PREFACE

This report contains the findings of a water quality survey of Chocorua Lake, Tamworth New Hampshire, conducted in the summer of 2005 by the University of New Hampshire **Center For Freshwater Biology (CFB)** in conjunction with the Chocorua Lake Association.

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 "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGMENTS

The year 2005 was the twenty-fourth year Chocorua Lake was monitored in conjunction with the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors who collected and analyzed water quality samples are highlighted in Table 1 while Dwight Baldwin again acted as the liaison to the **University of New Hampshire Center for Freshwater Biology (CFB)**. The **Center for Freshwater Biology** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Chocorua Lake water quality monitoring effort in 2006 and contribute to the expanding water quality database. The Chocorua Lake Association provided the funding for the volunteer monitoring program while the **CFB** provided at-cost services and subsidized analyses.

Table 1. Chocorua Lake Volunteer Monitors (2005)

Monitor Name
Dwight & Barbara Baldwin
Melissa Baldwin
Renne Baldwin

The **Center for Freshwater Biology** is a not-for-profit research program coordinated by Jeffrey Schloss and Robert Craycraft. Members of the **CFB** summer field team included Ashlee Cieslak, Laura Morcom and Michelle Williams while Thais Fournier, Adam Karr, Kellie Norris, Cassandra Payne and Julie Shelly provided additional assistance in the fall compiling and organizing the water quality data.

The **CFB** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The **CFB** would like to thank the **Caswell Family Foundation** for their generosity in providing long-term support for undergraduate assistantships. A gift from the **Samuel P. Pardoe Foundation** allowed for an update of our volunteer temperature profiling equipment, as well as, financial support to develop a data server for our **LLMP** web site while the **United States Geological Survey**, through the **University of New Hampshire Water Resources Research Center**, provided some resources for staff support. Additional support for administering the **NH LLMP** comes from the **United States Department of Agriculture Cooperative State Research, Education and Extension Service** through support from the New England Regional Water Quality Program (http://www.usawaterquality.org/newengland/).

Participating groups in the **LLMP** include: The Center Harbor Conservation Commission, Dublin Garden Club, Eaton Conservation Commission, Governor's Island Club Inc., Green Mountain Conservation Group, Meredith Bay Rotary Club, North River Lake Monitors, Walker's Pond Conservation Society, the associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Crystal Lake, Dublin Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth, Winnisquam Drive, and the towns of Alton, Amherst, Enfield, Madison, Meredith, Merrimack, Milton, Strafford, Whitefield and Wolfeboro.

CHOCORUA LAKE 2005 NON-TECHNICAL SUMMARY

Chocorua Lake, located at the base of Mount Chocorua, continues to serve as a portal to the White Mountains National Forest and as a gateway to the North Country. Long-term water quality monitoring was instituted on Chocorua Lake in 1978 and the monitoring has served to identify potential problems early on and address the threats at hand. This proactive approach continues to ensure that Chocorua Lake will remain a natural resource asset for future generations.

Volunteer water quality monitoring, instituted on Chocorua Lake in 1982, continued in 2005 and spanned the period of May 3 to November 2. The 2005 water quality monitoring focused on the collection of water quality data at the deep sampling station, Site 1 South, that provides insight into the overall condition of Chocorua Lake. The 2005 water quality monitoring included some interesting results that coincided with the extreme weather events; 2005 included a heavy spring runoff period that was associated with the above average spring rainfall coupled with the accumulated snowpack, as well as, heavy rainfall events that occurred during the month of October and that set all-time records in some parts of the state.

Water transparency measurements are collected with a standardized eight inch diameter black and white disk that is lowered into the water column until it can no longer be seen. The Chocorua Lake water transparency measurements remained high through most of the sampling season with the shallowest water clarity measurement of 12.2 feet (3.7 meters), documented on November 2, 2005, being documented following the heavy October rains.

The amount of microscopic plant growth (visually detectible as golden or green water) remained low through most of the year and remained well below nuisance levels. The total phosphorus (nutrient) concentrations were generally low and corresponded to the low levels of algal growth documented in 2005.

Lake acidity, measured as pH, was near neutrality for most of the year and remained within the tolerable range for most aquatic organisms throughout the 2005 sampling season. The pH measurements documented during the months of May and November were lower (i.e. more acidic water) than those recorded during other periods of the year and are likely associated with the heavy rainfall and runoff during those respective time periods.

Refer to Appendix A for a complete listing of the 2005 Chocorua Lake water quality data collected at the centrally located deep sampling station, Site 1 South. Refer to Table 2 for a brief summary of select water quality parameters that were measured in 2005.

Table 2: 2005 Chocorua Lake Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic “Pristine”	Mesotrophic “Transitional”	Eutrophic “Enriched”	Chocorua Lake Seasonal Average (range)	Chocorua Lake Classification
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	4.7 meters (range: 3.7 – 5.7)	Oligotrophic
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	2.1 ppb (range: 1.4 – 3.7)	Oligotrophic
Total Phosphorus (ppb)	< 15.0	15.0 - 25.0	> 25.0	5.1 ppb (range: 2.5 – 12.5)	Oligotrophic

***1)* Water Clarity (measured as Secchi Disk transparency)** – The 2005 seasonal average water transparency average of 15.5 feet (4.7 meters) is characteristic of an unproductive New Hampshire lake. The 2005 Chocorua Lake Secchi disk transparency measurements generally remained visible deeper than the depth of 13.2 feet (4.0 meters) that is considered the boundary between and unproductive and moderately productive New Hampshire lake. A Secchi Disk transparency of 12.2 feet (3.7 meters) was the single measurement that did not reach the 13.2 foot threshold. *Refer to figures 10 and 11 for a visual depiction of the 2005 seasonal water transparency data.*

The 2005 seasonal average, and median, water transparency values were slightly shallower than the 2005 values although the differences were minor. The 2005 Secchi Disk transparency measurements remained well within the range of historical values documented since volunteer water quality monitoring was initiated on Chocorua Lake in 1982 (Figure 12).

2) Microscopic plant abundance “greenness” (measured as chlorophyll *a*) – The 2005 seasonal average Chocorua Lake chlorophyll *a* concentration of 2.1 parts per billion (ppb) remained well below the concentration of 3.0 ppb that is considered the boundary between an unproductive and moderately productive New Hampshire lake. A single chlorophyll *a* concentration (documented on September 20, 2005) reached 3.7 ppb and corresponded to the highest total phosphorus concentrations that was documented during the 2005 sampling season (Figure 10). The September 20 chlorophyll *a* “spike” followed a period of rainfall over the previous week might be associated with natural water quality fluctuations; most New Hampshire lakes exhibit poorer water quality following heavy periods of rainfall. In some lakes, the algal blooms reach problematic levels (i.e. green water and noxious surface scums) that can be an indication of excessive nutrient loading. However, all of the 2005 Chocorua Lake chlorophyll *a* concentrations remained well below nuisance levels.

The 2005 seasonal average and median Chocorua Lake chlorophyll *a* concentrations increased, relative to the 2004 chlorophyll *a* concentrations, but remained well within the range of historical concentrations documented since 1982 (Figure 13).

3) Background (dissolved) water color: often perceived as a "tea" color in our more highly stained lakes – The 2005 seasonal average Chocorua Lake dissolved color concentration of 34.2 chloroplatinate units (cpu) falls within the classification of a lightly "tea" colored lake (Table 3). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. The 2005 Chocorua Lake seasonal average dissolved color concentration was eight units higher than the 2004 seasonal average concentration (26.2 cpu) and likely reflects the heavy flushing of the Chocorua River sub-watershed where extensive wetland complexes are characterized by more "tea" colored water (Figure 11). The 2005 dissolved color concentrations did vary seasonally and the highest dissolved color concentration of 49.5 cpu was documented on November 2, 2005 following a series of intense October storm events (Figure 11).

Table 3. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range	Classification
0 - 10	Clear
10 - 20	Slightly colored
20 - 40	light tea color
40 - 80	tea colored
> 80	highly tea colored

4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire lakes. - Total phosphorus concentrations, measured in the Chocorua Lake surface waters (epilimnion), were low in 2005 (range: 2.5 to 12.5 parts per billion) and remained below the concentration of 15 ppb that is considered the boundary between an unproductive "pristine" and more nutrient enriched "transitional" New Hampshire Lake. The 2005 median total phosphorus concentration was at the lowest concentration documented since 1999 while the distribution of total phosphorus concentrations was more variable than usual (Figure 14). The highly variable total phosphorus concentrations were likely influenced, at least in part, by the atypically variable weather patterns that included heavy storm events as well as relatively dry periods during the 2005 sampling season. However, considering the number of intense storm events and the corresponding heavy runoff periods, the 2005 total phosphorus concentrations did not exhibit signs of gross water quality problems in Chocorua Lake such as atypically high total phosphorus "spikes".

5) Dissolved salts: measured as specific conductivity – The 2005 Chocorua Lake, Site 1 South, specific conductivity was low and ranged from 26.3 to 36.7 micro-Siemans (*u*S). High specific conductivity values can be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications and sedimentation are contributing "excessive" nutrients into the lake. High specific conductivity values can also be an indication of heavy road salt applications within the Chocorua Lake watershed.

6) Resistance against acid precipitation (measured as total alkalinity) – The 2005 seasonal average Chocorua Lake alkalinity measured 2.8 milligrams per liter (mg/l) which is considered typical of a lake that is moderately vulnerable to acid precipitation according to the standards devised by the New Hampshire Department of Environmental Services (Table 4). Generally speaking, the geology of the region does not contain the appropriate mineral content (e.g. limestone) that increases the buffering capacity of our surface waters. Thus, lakes in the region (e.g. Conway Lake, Ossipee Lake and Silver Lake) have naturally low alkalinities. The 2005 alkalinity measurements were lower than those that have been documented during most years of sampling and likely reflect the influence of the intense rainfall events that can include acidic rainfall.

Table 4. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range	Classification
< 0	Acidified
0 -2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

Lake acidity (measured as pH) – The 2005 Chocorua Lake, Site 1 South, volunteer monitor pH data ranged from 6.2 to 6.9 units and remained well within the tolerable range for most aquatic organisms. Lower pH values were documented both early and again late in the sampling season during and following periods of sustained heavy rainfall and runoff. Acidic precipitation and the flushing of naturally acidic wetlands, most notably along the Chocorua River inlet, likely contributed to the relatively short-term pH reductions that were documented in 2005.

7) Temperature and dissolved oxygen profiles – Temperature profiles collected by the volunteer monitors indicate Chocorua Lake becomes stratified into two distinct thermal layers during the summer months; a warm upper water layer, the **epilimnion**, overlies a layer of rapidly decreasing temperature known as the **thermocline**. The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under adverse conditions can favor oxygen depletion near the lake-bottom. Historical data collected by the **Center for Freshwater Biology** indicate dissolved oxygen concentrations become reduced near the lakebottom and restrict the Chocorua Lake fishery to the warm surface waters late in the summer.

Based on the current and historical water quality data, Chocorua Lake would be considered an unproductive "pristine" New Hampshire lake that at times borders conditions typical of a more nutrient enriched, **mesotrophic**, lake. While the current Chocorua Lake water quality is high, developmental pressures within the Chocorua Lake watershed continue to pose a threat to the lake. A first step towards preserving the high water quality characteristic of Chocorua Lake is to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) that enter the lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake since the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained** and have it pumped out on a regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and result in early failure, costing thousands of dollars to repair or replace. Future volunteer monitoring efforts should continue to be directed at pinpointing problematic regions around the lake where corrective and educational efforts should be focused.

COMMENTS AND RECOMMENDATIONS

1) Some lake associations have become increasingly interested in conducting supplemental near-shore sampling and/or stream sampling to better assess whether localized water quality variations exist. The supplemental near-shore and tributary sampling would facilitate the targeting of resources (i.e. money and volunteer hours) to the most critical areas within the watershed where future monitoring and corrective efforts should be directed. Expanded water quality monitoring could be as simple as collecting additional near-shore/tributary total phosphorus or chlorophyll *a* samples or could involve the expansion to the collection of additional water quality parameters such as dissolved oxygen and specific conductivity measurements. Advanced water quality monitoring efforts might also include more in-depth shoreline/watershed surveys aimed at visually identifying the land-use patterns and potential problem areas within the drainage basin. If you are interested in discussing additional water quality monitoring options that would meet your needs please contact Bob Craycraft @ 862-3696 or via email, bob.craycraft@unh.edu.

2) We recommend that each participating lake association, including the Chocorua Lake Association, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in Chocorua Lake and through continued monitoring will enable more reliable predictions of both short-term and long-term water quality trends.

3) We recommend continued lake sampling early in the season (April/May) to document Chocorua Lake's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color and Secchi Disk transparency measurements. Phosphorus samples are also recommended from both the in-lake and the tributary sampling sites. When tributary samples are collected, streamflow measurements should be included whenever possible.

4) The 2005 Chocorua Lake water quality remained high despite numerous heavy precipitation events; the predominantly forested nature of the Chocorua Lake watershed afforded protection against excessive erosion and excessive nutrient loading that would have otherwise degraded the lake. Local efforts should continue to focus on mechanisms that will protect streamside buffers and preserve tracts of land that are deemed important to protecting water quality and other natural resource features.

5) The Chocorua Lake Association should inspect the berms, swales and the rip-rap culverts along the Route 16 travel corridor this spring to ensure they have not become overly “clogged” with sediment and other debris. The ability of the best management practices to mitigate the nutrient and sediment load lies in a regularly scheduled inspection and maintenance plan.

Climatic Summary - 2005

Water Quality and the Weather

Water quality variations are commonly observed over the course of the year and among years in our New Hampshire lakes, ponds, wetlands and streams. The most commonly noticed changes are those associated with decreasing water clarities, increasing algal growth (greenness), and increasing plant growth around the lake's periphery. Over the long haul, changes such as these are attributed to a lake's natural aging process; what is known as **"eutrophication"**. However, short-term water quality changes such as those mentioned above are often encountered even in our most pristine lakes and ponds. These water quality changes often coincide with variations in weather patterns that include precipitation and temperature fluctuations and even variations in the sunlight intensity that can accelerate or suppress the photosynthetic process.

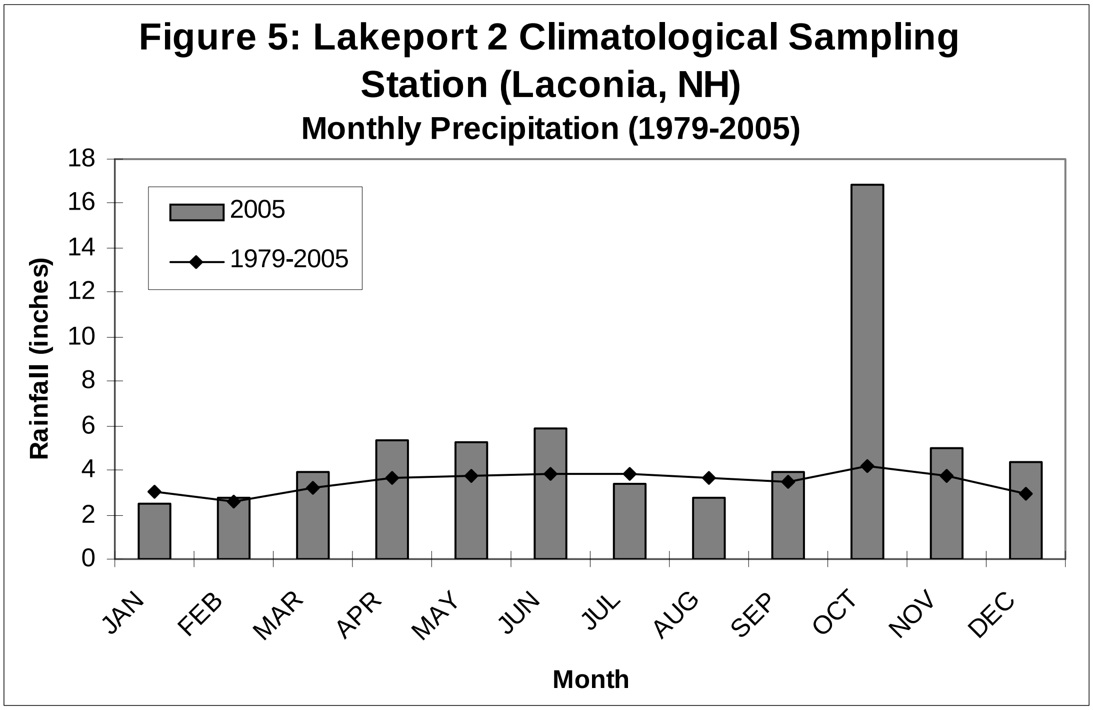
Climatic "swings" can have a profound effect on water quality, sometimes positive and other times negative. For instance, 1996 was a wet year relative to other years of **LLMP** water quality monitoring. This translated into reduced water clarities, elevated microscopic plant "algal" growth and increased total phosphorus concentrations for most participating **LLMP** lakes. "Excessive" runoff associated with wet periods often facilitates the transport of pollutants such as nutrients (including phosphorus), sediment, dissolved colored compounds, as well as toxic materials such as herbicides, automotive oils, etc. into water bodies. As a result, lakes often respond with shallower (less clear) water clarities and elevated algal abundance "greenness" during these periods as evidence by historical monitoring through the **NH LLMP**. Similarly, short-term storm events can have a profound effect on the water quality. Take for instance the "100 year storm" (October 21-22, 1996) that blanketed southern New Hampshire with approximately 6 inches of rain over a 30-hour period. This storm resulted in increased sedimentation and organic matter loading into our lakes as materials were flushed into the water bodies from the adjacent uplands. Likewise, the heavy rains that saturated the soil and resulted in flood conditions in June 1998 (heaviest rains occurring on June 12 and 13) resulted in significantly shallower water transparency readings in the weeks to months that followed. While events such as the October 1996 and the June 1998 storms are short lived, they can have a profound effect on our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake.

NH LLMP data collected during dry years such as 1985 and 2001, on the other hand, have coincided with improved water quality for many New Hampshire lakes. Reduced transport of pollutants into the lake often results in higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. Do all lakes experience poorer water quality as a result of heavy precipitation events? Simply stated, the answer is no. While most New Hampshire lakes are characterized by reduced water clarities, increased nutrients and elevated plant "algal" concentrations following periods, or years, of heavy precipitation, a handful of lakes actually benefit from these types of events. The water bodies that improve during wet periods are generally lakes characterized by high nutrient concentrations and high "algal" concentrations that are diluted by watershed runoff and thus benefit during periods, or years, of heavy rainfall. However, these more nutrient enriched lakes remain susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems.

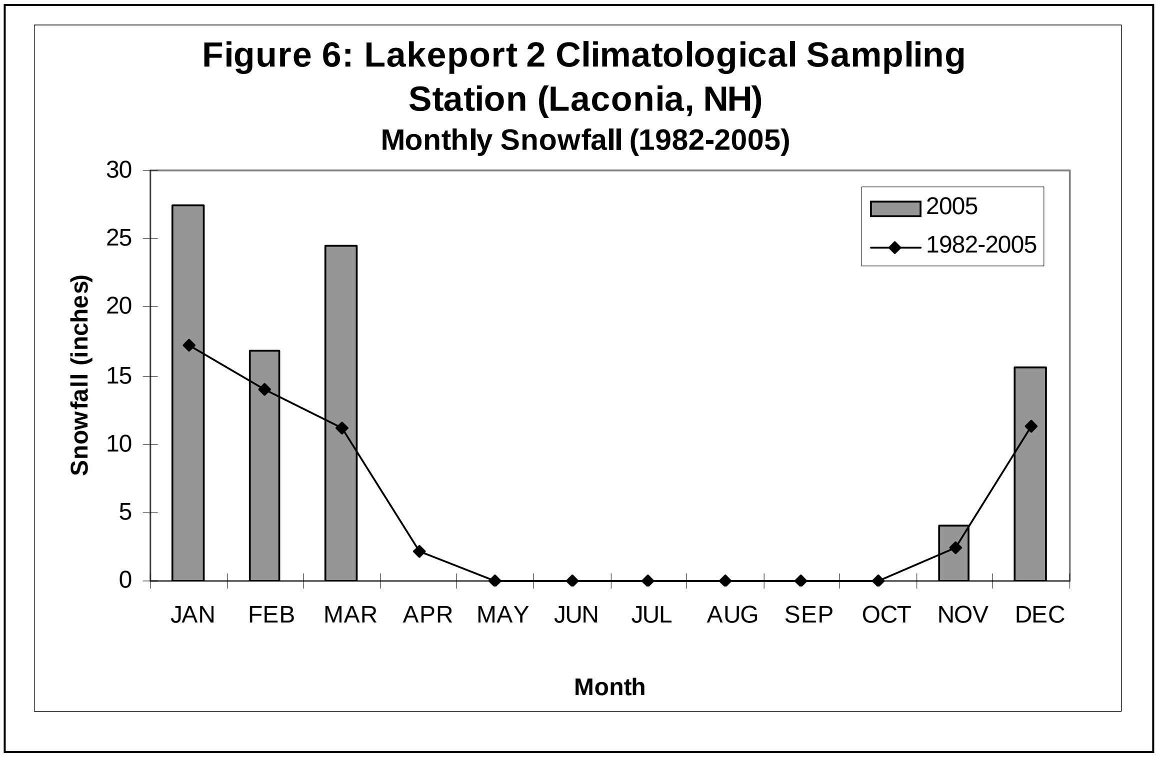
Precipitation (2005)

The 2005 annual precipitation (reported as "rainfall" water equivalent) measured 61.94 inches and was the highest "rainfall" amount that has been documented over the past 27 years: 1979-2005 (note: precipitation data are reported for the Lakeport 2 Climatological sampling station located in Laconia New Hampshire: 43°33'N and 71°28'W). The monthly precipitation totals documented during the months of January and February were near/below average although the timing of the rainfall events coincided with low temperatures that translated into relatively heavy periods of snowfall during January and February. The March precipitation was above average and was coupled with two snow-storms, and below average temperatures, during the first third of the month that culminated in of the additional snowpack accumulation that contributed to periods of heavy runoff later in the month of March and into the Month of May (Figures 5 & 6). Significant accumulations of winter snowpack can result in a period of heavy overland runoff in the spring that oftentimes coincides with increased sediment and nutrient loading that negatively impacts water quality. Above average rainfall continued into the month of June during which the rainfall was largely concentrated to the middle of the month. The subsequent months of July and August were characterized by below average rainfall followed by slightly above average rainfall during the month of September.

A series of storms swept through New Hampshire during the month of October during which the rainfall amount was nearly four times above the 27 year average documented between 1979 to 2005 (Figure 5). Futhermore, the October 2005 rainfall reached record levels in some locations in southern New Hampshire. The months of November and December rounded out the years with above average rainfall and above av-



erage snowfall.

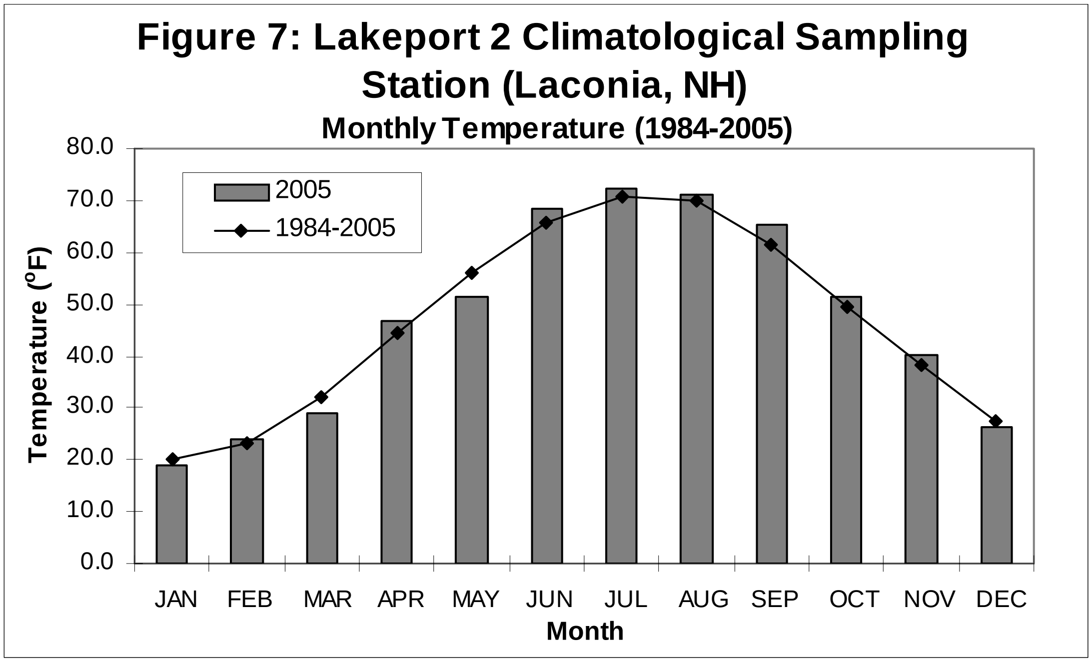


Temperature (2005)

Similar to the impact of precipitation extremes, temperature extremes can have far reaching effects on the water quality, particularly early in the year and during the summer months. Atypically warm spells can account for a rapid snowpack melt resulting in flooding and a massive influx of materials (e.g. nutrients, sediments) into our lakes during the late winter and early spring months. Early spring runoff periods coincide with minimal vegetative cover (that acts as a pollutant filter and soil stabilizer) and thus leaves the landscape highly susceptible to erosion. As we progress into the summer months, atypically warm periods can enhance both microscopic "algal" and macroscopic aquatic "weed" plant growth. During the summer growing season, above average temperatures often result in algal blooms that can reach nuisance proportions under optimal conditions. These nuisance blooms can include surface algal "scums" that cover the lake and wash up on the windward lakeshores.

During years such as 1994 and 1995, when above average temperatures characterized the summer months, participating **NH LLMP** lakes were generally characterized by increased algal concentrations, particularly in the shallows, where filamentous cotton candy like clouds of algae (i.e. *Mougeotia*) flourished. Other **NH LLMP** lakes had increased algal growth "greenness" and shallower water transparencies during these "hot" periods.

The January and February 2005 monthly temperatures were near the twenty two year average while the March, 2005 temperature was approximately 3^{o}F below the 22 year average (Figure 7). Increasing temperatures and above average rainfall during the months of April and May contributed to periods of heavy spring runoff. The



monthly temperature averages documented between April and December 2005 oscillated from near average temperatures to slightly above or slightly below average temperatures (Figure 7). Below average temperatures during the month of May (over four °F below the twenty two year average) corresponded to some of the colder in-lake water temperatures documented in recent years through the month of June. The below average water temperatures that were documented into June might have suppressed some of the microscopic plant "algal" and macroscopic plant growth early in the 2005 sampling season.

Water Quality Impacts

Water Transparency and Dissolved "tea" Colored Water

As previously mentioned shallower water transparency readings are characteristic of most New Hampshire lakes during wet years and following short term precipitation events. Wet periods often coincide with greater concentrations of dissolved "tea" colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Data collected by the **Center for Freshwater Biology (CFB)** since 1985 indicate most lakes are characterized by higher dissolved "tea" colored water during wet years relative to years more typical in terms of annual precipitation levels. In some of our more highly "tea" colored lakes the early spring months are also characterized by higher dissolved color concentrations, relative to mid-summer levels, due to the heavy runoff periods that flush highly colored water into our lakes during the period of spring snowmelt and following heavy spring rains.

Sediment Loading

Sediments are continuously flushed into our lakes and ponds during periods of heavy watershed runoff, particularly during snowmelt and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experience water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreside buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the particulate debris and dissolved materials are flushed into the lake. Human activities such as logging, agriculture, construction and land clearing can also increase sediment displacement during and following heavy storm events throughout the year. These activities are often associated with excessive sediment loading in many of our lakes and ponds. As these materials (sediments) are transported into surface waters they can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth that can result in plant die-offs and the subsequent oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and fish spawning habitat. As the dead materials begin to decay the result can be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lakebottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water milfoil (*Myriophyllum heterophyllum*) will generally regenerate more rapidly than more favorable plant forms. This can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated “muck” might also favor increased nuisance plant growth in the future. Another unfavorable attribute of sediment loading is that the sediments tend to carry with them other sorts of contaminant such as pathogens, nutrients and toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lakebottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lakebottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lakebottom you might notice a change in the weed composition reflecting a change in the substrate type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to other factors.

Nutrient Loading

Nutrient loading is often greatest during heavy precipitation events, particularly during the periods of heavy watershed runoff. Phosphorus is generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes. Elevated phosphorus concentrations are generally most visible when documented in our tributary inlets where nutrients are concentrated in a relatively small volume of water. Much of the phosphorus entering our lakes is attached to particulate matter (i.e. sediments, vegetative debris), but may also include dissolved phosphorus associated with fertilizer applications and septic system discharge.

Microscopic “Algal” and Macroscopic “Weed” Plant Growth

Historical **Lakes Lay Monitoring Program** data indicate most lakes experience "algal blooms" during years with above average summer temperatures (June, July and August) while years with heavy precipitation are also associated with an increased frequency and occurrence of “algal blooms” among participating **LLMP** lakes. Algal blooms are often green water events associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". During some years, such as 1996, the algal blooms are predominantly green water events composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with an atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices and construction activities favor the displacement of nutrients into surface waters. The occasional formation of certain algal blooms is a naturally occurring phenomenon and is not necessarily associated with changes in lake productivity. However, increases in the occurrence of bloom conditions can be a sign of eutrophication (the "greening" of a lake). Shifts from benign (clean water) forms to nuisance (polluted water) cyanobacterial forms such as *Anabaena*, *Aphanizomenon* and *Oscillatoria*, can also be a warning sign that improper land use practices are contributing excessive nutrients into the lake.

Filamentous cotton-candy like "clouds" of the nuisance green algae, *Mougeotia* and related species, have been well documented in 1994 and 1995 when the temperatures during the months of June and July were well above normal. These algal “clouds” often develop within nearshore weed beds where they can be seen along the lakebottom and tend to flourish during warm periods. During cooler years, this type of algal growth is kept “in check” and generally does not reach nuisance proportions. In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

APPENDIX A

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

Chocorua Lake, Tamworth New Hampshire
-- subset of trophic indicators, Site 1 South, 2005

Average transparency:	4.7	(2005:	11	values;	3.7	-	5.7	range)
Average chlorophyll:	2.1	(2005:	11	values;	1.4	-	3.7	range)
Average color:	34.2	(2005:	10	values;	25.2	-	49.5	range)
Total phosphorus (*u*g/L)	5.1	(2005:	11	values;	2.5	-	12.5	range)
Average alkalinity (gray):	2.8	(2005:	11	values;	1.6	-	3.9	range)
Average alkalinity (pink):	3.1	(2005:	11	values;	1.9	-	4.2	range)
Specific conductivity (*uS*/cm)	33.3	(2005:	11	Values;	26.3	-	36.7	range)

Date	**Secchi Disk Depth (meters)**	**Chl *a* (*ug*/L)**	**Dissolved Color (CPU)**	**Total Phos. (*ug*/L)**	**Alkalinity gray end pt. @ pH 5.1 (mg/L)**	**Alkalinity pink end pt. @ pH 4.6 (mg/L)**	**pH (std units)**	**Specific Conductivity @ 25^{o}C (*u*S/cm)**
5/3/2005	5.1	1.4	28.7	3.7	1.8	2.2	6.4	34.2
5/16/2005	5.7	1.6	29.5	2.9	1.8	2.1	6.4	31.2
5/26/2005	5.5	1.8	31.3	3.3	1.6	1.9	6.6	30.7
7/5/2005	4.3	2.1	47.8	7.4	3.0	3.3	------	33.5
7/16/2005	4.6	2.7	34.8	4.4	2.9	3.2	6.7	33.2
7/24/2005	4.1	2.0	36.5	7.1	3.2	3.4	6.9	34.0
8/6/2005	4.3	2.3	33.9	2.5	3.6	3.8	------	34.8
8/18/2005	4.4	2.2	25.2	3.1	3.3	3.7	6.9	35.8
9/20/2005	5.0	3.7	------	12.5	3.6	4.0	6.9	35.9
10/7/2005	5.0	1.6	25.2	2.7	3.9	4.2	6.9	36.7
11/2/2005	3.7	1.9	49.5	7.0	1.7	2.0	6.2	26.3

<< End of 2005 data listing; 11 records >>

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

Chocorua Lake, Tamworth New Hampshire
- total phosphorus summary, Site 1 South, 1999-2004

Site	Date	Total Phosphorus (*ug*/l)
1 South	5/30/99	6.6
1 South	6/10/99	4.2
1 South	7/15/99	5.3
1 South	8/17/99	3.7
1 South	9/9/99	4.6
1 South	10/12/99	5.9
1 South	10/25/99	4.6
1 South	6/20/00	6.1
1 South	7/1/00	7.2
1 South	7/13/00	6.7
1 South	7/20/00	6.4
1 South	8/3/00	6.0
1 South	8/10/00	5.8
1 South	8/20/00	3.3
1 South	9/5/00	3.5
1 South	5/11/01	4.4
1 South	5/25/01	4.4
1 South	6/7/01	4.5
1 South	6/15/01	18.3
1 South	7/13/01	4.5
1 South	7/21/01	3.6
1 South	8/1/01	3.5
1 South	8/11/01	3.2
1 South	8/19/01	3.2
1 South	9/2/01	4.3
1 South	9/18/01	4.5
1 South	5/5/02	7.5
1 South	5/22/02	5.3
1 South	5/30/02	5.3
1 South	6/7/02	4.4
1 South	6/20/02	6.2
1 South	7/1/02	6.4
1 South	7/8/02	5.8
1 South	7/14/02	4.2
1 South	7/24/02	3.9
1 South	8/8/02	5.8
1 South	8/15/02	3.5
1 South	8/22/02	3.1
1 South	9/1/02	4.5
1 South	9/17/02	5.6
1 South	10/12/02	4.9
1 South	5/6/03	5.8
1 South	5/16/03	3.4
1 South	5/22/03	3.5
1 South	6/2/03	3.8
1 South	6/20/03	4.8
1 South	8/8/03	4.3
1 South	8/21/03	7.5
1 South	9/3/03	6.0
1 South	10/7/03	7.1
1 South	6/8/04	4.2
1 South	7/11/04	4.0
1 South	7/21/04	6.4
1 South	7/30/04	5.1
1 South	8/8/04	3.8
1 South	8/17/04	3.9
1 South	8/23/04	4.5
1 South	9/3/04	3.2

APPENDIX B

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 are replacing 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.

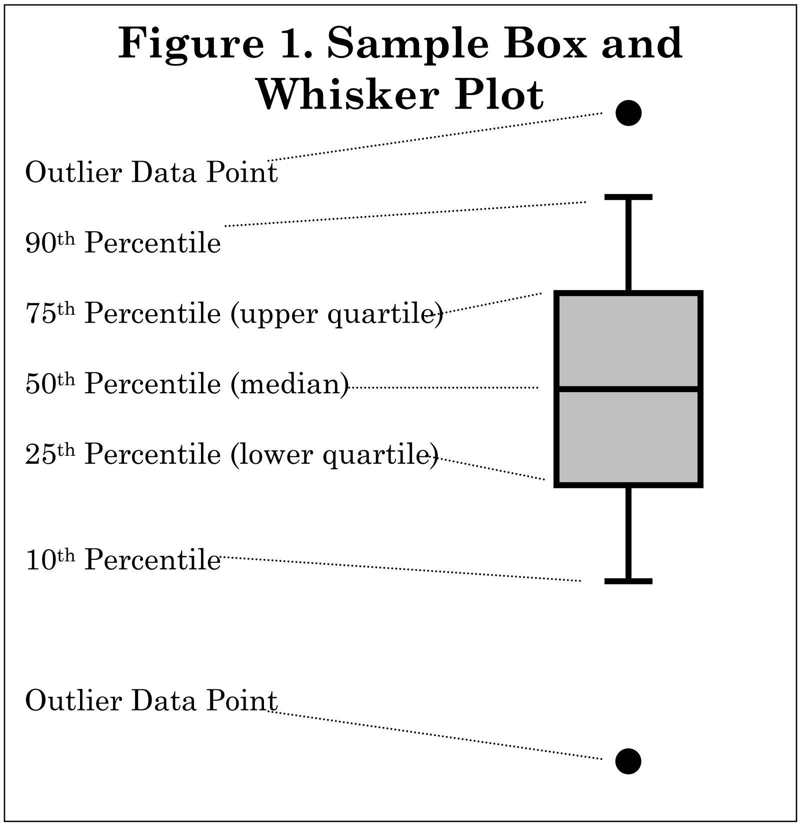


Figure 1. Sample Box and Whisker Plot

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 between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements have 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.

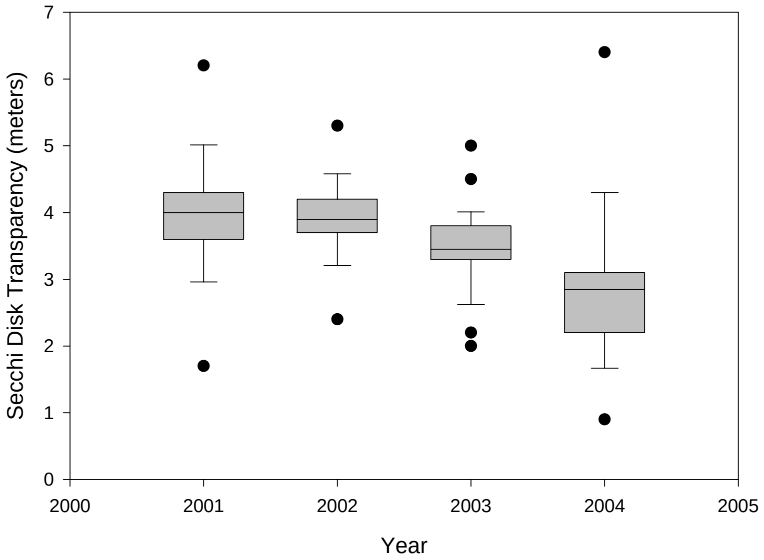


Figure 2.

Sample Lake - Site 1 Deep
Annual Secchi Disk Transparency Comparisions
Box and Whisker Plots: 2001-2004

Note: The number of outlier data points is dependant on the size of the dataset.

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, when Secchi Disk transparency measurements occasionally become significantly reduced (i.e. shallower water) such phenomenon can be an indication of short-term water quality problems such as excessive sediment 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 claries.

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 thoughts on these graphs and whether they are appropriate for our volunteer monitoring audience.