophyll *a* concentrations in Upper Saranac Lake south basin

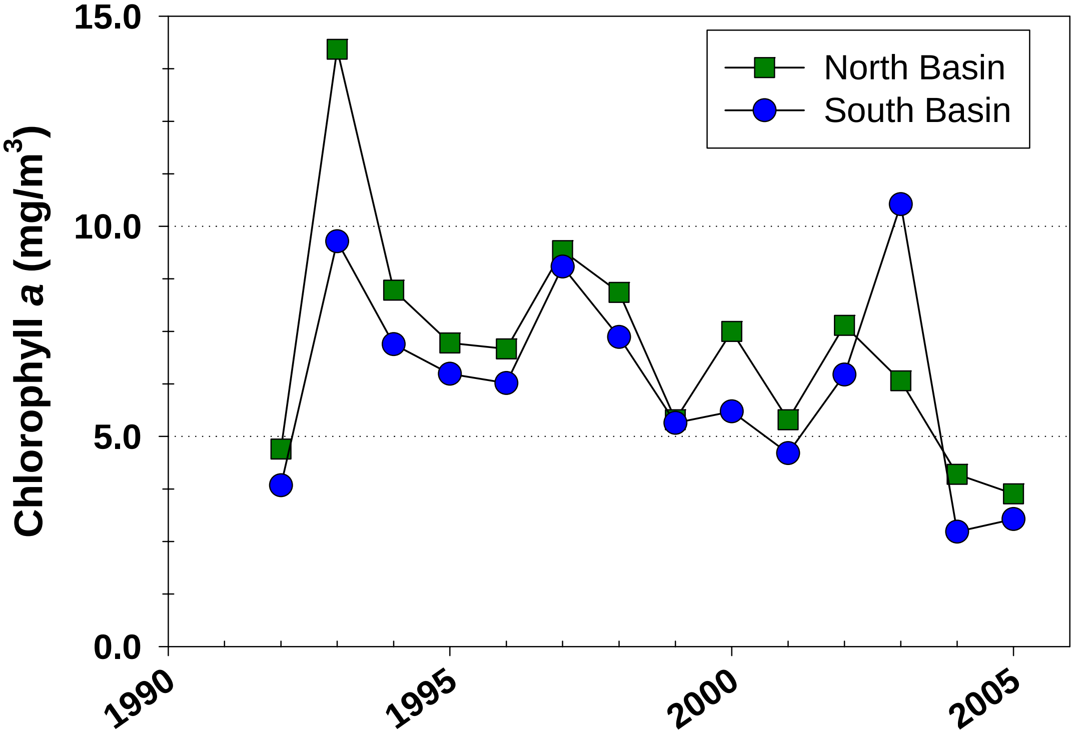

Figure 30 Average post-bloom summer chlorophyll *a* concentrations in Upper Saranac Lake

Transparency

Transparency is a measure of water clarity in lakes and ponds. It is determined by lowering a 20 cm black and white disk (Secchi disk) into a lake to the depth where it is no longer visible from the surface. Since algae are the main determinant of water clarity in non-stained lakes that lack excessive amounts of inorganic turbidity (suspended silt), transparency is used as an indicator of lake trophic state. Transparencies greater than 4.6 meters are associated with oligotrophic conditions, while transparencies less than 2 meters are associated with eutrophic conditions (DEC & FOLA 1990).

Summer transparency trends in the north basin and south basin for the entire period of record are presented in Figures 31 and 32, respectively. Post-bloom trends for the north and south basin are presented in Figure 33. Average summer transparency has shown a steady improvement since the lakewide blooms of 2003, although the overall post-1990 bloom trend (Figure 33) suggests a decline in transparency in both basins.

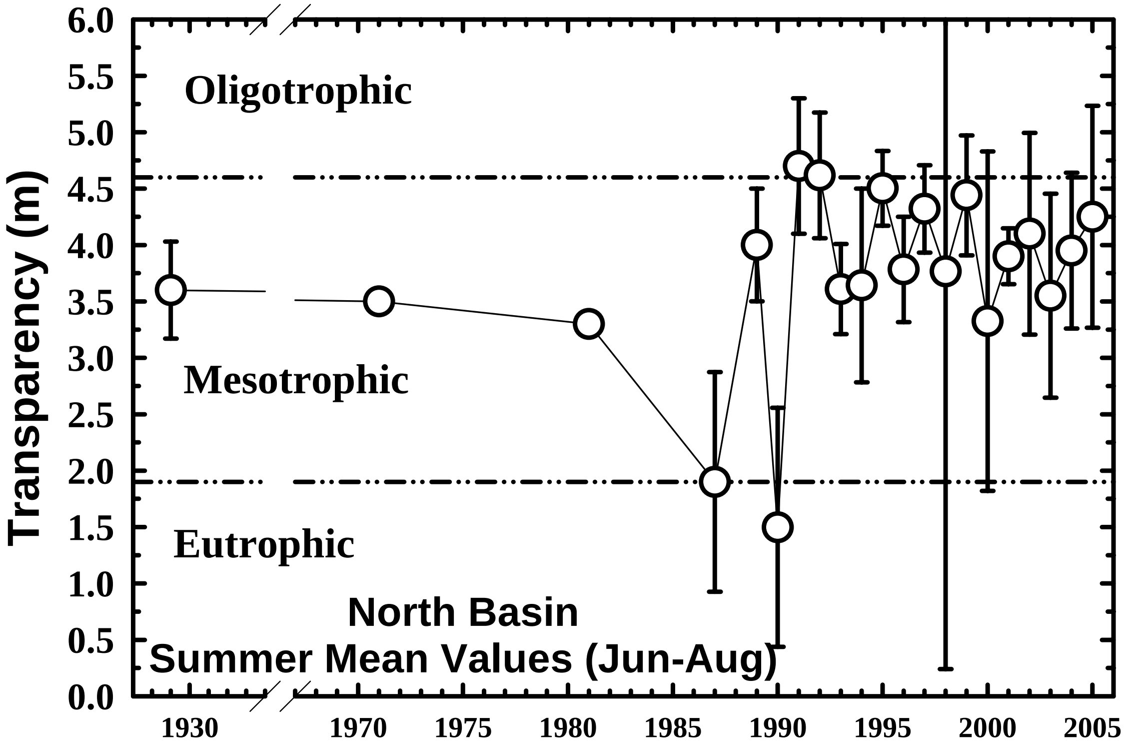

Figure 31 Average summer transparency in Upper Saranac Lake north basin

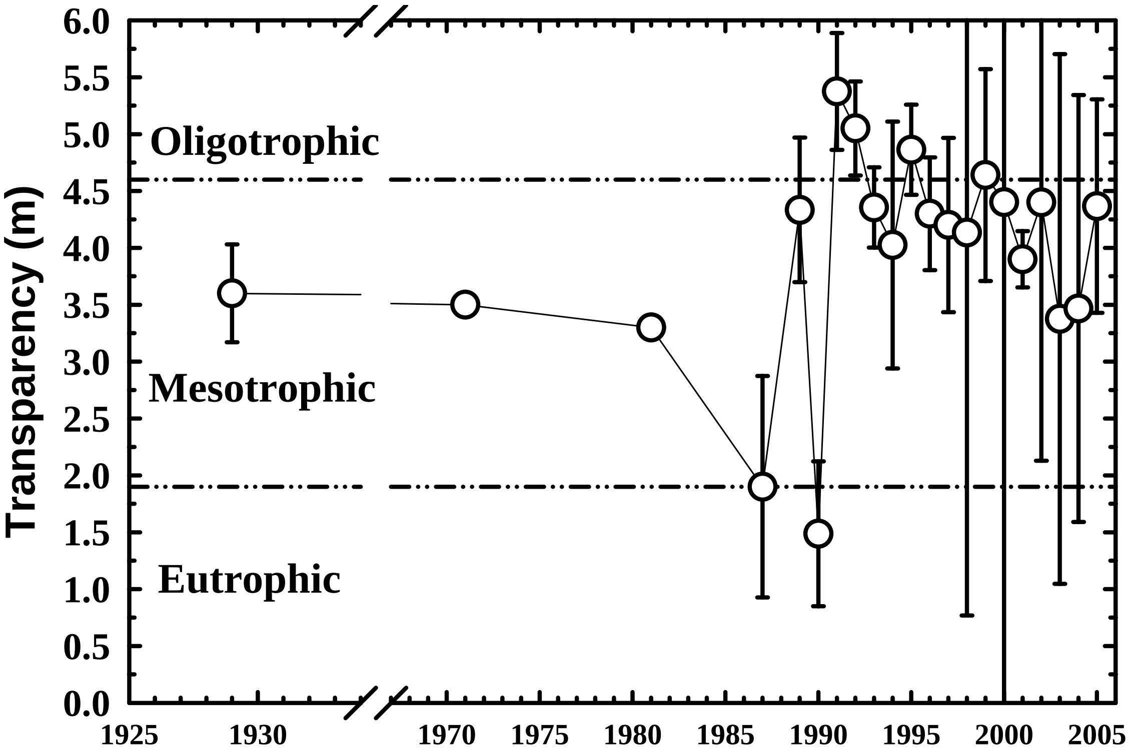

Figure 32 Average summer transparency in Upper Saranac Lake south basin

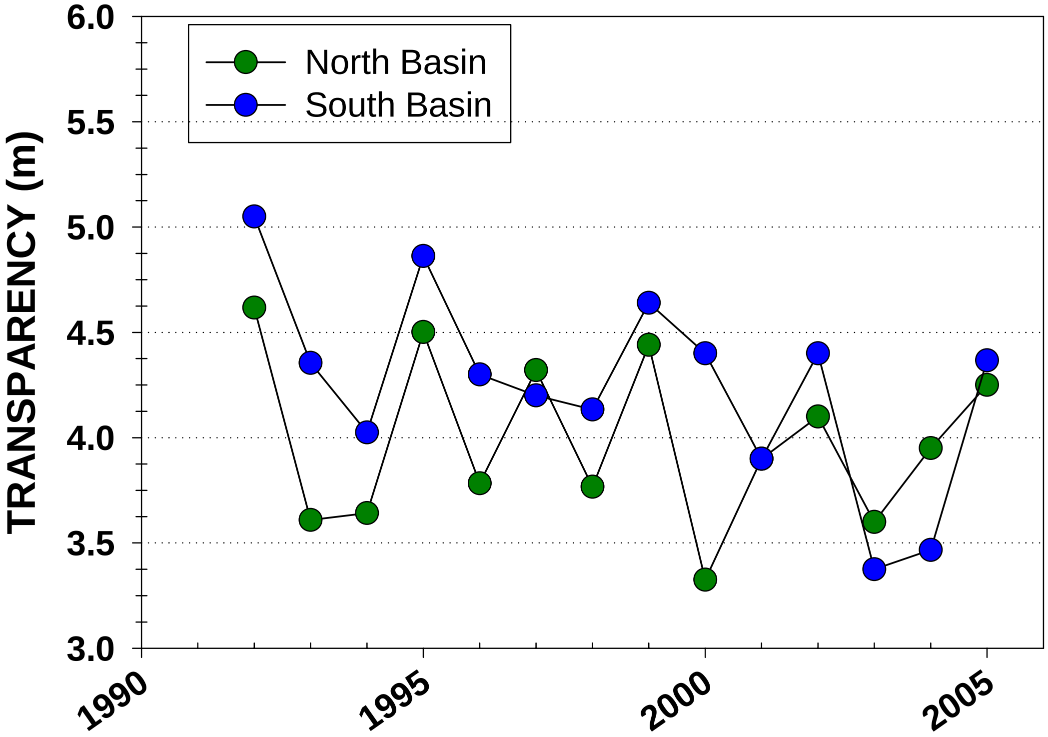

Figure 33 Average post-bloom transparency in Upper Saranac Lake

Conclusions

Based upon the three trophic (lake health) parameters, the overall water quality of Upper Saranac Lake in 2005 exhibited a continued improvement from conditions in 2003 when the lake extensive blooms throughout July and August. Total phosphorus concentrations remain higher than historical, pre-development concentrations estimated from sediment cores to be 8 to 10 ppb. There is still considerable variability in concentrations with each sampling season, as evidenced by the large error bars on the graphs. This is indicative of a lake system that is susceptible to water quality perturbations such as observed in 2003.

Dissolved Oxygen

Both the north and south basins exhibited low to no oxygen periods throughout much of the monitoring period and continue to experience periods of time during the summer when oxygen levels throughout the colder waters of the hypolimnion are too low to support cold water fish species. In the north basin, the period of low or no oxygen at the lake bottom lasted longer than in 2004, while the period was slightly less within the south basin.

Acidity Status

Upper Saranac Lake and its tributaries maintained a good pH level throughout the monitoring period and has a relatively good level of alkalinity for an Adirondack lake. Upper Saranac Lake is therefore unlikely to be impacted by acid precipitation.

Conductivity

Conductivity levels in Upper Saranac Lake were typical for a lake receiving drainage from an extensive network of wetlands. Lake Clear Outlet and Little Clear Outlet had higher conductivities throughout the monitoring season due to influence from wetlands and septic systems in the case of Lake Clear Outlet and the fish hatchery discharge in the case of Little Clear Outlet. The differences among tributaries was not as great this year, and a seasonal increase in Lake Clear Outlet due to septic systems was not observed, possibly due to dilution from the large storm events received throughout the season.

Nutrients (phosphorus and nitrogen)

Total phosphorus concentrations within the lake continue to recover following the widespread bloom conditions of 2003. Total phosphorus concentrations in 2005 were lower than the past two years, but have still not reached the levels they were at prior to 2003. This is the first year that we have had complete nitrogen series data, so it is difficult to make too many determinations from the results yet. It has been determined that the lake is slightly phosphorus limited, indicating that nitrogen is readily available for plant growth and increasing or decreasing levels of phosphorus will cause observable water quality changes more than manipulating nitrogen concentrations.

Lake Clear Outlet and Little Clear Pond Outlet continue to exhibit apparent eutrophication impacts from human activities, with significantly higher phosphorus and nitrogen concentrations of the measured tributaries. Little Clear Pond Outlet is influenced by the fish hatchery discharge while Lake Clear Outlet is influenced by wetlands and possible shorefront septic systems. The seasonal trend observed in Lake Clear Outlet last year did not occur this year, possibly due to the heavy rains and high flows.

The presence of measurable ammonia below the fish hatchery causes concern, since ammonia in surface waters can be toxic at low levels depending upon water temperature and pH.

Transparency

Transparency was better in 2005 than in the past two years, but still remain slightly below levels typical of a decade ago. There is an apparent trend of decreasing transparencies from 1991 to present.

Chlorophyll *a*

Chlorophyll *a* concentrations in 2005 continue to be among the lowest measured in the lake, indicating algae concentrations were also low. The lake still experiences spring and fall blooms of algae that are typical of dimictic lakes. The continued dominance of certain bluegreen algal species during those blooms remains a concern.

Trophic State Index

The lake was mesotrophic according to the TSI calculations for both basins.

Recommendations

Water Quality Monitoring

A key to the success of USLA in protecting its aquatic resource has been its long-term commitment to water quality monitoring. This program has allowed us to detect both positive and negative changes in water quality. Although nitrate/nitrite and ammonia nitrogen are often below detection, their presence when they do show up is sometimes illuminating. Therefore,

1. It is recommended that the long-term water quality monitoring program at Upper Saranac Lake be continued, as it is crucial to understanding water quality trends in the lake.

2. It is recommended that the Spider Creek station be continued, since it provides a tributary that receives little influence from development.

3. It is recommended that the nitrogen series analysis continues (ammonia, TKN, and nitrate) to provide a better understanding of this nutrient in the lake and its tributaries.

Lake Restoration Activities

The north basin hypolimnion continues to exhibit a build-up of phosphorus and nitrogen throughout the summer that is circulated throughout the lake when the north basin destratifies at the end of September. This *internal loading* of phosphorus contributes to fall blooms of bluegreen bacteria, and could also contribute to blooms during the summer months through vertical entrainment. The most cost-effective long term solution is to apply aluminum salts (aluminum sulfate and sodium aluminate) to the lake sediments. The aluminum binds with phosphorus and prevents its release from the sediments into overlying waters. A single application may last 15 years or ever much longer.

1. It is recommended that a study of the mass balance of phosphorus release and migration within the north basin water column be conducted to determine how

much phosphorus is released from the sediments and how much, if any, migrates into the surface waters during the summer when it can cause algae blooms (proposal is being prepared for USLF consideration).

2. It is recommended that a feasibility study of phosphorus inactivation using alum be conducted to determine dosage rates and costs.

Watershed Restoration Activities

Although old septic systems remain a significant source of nutrient pollution around Upper Saranac Lake and throughout its watershed, as around all Adirondack waters, the more immediate water quality threat is poor land use management and construction site practices.

There are two issues that USLA should address: construction site activities – that is the short term issue, and tiered development – the long term issue. First, I will address construction site impacts. For some reason, New York State, and the Adirondacks in particular, have poor construction site erosion and sediment control practices. Mainly, they have NO construction site erosion and sediment control practices. While regulations do exist to require that an Erosion and Sediment Control Plan (E&S Plan) be developed for sites larger than one acre, this is rarely enforced. If an E&S Plan be created, it is rarely followed and even less rarely enforced or inspected. Runoff from construction sites contributes massive amounts of sediments and nutrients to lakes and streams. The water quality impact from these activities would be significant. It is not acceptable and does not protect the lake to find out about a large lot development project after the ground has been cleared, since by that time the damage has been started and continues until the ground is completely restabilized. It is likely that the large-scale blooms of July and August 2003 were caused by a large lot development if there was one or more underway at the time (I can't recall if there were any, but that illustrates the significance of managing these activities). The idea is not to necessarily prevent large lot development, but to ensure that any land development follows the strictest practices for protecting water quality.

Silvicultural (logging) activities are similar in impact to construction site activities. Small time operators often conduct their practices without regard to environmental protection. Logging activity within the Upper Saranac Lake watershed could have a significant negative impact on water quality and is something for which USLA should be on the watch.

Tiered development is the age-old trend of developing a second row and then third, fourth, and more rows of houses on hills progressively further back from a lakeshore over time. We are just now beginning to see this happening around Upper Saranac Lake (e.g., Panther Mountain Road). USLA needs be aware that this development trend around the lake for second and third tier homes will have a significant long term negative impact on water quality. Second and third tier development increases nutrient-laden runoff into the lake through erosion and the creation of impervious surfaces. Second and third tier development also contributes to nutrient loading through the installation of septic systems, particularly where slopes are steep and soils are shallow or otherwise inadequate to properly treat wastewater. There are numerous examples where second and third tier growth has resulted in impaired water quality. This kind of growth can best be managed through local ordinances.

The replacement of old septic systems around the lake remains a priority for managing phosphorus inputs to the lake. Septic systems continue to be one of the largest controllable sources of phosphorus in the watershed. Watershed residents and municipalities can minimize the amount of phosphorus that comes from their land by minimizing water use in existing systems, identifying and treating nonpoint source problem areas, preventing erosion during construction, and instituting homeowner stewardship practices (non-phosphorus detergents, no P fertilizers, shoreline buffers). An integrated approach is recommended to reduce phosphorus levels in Upper Saranac Lake, including the use of oxygen or alum to reduce internal phosphorus loading in the north basin of the lake, an aggressive effort to support upgrading of near-shore septic systems to include composting or incinerating alternative toilets, and instituting good land practices and homeowner stewardship. Together, these activities will result in improved water quality in Upper Saranac Lake.

Recommendations

1. Construction Site/Land Clearing: Work with local governments to establish strict land clearance regulations to ensure the protection of water quality. Ensure existing rules and regulations such as SPDES Stormwater Regulations for Disturbed Areas over 1 Acre are enforced.

2. Watershed Logging: Work with DEC Forestry to ensure that silviculture BMPs are used whenever logging is undertaken within the watershed.

3. Land Use Regulations: Work with local governments to establish stricter land development guidelines to ensure protection of Upper Saranac Lake from tiered development. There are numerous issues to address, including development along slopes, land clearance, development densities near shores, depth to water table/depth to ledge for septic systems.

4. Phosphorus Reductions: Work with lake residents to reduce phosphorus from all sources by promoting Homeowner Stewardship Practices. Encourage the replacement of old standard/sub-standard septic systems with alternate technologies (composting/incinerating toilet w/grey water system).

5. Consider the establishment of protective district around the lakeshore. This would make it easier to implement protective land use measures.