SUMMARY AND RECOMMENDATIONS

BOW LAKE

WATER QUALITY MONITORING: 2005
The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of the 2005 results as well as more detailed information.

This report contains the findings of a water quality survey of Bow Lake.
In Lake C, choose Pond, Great East Lake, Lake Hammett, Watershed, Crystal Lake, Hug." for Peaceful Pond. For Lake Camp O, choose Lake Camp O, the associated Quinnipiac University, Walker's Pond, Conservation Society, the Association. For the New Hampshire Audubon Society, North River, Lake Water, Hayes River, and Water Protection.

Participating groups in the LIMP include: Center Harbor Bay, Camps, and New Hampshire Water Resources.

Program (http://www.nhwaterquality.org/mass/eplan.html).

The Center for Freshwater Biological (CFF.) is a non-profit research program that supports research and education in freshwater biology and ecology. The Center for Freshwater Biological (CFF.) is a non-profit research program that supports research and education in freshwater biology and ecology.

<table>
<thead>
<tr>
<th>Volunteer Name</th>
<th>Monitoring Locations</th>
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<tr>
<td>John Young</td>
<td>Camps</td>
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<tr>
<td>Carolyn T.</td>
<td>Hug</td>
</tr>
<tr>
<td>Martha Walker</td>
<td>Crystal Lake</td>
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<tr>
<td>Bill Walker</td>
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<tr>
<td>Kathy Snowberger</td>
<td>Crystal Lake</td>
</tr>
<tr>
<td>Jim Mecany</td>
<td>Crystal Lake</td>
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Table 1: Bow Lake Volunteer Monitors (2005)
Meriden, Merrifield, Milford, Stratford, Whitneyfield and Wolcott.

Worth, Winchendon Drive, and the towns of Athol, Amherst, Enfield, Medford, Silver Lake (Madison), Squam Lake, Sunset Lake, Swaim's Lake, Lake Wey-erough Bay, Lake Winnebago, Naticook Lake, Newfound Lake, Mippo Lake, Lake, Millon Ponds, Lake Ledy, Monticello, Mirror Lake (Tutunboro), Mohican, Cove, Long Island Landowners, Lovell Lake, Mendump's Pond, Merrymeeting
Table 2: Seasonal Average Water Quality Readings and Water Quality

<table>
<thead>
<tr>
<th>Date</th>
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<td>68.0</td>
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Classification criteria used by the New Hampshire Lakes Lay Monitoring Program included in the 2005 Bow Lake Summary Report:

- **Optomictrophic**: Phosphorus (ppm) ≤ 0.04, Chlorophyll-a (ppm) ≤ 2.5
- **Mesomictrophic**: Phosphorus (ppm) > 0.04 to ≤ 0.2, Chlorophyll-a (ppm) > 2.5 to ≤ 7.0
- **Chromatic**: Phosphorus (ppm) > 0.2, Chlorophyll-a (ppm) > 7.0

Water Clarity (measured as Secchi Disk Transparency - The 2005)

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watercolor from the natural breakdown of plant materials and around a lake. In the water, the color is sometimes called dissolved organic carbon or carbon eaten by microorganisms. The color of the Chl-a concentration in Bow Lake is lower than the extreme readings measured in 2004. The average concentration of Chl-a in Bow Lake is lower than the extreme concentration measured in 2004. The Bow Lake concentration in 2005 was the result of such a deep water algal population sustained at that time.

In recent years, Bow Lake has experienced few algae blooms of nuisance magnitude. The natural growth process is easier and less clear water of a lake.


<table>
<thead>
<tr>
<th>Bow Lake</th>
<th>10 Cruise (Mean)</th>
<th>18 Cruise (Range: 10-2)</th>
<th>Seasonal Average Chl-a (ppb)</th>
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<tbody>
<tr>
<td>3 Benwell</td>
<td>1.6 ppb (single value)</td>
<td>19 ppb (range: 1-2)</td>
<td>The average for Bow Lake</td>
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A comparison among the 2005 Bow Lake Chl-a concentrations that were measured between June and September, by the volunteer monitors, did not include the season's algal blooms (e.g., green algae blooms) that have historically been documented during the months of August and September. While the volunteer monitors did not include the season's algal blooms (e.g., green algae blooms) that have historically been documented during the months of August and September, a significant increase in Bow Lake's Chl-a concentration was observed in 2005 (Table 4).

The average for Bow Lake Chl-a concentration was measured at 1.6 ppb in 2005. In comparison, the average for Bow Lake Chl-a concentration was measured at 18 ppb in 2004. The increase in Bow Lake's Chl-a concentration was observed in 2005 (Table 4).
Dissolved Salts: measured as specific conductivity

<table>
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<th>Range</th>
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<tr>
<td>None Viable</td>
<td>&lt; 23.6</td>
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<tr>
<td>Low Viable</td>
<td>10.1 - 23.6</td>
</tr>
<tr>
<td>Moderately Viable</td>
<td>0.0 - 10.0</td>
</tr>
<tr>
<td>Extremely Viable</td>
<td>0 - 2.0</td>
</tr>
<tr>
<td>Addled</td>
<td>&gt; 2.0</td>
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Table 8. Alkalinity Classification

New Hampshire Lake

- pH of Lake Alkalinity (measured as total alkalinity) averaged between 7.3 and 8.0, which is considered typical of a lake that is minimally buffered by the New Hampshire Department of Environmental Services.

- Total phosphorus: The nutrient most responsible for eutrophic conditions.

- New Hampshire lake lay - Total phosphorus concentrations measured in our New Hampshire seaport plant exceed the standard for phosphorus limitations, which are not considered to be detrimental to water quality.

Biodiversity in 2005 due to equipment malfunction, however, the interstate river

- Dissolved salinity: measured as specific conductivity (le more salty water)

- that are essential to aquatic organisms.
It is important to make sure the watershed residents are well-educated on the need to properly aerate their wells. Properly aerated wells can reduce nutrient and dissolved oxygen concentrations, which can help prevent the growth of aquatic plants and animals that can harm the lake's ecosystem. Additionally, implementing best management practices such as limiting fertilizer use and maintaining riparian buffers can help prevent nutrient runoff into the lake.

Maintaining riparian buffers, or buffer strips along the lake's edge, is crucial for preserving water quality. These buffers act as natural filters, trapping sediment and nutrients before they enter the lake. By maintaining healthy riparian buffers, we can help prevent nutrient runoff and ensure a healthy lake ecosystem.

If nutrient concentrations in the lake exceed safe levels, interventions such as the implementation of best management practices and increased monitoring efforts may be necessary. Regular monitoring of the lake's water quality is essential for identifying trends and taking proactive measures to protect the lake's health.

In summary, protecting the lake's water quality requires a collaborative effort between residents, local agencies, and environmental organizations. By working together, we can ensure the long-term health of Lake Wilhelmina and its surrounding ecosystem.
mentation if water quality degradation is to be minimized.

Issues within the Bow Lake watershed are carefully thought out beforeimple-
menting any changes. It is imperative that future ac-
"Understanding Lake Age (Euproduction) for a Brief History of some of the"
Recommendations

COMMENDATIONS
color, total phosphorus, and Secchi Disk transparency measurements.

After spring thaw, sampling should include algal diversity, orthophosphate, dissolved oxygen, and Lake's reaction to the nutrient and acid loadings that typically occur during spring. We recommend initiating lake sampling in April or May to document bow.

We recommend initiating lake sampling during the summer months. Nutrient and acid loadings during the summer months.

Healthy and local phosphorus samples will help assess Bow Lake's response to

- Improved "weekly/weekly" water quality samples, necessary to assess

- Cyanate at 862-8696 or via email at bctraveler@um.edu.

where potential water quality monitoring strategies. However, please contact Bob

due to educational efforts could be focused on those priority regions. Should you want to

evaluate that enter the Lake. Should potential "hot spots" be identified, permits

Lake), and increase the nutrient load associated with lawn fertilizers and pesticides.
APPENDIX D: GLOSSARY OF LIMNOLOGICAL TERMS
APPENDIX C: INTERPRETING WATER QUALITY CHANGES AND TRENDSCAPES
APPENDIX B: 2006 BOW LAKE WATER QUALITY DATA SUMMARY
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Figures

1. Comparison of the annual Bow Lake Site I Ledges, May monitoring chlorophyll
2. Comparison of the annual Bow Lake Site I Ledges, May monitoring Secchi Disk
3. Trends for Site I Ledges, Bow Lake, 2006, Seasonal Secchi Dish (water transparency) and dissolved
5. Trends for Site I Ledges, Bow Lake, 2006, Seasonal Secchi Dish (water transparency) and chlorophyll
6. Location of the 2005 Bow Lake deep sampling stations, Site I Ledges and
11. National Impacts Support to Manufacturer Monitoring Programs
12. IMP Objectives
The New HampShire Lakes Lay Monitoring Program

Introduction
Over 1,000 new articles in the Volunteer Monitor, the national newsletter, with a distribution of
reefall articles in the latest quarterly issue. The newsletter is distributed and provides the latest news on the
best practices and emerging trends in lake monitoring.

Recent interest in the success of our NH LIMP program continues to grow.

To support these efforts, we have launched a new NH LIMP program that focuses on the need for
better monitoring capabilities and data collection in our New Hampshire lakes. Participating
monitoring programs will provide a wide range of data, including water quality, temperature,
and other important parameters.

In addition, our ongoing research is focused on the use of satellite imagery as well as
traditional field observations.

Certain blue-green algae (cyanobacteria) can produce toxins that pose serious health risks.

We continue the research initiated by collaborators Dr. John Sasser and Dr. Jim

Study examining the potential to measure exact nutrient levels using passive sensing
methods reveals significant promise. We are also testing new techniques for
paradigm in testing an integrated nutrient management approach (see our “Special Topic” in

We have also been a key

and land uses.

The benefits we can expect from different interventions are close to understanding
the potential of nutrient control. Are the issues underestimates or are they
overestimates? Our current project is focused on

Our volunteer interested in water quality

Nutrient Budget Study of the

We are excited by the results of our

NH LIMP

Programs in 24 States.

Expansion of Support of Volunteer

NH LIMP Directly Involved with the Initiation,

Figure 2: National LIMP Support to

Programs

Volunteer Monitoring Programs to

Light gray shading denotes LIMP assisted states.
We continue to be listed as a model citizen-monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To date, the approach and methods of the NH LLMP have been adopted by new or existing programs in twenty-four states and eleven countries (Figure 2)!

Importance of Long-term Monitoring

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For over two decades, weekly data collected from lakes participating in the New Hampshire Lakes Lay Monitoring Program have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Consider the hypothetical data depicted in Figure 3. Limiting sampling to only once a year during August, from 1988 to 1992, produced a plot suggesting a decrease in eutrophication. However, the actual long-term trend of the lake, increasing eutrophy, can only be clearly discerned by frequent sampling over a ten year period (Figure 5). In this instance, the information necessary to distinguish between short-term fluctuations "noise" and long-term trends "signal" could only be accomplished through the frequent collection of water quality data over many years. To that end, the establishment of a long term database was essential to trend detection.
The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term database will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the NH Lakes Lay Monitoring Program. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next week's data. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the NH LLMP the most extensive, and we believe, the best volunteer program of its kind.

**Purpose and Scope of This Effort**

2005 was the twenty-second year that water quality monitoring of Bow Lake was undertaken in conjunction with the NH Lakes Lay Monitoring Program (NH LLMP). The monitoring program is designed to establish a long-term database to which future data could be compared and to identify localized problem areas where future educational and corrective efforts should be focused. Sampling emphasis was placed on one open water sampling station while supplemental tributary sampling was also undertaken at the major stream inlets to better understand the sources of phosphorus inputs into Bow Lake.

The primary purpose of annual lake reporting is to discuss results of the current monitoring season with emphasis on current conditions of New Hampshire lakes including the extent of eutrophication and the lakes' susceptibility to increasing acid precipitation. If there are additional water quality concerns we advise the lake association to
Testing:

cal difference of the various analytical facilities and technological improvements in
parting current results with early studies. Many complications arise due to methodology

that Commission and the CRP/EC surveys. However, care must be taken when com-

1990's, the surveys conducted by the New Hampshire Water Supply and Pollution Con-

New Hampshire Lakes that include New Hampshire River and Great Lakes of the

base of historical and more recent data compiled and entered into our computer files for

also strive to place the recent results into a historical context using past NH LTAP data

contact our program staff to discuss additional monitoring options. When applicable we
Water Quality and the Weather

Climatic Summary - 2005
Figure 5: Precipitation (1979-2005)
Station (Lacoxa, NH)

Precipitation (2005)
mostly snowfall.

Legend and December recorded the years with above-average rainfall and above-average snowfall.

A series of storms swept through New Hampshire during the month of September.
The subsequent months of July and August were characterized by below-average rainfall followed by slightly above-average rainfall in the middle of the month of June. During which the rainfall was largely concentrated in the middle of the month of May. The month of March into the month of July and into the month of May (Figures 4, 5, 6).

Significant accumulations of snowfall can result in a period of heavy overland flow, which is reflected in the additional snowfall accumulation that contributed to periods that ultimately exceeded the additional snowfall accumulation that contributed to periods that exceeded the average.

The monthly precipitation totals documented during the months of January and February were below average although the timing of the precipitation events coincided with low temperatures that resulted in relatively heavy periods of snowfall during January.

The 2005 annual precipitation (reported as "rainfall equivalent") amount has been documented over the past 27 years: 1979-2005 (June precipitation data are reported for the Lakeport 2 Station).

Precipitation such as poor functional seepage systems.

Such lakes remain susceptible to nutrients entering the lake from seepage sources.
Monthly temperature averages documented between April and December 2005 oscillate around the previous annual mean of the 25-year average (Fig. 7). Increasing temperatures and above-average rainfall during the months of April and May contributed to periods of heavy spring runoff. The subsequent high flows, increased surface flow, temperature, and water transparencies during these periods increased algal growth, freshwater blooms, and shallower water temperatures. During these months, the peaks had coincided with the blooms of algae (e.g., Mougeotia) throughout. Other NH TIGP lakes, such as the Rand Lake in Michigan, showed similar patterns.

During years such as 1994 and 1995, when above-average temperature changes occurred, the lake and wash up on the windward beaches.

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Water Quality Impacts

Spring season

A few water temperatures that were documented in June month of June. The below lower temperatures corresponded to some of the cooler water temperatures (Figure 7). Below average temperatures during the month of May (over forty

Figure 7: Lakeport 2 Climatological Sampling

Monthly Temperature (°F)
 Much of the phosphorus entering our lakes is attached to particulate matter (e.g. sediments). If excess phosphorus concentrations are generally most soluble when documented in our water, phosphorus concentrations are generally most soluble when dissolved in our water. Therefore, during summer when water temperatures are elevated, phosphorus is generally considered to be more mobile and potentially more harmful to aquatic ecosystems. Nutrient loading is often greatest during heavy precipitation events, particularly

**Nutrient Loading**

...
The certain green or blue-green algae, they can be an early indication of nutrient load. Like surface scum (green algae blooms) even. If those algae are predominantly nuisance forms, the thermal stratification in a lake, midlake depth, sometimes called the "Bloom Index". In other lakes, nuisance algae are able to grow in a thin layer above.

In lakes "clouds" and especially those not reach nuisance proportions, it is kept in check, and generally these do not reach nuisance proportions. If, on the other hand, the algae growth and extend to the yellowish brown to tan, this is called "algal growth" and can develop with nutrient enrichment, dead zones where they can be seen and often the algal bloom increases during the months of June and July when water temperatures and nutrient levels have been well documented in 1974, 1975, and 1976 when the temperature and nutrient levels have been well documented. The presence of "clouds" can lead to nuisance forms, "clouds" of the nuisance green algae, "Aphanizomenon". But improperly handled use practices can contribute to nuisance nuisance into the lake.

Forms such as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaena", Aphanizomenon and Oscillatoria, can also be a warming sign. Such forms as "Anabaen
The chlorophyll a concentration is a measurement of the standing crop of phyto-
plankton and is often used to classify lakes into categories of productivity called trophic-

Chlorophyll a

Chlorophyll a concentration is also measured in moderately productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered lower than 2.5 meters are typical of clear, unpolluted lakes. Values greater than 4 meters are typical of clear, unpolluted lakes. The growth of algae in clear lakes is limited by light, and the depth at which light is absorbed becomes significant. In such lakes, the depth of the water column is often referred to as the 'light penetration depth'.

Water Transparency

Water transparency and chlorophyll a concentration can be used to classify lakes into categories of productivity. Water transparency is the distance that light can penetrate the water column. The deeper the water column, the lower the chlorophyll a concentration. 

Thermal Stratification in the Deep Water Sties

Lakes in the New Hampshire region exhibit thermal stratification during the summer. A layer of warm water forms on top of a layer of cold water, creating two distinct temperature profiles. 

Measurements

Stream Monitoring Discussion of Lake and
states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll $a$ concentrations average above 7 mg m$^3$ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll $a$ concentrations that are generally less than 3 mg m$^3$. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll $a$ generally between 3 mg m$^3$ and 7 mg m$^3$. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

**Turbidity**

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment flushing into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lake bottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

**Dissolved Color**

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency.

Dissolved color is measured on a comparative scale that uses standard chloroplutinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu
are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

**Total Phosphorus**

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Logging, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

**Streamflow**

Streamflow, when collected in conjunction with depth contour information, is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

**pH**

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

**Alkalinity**

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler,
gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the Center for Freshwater Biology includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1 ) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

**Specific Conductivity** *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micromhos (the opposite of the measurement of resistance ohms) per centimeter, more commonly referred to as micro-Siemans (μS).

**Dissolved Oxygen and Free Carbon Dioxide** *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through photosynthesis by day. Respiration by both animals and plants uses up oxygen continually and creates carbon dioxide. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other decomposers in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain un oxygenated or anaerobic until fall mixing occurs.
The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic heterograde oxygen curves are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

**Underwater Light** *

Underwater light available to photosynthetic organisms is measured with an underwater photometer which is much like the light meter of a camera (only waterproof!). The photic zone of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water’s surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the compensation depth. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

**Indicator Bacteria** *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

Total coliform includes all coliform bacteria that arise from the gut of animals or from vegetative materials. Fecal coliform are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism Fecal streptococcus (sometimes referred to as enterococcus) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A “bathing waters” to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offer-
ings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

**Phytoplankton** *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example diatoms, tend to be most abundant in April–June and October–November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to green algae or golden algae. By late season Blue-green bacteria generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

**Zooplankton** *

There are three groups of zooplankton that are generally prevalent in lakes: the *protozoa*, *rotifers* and *crustaceans*. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the *cladocerans* (which include the "water fleas") and the *copepods*.

Macronzooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

**Macroinvertebrates** *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are...
probably the most well known example of a seasonal aquatic macroinvertebrate as mayflies populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name “mayflies”. Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddis flies (Trichoptera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the “true” flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify “hot” spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the LLMP coordinator.

**Fish Condition**

The assessment of fish species “health” is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the New Hampshire Fish Condition Program is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish’s health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the “health” of the various fish species reflects the overall water quality in the respective lake or pond.
Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. The veligers (larval form) are free swimming, nearly invisible, and profuse. Adult zebra mussel shells are elongate (D-shaped), about the size of a thumbnail and are usually striped. Zebra Mussels are the only freshwater mussel that can attach to objects using sticky threads (byssal threads like those found on the marine blue mussels). These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years. A gritty feeling on your boat's hull or other immersed surfaces might indicate that larval zebra mussels have settled.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in western Europe freshwaters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least three years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the New Hampshire Lakes Lay Monitoring Program will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

**Inspect** your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

**Flush** the cooling system, bilge areas and live wells with tap water.

**Leave** unused bait behind and discard bait bucket water away from surface waters.

**Keep** your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry or...

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Wash down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

Learn more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

Share information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group or civic organization.

Report any sightings to the New Hampshire Lakes Lay Monitoring Program. Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

Jeff Schloss
Lakes Lay Monitoring Program
38 College Road  Room 133 Spaulding Hall
University of New Hampshire
Durham NH 03824-3512
(603) 862-3848
Understanding Lake Aging
(Eutrophication)

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and Jeff Schloss
UNH Cooperative Extension Water Resources Specialist

A common concern among New Hampshire Lakes Lay Monitoring Program (NH LLMP) participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant “algae” growth (detected as greener water), and water transparency decreases; what is known as eutrophication. Eutrophication is a natural process by which all lakes age and progress from clear, pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients that enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to naturally occurring attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from extremely pristine to very enriched.

Classification criteria are often used to categorize lakes into what are known as trophic states, in other words, levels of lake plant and algae productivity or “greenness” Refer to Table 6 below for a summary of commonly used eutrophication parameters.

Table 6: Eutrophication Parameters and Categorization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Oligotrophic “pristine”</th>
<th>Mesotrophic “transitional”</th>
<th>Eutrophic “enriched”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorophyll a (µg/l) *</td>
<td>&lt;3.0</td>
<td>3.0-7.0</td>
<td>&gt;7.0</td>
</tr>
<tr>
<td>Water Transparency (meters) *</td>
<td>&gt;4.0</td>
<td>2.5-4.0</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Total Phosphorus (µg/l) *</td>
<td>&lt;15.0</td>
<td>15.0-25.0</td>
<td>&gt;25.0</td>
</tr>
<tr>
<td>Dissolved Oxygen (saturation) #</td>
<td>high to moderate</td>
<td>moderate to low</td>
<td>low to zero</td>
</tr>
<tr>
<td>Macroscopic Plant (Weed) Abundance</td>
<td>low</td>
<td>moderate</td>
<td>high</td>
</tr>
</tbody>
</table>

* Denotes classification criteria employed by Forsberg and Ryding (1980).
# Denotes dissolved oxygen concentrations near the lakebottom.
Oligotrophic lakes are considered “unproductive” pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant “weed” growth, and high dissolved oxygen concentrations near the lake bottom. Eutrophic lakes are considered “highly productive” enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lake bottom. Mesotrophic lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant “weed” growth and decreasing dissolved oxygen concentrations near the lake bottom.

Is a pristine, oligotrophic, lake “better than” an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic; an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period that should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of once forested or agricultural lands are being developed, with the potential for increased sediment and nutrient loadings into our lakes which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake’s “health”. A “healthy” lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well-managed pasture: nutrients stimulate the growth of grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (zooplankton) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- **Removal of shore side vegetation and loss of wetlands** - shore side vegetation (what is known as riparian vegetation) and wetlands provide a protective buffer that “traps” pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality.

- **Excessive fertilizer applications** - fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface “scums” that can wash up on the shoreline producing unpleasant smells as the material decomposes. Excessive nutrient
concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested.

- **Increased organic matter loading** - organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are “freed up” and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- **Septic problems** - faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.

- **Loss of vegetative cover and the creation of impervious surfaces** - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water’s capacity to infiltrate into the ground, and in turn, go through nature’s water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify pollutants and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities that favor the transport of a greater load of suspended and dissolved pollutants into your lake.

**How can you minimize your water quality impacts?**

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody in the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested for a nominal fee (contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and soil amendments and really needed. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties. And remember that under the current NH Comprehensive Shoreline Protection Act (CSPA) you cannot apply any fertilizers or amendments within 25 feet of the shore.

- Don’t dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).
• Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system’s life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

*Septic Systems, How they work and how to keep them working.* $1.00/ea University of New Hampshire Publications Center (603) 862-2346


• Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge. Refer to:

*A Guide to Developing and Re-Developing Shoreland Property in New Hampshire: A Blueprint to Help You Live by the Water.* North Country Resource Conservation and Development Area, Inc. 103 Main Street-Suite #1, Meredith NH 03253-9266 (603) 279-6546

• Maintain shore side (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

*Planting Shoreland Areas* (no charge) University of New Hampshire Cooperative Extension Publication Center. (603) 862-2346

*A Guide to Developing and Re-Developing Shoreland Property in New Hampshire: A Blueprint to Help You Live by the Water.* North Country Resource Conservation and Development Area, Inc. 103 Main Street-Suite #1, Meredith NH 03253-9266 (603) 279-6546

*Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities.* Audubon Society of New Hampshire. 3 Silk Farm Road, Concord NH 03301 (603) 224-9909 (free for towns, $5.00 for others).

• Review the New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the *Shoreline Protection Act Coordinator* at (603) 271-3503.
REFERENCES


Figure 9. Location of the 2005 Bow Lake deep sampling stations, Site 1 Ledges and Site 3 Bennett.
Figure 10. Bow Lake, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll a trends for Site 1 Ledges. Note: The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll a data are reported to the nearest 0.1 parts per billion (ppb).

Figure 11. Bow Lake, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 1 Ledges. Note: The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll a and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll a and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).
Bow Lake - 1 Ledges
(2005 Seasonal Data)

Date

8/1/05  7/28/05  7/17/05  7/31/05  8/14/05  8/28/05  9/11/05

Secchi Disk Transparency  Chlorophyll a

Bow Lake - 1 Ledges
(2005 Seasonal Data)

Date

8/1/05  7/28/05  7/17/05  7/31/05  8/14/05  8/28/05  9/11/05

Secchi Disk Transparency  Dissolved Color (CPU)
**Figure 12.** Comparison of the annual Bow Lake, Site 1 Ledges, lay monitor Secchi Disk transparency data (1984-2005) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

**Figure 13.** Comparison of the annual Bow Lake, Site 1 Ledges, lay monitor chlorophyll a data (1984-2005) that are presented as box and whisker plots. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.
The following graphs illustrate the dissolved oxygen and temperature data collected at the Bow Lake deep sampling stations, Sites 1 Ledges and 3 Bennett, between June 22 and September 15, 2005. Temperature and dissolved oxygen data were generally collected at one-half meter intervals from the surface down to the lakebottom. The temperature units are degrees Celsius (°C) while the dissolved oxygen units are parts per million (ppm). The gray shaded region on the graphs represents dissolved oxygen concentrations stressful to coldwater fish species (dissolved oxygen concentrations less than 5 parts per million). Notice the low dissolved oxygen concentrations near the lakebottom.
Bow Lake - Site 1 Ledges
June 22, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.

Depth (meters)

Dissolved Oxygen (mg/l)

- ▲ Dissolved Oxygen (mg/l)
- ● Temperature (°C)

Bow Lake - Site 1 Ledges
July 7, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.

Depth (meters)

Dissolved Oxygen (mg/l)

- ▲ Dissolved Oxygen (mg/l)
- ● Temperature (°C)
Bow Lake - Site 1 Ledges
July 20, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.

Depth (meters)

Dissolved Oxygen (mg/l)

- ▲ Dissolved Oxygen (mg/l)
- ○ Temperature (°C)

Bow Lake - Site 1 Ledges
August 3, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.

Depth (meters)

Dissolved Oxygen (mg/l)

- ▲ Dissolved Oxygen (mg/l)
- ○ Temperature (°C)
Bow Lake - Site 1 Ledges
August 16, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.

Depth (meters)

Dissolved Oxygen (mg/l)

Temperature (°C)

Bow Lake - Site 1 Ledges
September 1, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.

Depth (meters)

Dissolved Oxygen (mg/l)

Temperature (°C)
Bow - Site 3 Bennett
August 3, 2005

Temperature (°C)

Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stressful to coldwater fish species such as lake trout and salmon.
APPENDIX B

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Bow Lake, Strafford and Northwood New Hampshire
-- subset of trophic indicators, 2005

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<th>Average transparency:</th>
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### Lakes Lay Monitoring Program, U.N.H.
[June 6, 2005 CFB Data]

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Secchi Disk Transparency = 4.4 meters
APPENDIX C

DETERMINING WATER QUALITY CHANGES AND TRENDS

Box and Whisker Plots

Quick Overview:
The 2005 summary New Hampshire Lakes Lay Monitoring Program (NH LLMP) reports include box-and-whisker plots that have replaced the annual graphs that historically depicted the minimum, average and maximum values. The box-and-whisker plot provides a visual representation of how the data are spread out and how much variation there is. Thus, the box-and-whisker plots will provide more detail into how your data are distributed.

Basically, these plots show how the data group together for a given year. The line in the “box” represents the sample median, the extent of the “box” represents a statistical range for comparison to another year, the “whiskers” show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or “outliers” that represent an extreme condition or difference from that year’s data range. An algae bloom event may cause this type of outlier to occur in the chlorophyll data (high point) or Secchi disk clarity (low point).

We recommend that each NH LLMP participating group plan on collecting weekly or biweekly measurements throughout the sampling season to ensure that enough data are available for this type of statistical analysis. We suggest that at least 8 data collections per year occur and generally set 10 measurements per year as a sampling effort goal per site.

We can employ the appropriate statistical techniques for detecting the extent that change is occurring when the sampling effort recommendations are followed. Your report summary should include box and whisker plots as well as a basic interpretation for your lake. If you have additional questions on interpreting your results feel free to call the Educational Program Coordinator (Bob Craycraft) at 603-862-3696.

The Details:
In the sections below we further describe the use of the box and whisker plot for those that are interested on how they are determined and how they are interpreted:

The box-and-whisker plot is good at showing the extreme values and the range of middle values of your data (Figure 1). The box depicts the middle values of a variable, while the whiskers stretch to demonstrate the values between which 80% of the data points will fall. The filled circles then reflect the “outlier” data points that fall outside of the whiskers and reflect values that are atypically high or atypically low relative to the other data measured for a given year.
The box-and-whisker plots can be summarized as a graphic that displays the following important features of the data when they are arranged in order from least to greatest:

- Median (50th percentile) – the middle of the data.
- Lower Quartile (25th percentile) – the point below which 25% of the data points are located.
- Upper Quartile (75th percentile) – the point below which 75% of the data points are located.
- 90th Percentile – the point below which 90% of the data points are located.
- 10th Percentile – the point below which 10% of the data points are located.
- Outlier Data points – data points that represent the upper 10% or the lowest 10% of the data collected for a specific year.

Note: A minimum number of data points is required to compute each feature documented above. At least three points are required to compute the Lower and the Upper Quartiles, five points are needed to compute the 10th percentile, and six points are needed to compute the 90th percentile. In the event that insufficient data points have been collected, features will not be graphed due to the inability to reliably calculate the respective attribute.
Sample box-and-whisker plot interpretation:

A sample box-and-whisker plot is depicted in Figure 2 and it provides an opportunity to assess the usefulness of this type of plot at interpreting water quality monitoring data. The imaginary data depicted in Figure 2 reflect the annual water transparency measurements recorded between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements has shifted to less clear conditions between 2001 and 2004. The median values, as well as the upper and lower quartiles (what is represented by the gray shaded box) have gradually shifted to less clear conditions over the four year span. The data points that lie between the upper and lower quartiles reflect 50% of the data collected for a given year and can provide insight into whether or not the water quality data are varying significantly between or among years. In extreme cases, when the gray shaded regions do not overlap between successive years or among years, one can quickly determine that the data distribution is significantly different for those years where the middle data (gray shading) does not overlap. Such differences can reflect long-term trends or can be a reflection of extreme climatic conditions for a given year such as atypically wet or atypically dry conditions that can have a profound impact on water quality.

![Figure 2](image)

Additional evaluation of the data can include a review of the 10th and the 90th percentiles (the whiskers) that provide additional insight into the distribution of the data. In this case, the trends exhibited by the 10th and the 90th percentiles are following the pattern of decreasing Secchi Disk Transparency as is exhibited by boxes (gray shaded regions). Outlier data points that fall outside of the “whiskers” can also be insightful. Such extreme values can be an early indicator of coming trends or can be an early warning sign of potential water quality problems. For instance, the occurrence of atypically shallow Secchi Disk transparency measurements can be an indication of
short-term water quality problems such as excessive sediment loading or an algal bloom. If such problems are not contended with, but are instead left unattended, the longer-term impact could result in an increase in the magnitude and frequency of the water transparency reductions that, in turn, would result in a decreasing trend as evidenced by a shift of the “Boxes” to shallower water transparencies. There might also be occasions when the Secchi Disk transparency outliers reflect atypically clear water clarity. Such outliers can be a sign that conditions are improving or, as is often the case, the water quality is responding to short-term climatic variations that can have a profound impact on the water quality data. For instance, the outlier data point of 6.4 meters that was documented in 2004 (Figure 2) is counter intuitive to the long-term trend of decreasing water quality. Plausible explanations for such an anomaly could be due to short-term overgrazing of algae by zooplankton (typical for moderate to highly productive lakes), an abrupt shift in climate that might have favored clearer water (cloudy days or cooler water) or perhaps there was some sort of human intervention, such as a fish stocking or lake treatment that would have resulted in clearer water clarities.

Your 2005 non-technical summary in this report includes a basic interpretation of the box-and-whisker plots that are specific to your lake. However, since you have personal knowledge of the conditions of your lake and local events that might influence the water quality measurements, you might have additional insight into the cause of the water quality fluctuations that have not been discussed in the report. Should you want to discuss the water quality results further, or provide additional information that you feel is important, please contact Bob Craycraft by phone, (603) 862-3696, or by email, bob.craycraft@unh.edu. Since the box-and-whisker plots are being included for only the second time in the 2005 summary reports we would appreciate your feedback regarding your thought on these graphs and whether they are appropriate for our volunteer monitoring audience.
GLOSSARY OF LIMNOLOGICAL TERMS

**Aerobe**- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

**Algae**- See phytoplankton.

**Alkalinity**- Total concentration of bicarbonate and hydroxide ions (in most lakes).

**Anaerobe**- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

**Anoxic**- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

**Benthic**- Referring to the bottom sediments.

**Bacterioplankton**- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

**Bicarbonate**- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

**Buffering**- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

**Chloride**- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

**Chlorophyll a**- The main green pigment in plants. The concentration of chlorophyll a in lakewater is often used as an indicator of algal abundance.

**Circulation**- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

**Density**- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.
**Dimictic**: The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

**Dystrophy**: The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll a concentration may be low or high.

**Epilimnion**: The uppermost layer of water during periods of thermal stratification. (See lake diagram).

**Eutrophy**: The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll a, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

**Free CO2**: Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

**Holomixis**: The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

**Humic Acids**: Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

**Hydrogen Ion**: The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

**Hypolimnion**: The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

**Lake**: Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

**Lake Morphology**: The shape and size of a lake and its basin.

**Littoral**: The area of a lake shallow enough for submerged aquatic plants to grow.

**Meromixis**: The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)
Mesotrophy - The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll a, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion - The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis - Periods of lakewater mixing or circulation.

Mixotrophy - The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy - The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn - See circulation or mixis.

pH - A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^-5 molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!]. In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis - The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton - Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million - Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion - Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!
**Plankton** - Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

**Saturated** - When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

**Specific Conductivity** - A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

**Stratum** - A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

**Thermal Stratification** - The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

**Thermocline** - Region of temperature change. (See metalimnion.)

**Total Phosphorus** - A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

**Trophic Status** - A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

**Z** - A symbol used by limnologists as an abbreviation for depth.

**Zooplankton** - Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia, Cyclops, Bosmina,* and *Kellicottia.*