Little Island Pond

2022

Extension
Lakes Lay Monitoring Program

PREFACE

This report contains the findings of a water quality survey of Little Island Pond, Pelham, New Hampshire, conducted in the summer of 2022 by the University of New Hampshire and Center for Freshwater Biology (CFB) in conjunction with the Little Island Pond Association (https://littleislandpond.com/) and volunteer monitors. A "highlight report" on the water quality for Little Island Pond was also produced for distribution among interested residents and officials. These are shared with the lake association and are available on our website, as well as through the UNH Library Database.

Search for UNH LLMP water quality reports here:
https://experience.arcgis.com/experience/0782054f6ed446729463829b6a3921bb

The report is written with the concerned lake resident in mind and contains sections that discuss the historical water quality data collected through the New Hampshire Department of Environmental Services and others.

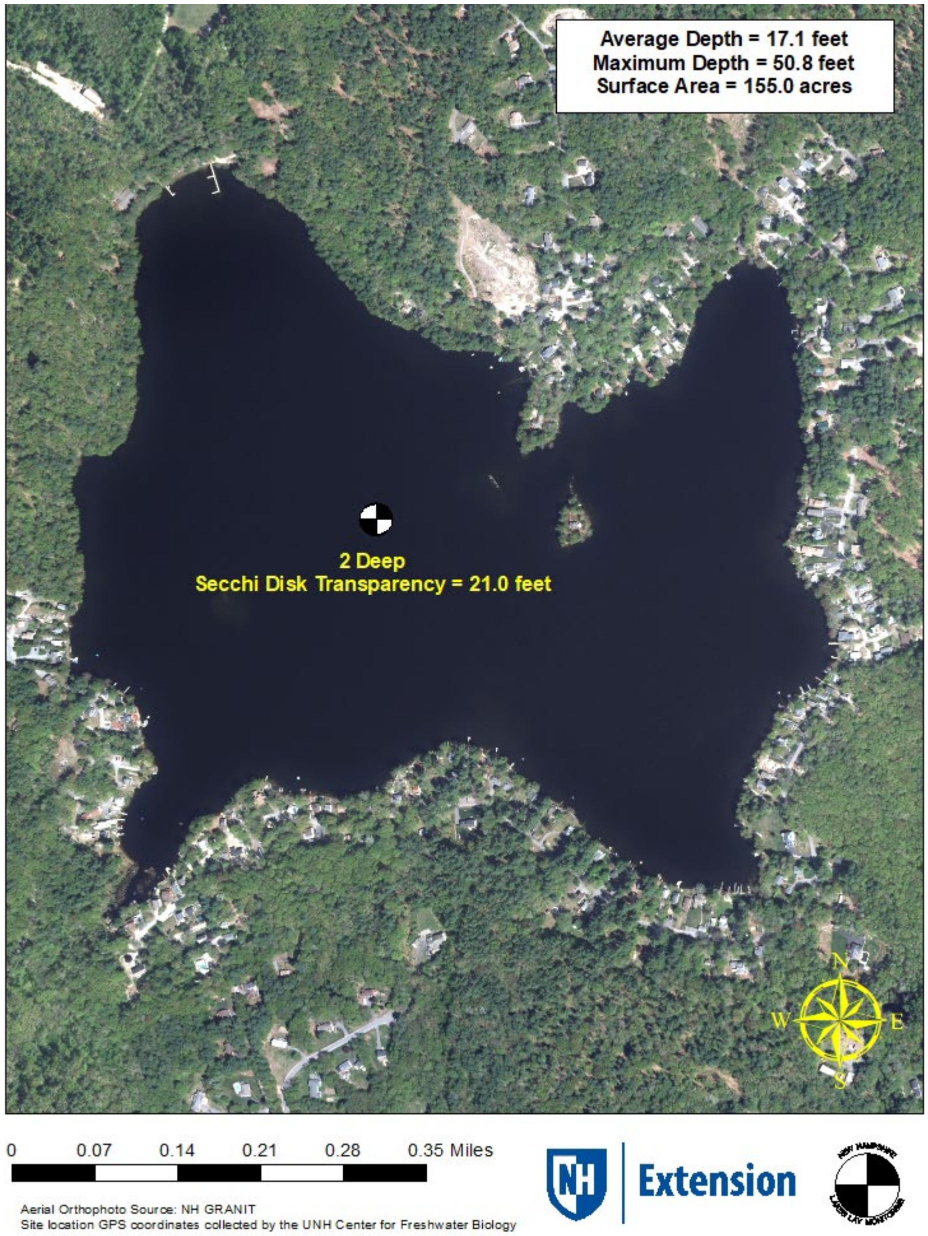


Figure 1. Little Island Pond; Deep Site Station (2 Deep) was sampled in 2022.

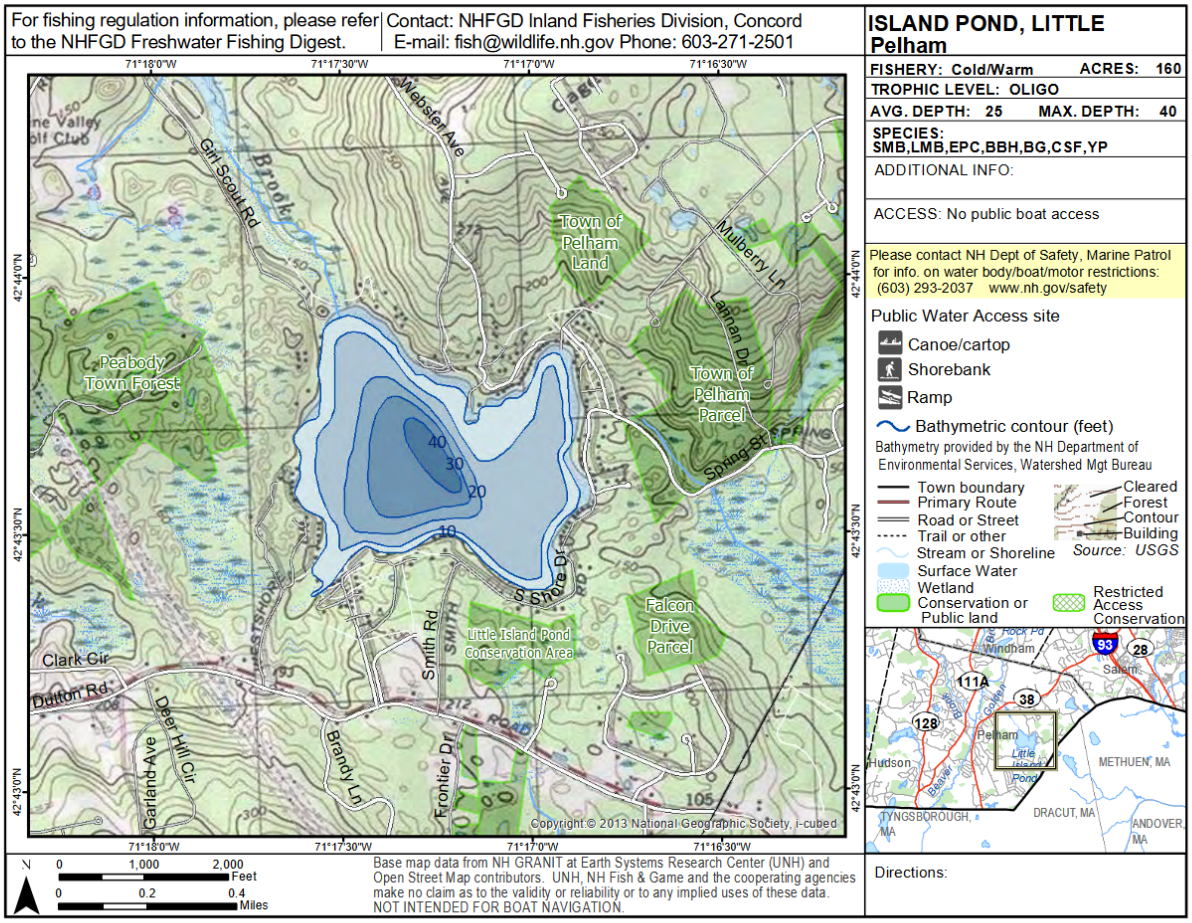


Figure 2. NHFGD map of Little Island Pond, Pelham, New Hampshire.

ACKNOWLEDGMENTS

The sampling season of 2022 marked the first year for the **Little Island Pond Association** and Volunteer Monitors participation in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. Earlier sampling efforts were conducted by the **Little Island Pond Rod and Gun Association in 1984-1986**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1. The **Center for Freshwater Biology (CFB)** 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 Little Island Pond water quality monitoring effort and expand upon the current database. Funding for the water quality monitoring program was provided by the Little Island Pond Association and Volunteer Monitors, while the CFB provided at-cost laboratory services.

Table 1. Little Island Pond Volunteer Monitors (2022)

Monitor Name
Krista Bajor
Pete Bajor
Brenda Godin
Mark Godin
John Hanson
Cindy Hay
Julia Steed Mawson
Ed Remeitis
Cindy Ronning
Joost Verhofstad

The New Hampshire Lakes Lay Monitoring Program is a not-for-profit citizen-based research program coordinated by Robert Craycraft and directed by Amanda McQuaid. Members of the LLMP summer field team included Georgia Bunnell, Raina Burke, Alyssa Daigle, Sara Forcina, and Ciana Lazu.

The LLMP acknowledges the University of New Hampshire Cooperative Extension for major funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The LLMP would like to thank the **Caswell Family Foundation** for their continued generosity in providing long-term support for undergraduate assistantships.

TABLE OF CONTENTS

Executive Summary

The New Hampshire Lakes Lay Monitoring Program

The 2022 sampling season marked the forty-third anniversary for the NH Lakes Lay Monitoring Program (LLMP). The LLMP has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program that has engaged thousands of volunteers and has worked collaboratively with over 100 lakes. Originally developed to establish a database for determining long-term trends of lake water quality for science and management, the program has expanded since 1979 with the help of several volunteers and many resources that citizen monitors can provide. The LLMP has established itself as an essential water quality program, serving the NH community through UNH Cooperative Extension.

Our active involvement with UNH research as part of the UNH Center for Freshwater Biology (CFB) (historically referred to as Freshwater Biology Group (FBG)) continues to drive relevant applied research. The work and research were founded by Dr. Jim Haney, Dr. Al Baker, Jeff Schloss, and Bob Craycraft. Program Manager, Bob Craycraft and the new LLMP director, Amanda McQuaid, will continue to focus on how watershed development and our activities on the landscape play an influential role in lake eutrophication and water quality. Researchers, including several undergraduate and graduate students and affiliates of the CFB, have especially focused efforts on understanding the occurrence of potentially toxic cyanobacteria blooms across NH lakes.

The LLMP has gained an international reputation as a successful cooperative monitoring, education, and research program. Current projects include: the use of volunteer generated data for non-point pollution studies associated with land use changes using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of watershed nutrient budgets and investigations of water quality impacts, including the formation of cyanobacteria blooms. National recognition for the high quality of work by you, the volunteer monitors, culminated with program awards, requests for program information and invitations to speak at national conferences.

Awards & Recognition

1983- NH Environmental Law Council Award
1984- Governor's Volunteer Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" award funded
1990- NH Journal TV coverage NHPTV
1991- Renew America Award
Environmental Success Index
White House Reception / Briefing
1992- EPA Administrators Award
1993- NH Lakes Association Award
1994- EPA Office of Watersheds Award
1995- Winnipesaukee Watershed Project
1998- Governor's Proclamation for 20th Anniversary
1999- EPA Watershed Academy Host
2001- Lake Chocorua Project highlighted at national conferences (invited presentations)
2002- Chocorua Project receives Technical Excellence Award from the North American Lake Management Society
2003- UNH CE Maynard and Audrey Heckel Extension Fellowship awarded to LLMP
2004- Participatory Research Model of NH LLMP highlighted at National Water Quality Monitoring Conference
2005- LLMP Coordinator J. Schloss receives the prestigious Secchi Disk Award from the North American Lakes Management Society
2007- Lake friendly landscaping manual introduced receives praise from New Hampshire agencies and waterfront landowners.
2008- NH LLMP's 30th year of sampling NH lakes!
2009- EPA Equipment support grant to the NH LLMP.
2010- NH LLMP becomes first citizen program to monitor cyanotoxins
2013- NH LLMP pilots a new volunteer monitor cyanobacteria monitoring option.
2014- KW Kellogg Foundation Community Engagement Scholarship Award.
2015- Invited speaker at the White House citizen science forum, "Open Science and Innovation forum, Of the People, by the People, for the People".
2018 – EPA Merit Award for cyanobacteria research and public engagement associated with the UNH Center for Freshwater Biology.
2019 – 40th Anniversary celebration held at the Squam Lakes Association.

The Lakes Lay Monitoring Program held its 40th anniversary celebration conference at the Squam Lakes Association in June of 2019 where some evolving cyanobacterial monitoring protocols were discussed and demonstrated. Additional ongoing research led by Dr. Shane Bradt (UNH Cooperative Extension, Geospatial State Specialist) has focused on the use of satellite and aerial imagery as well as on-lake optical devices as a means of determining the water transparency and amount of microscopic plant "algal" growth in our New Hampshire Lakes, particularly cyanobacteria. Water quality data, collected by the volunteer monitors, have served to ground-truth data to assess whether the satellite imagery shows promise. Data generated through this project have been presented at national conferences and are testament to the high-quality data generated by our volunteer monitors. Dr. Shane Bradt has also provided technical support to the LLMP database, an ongoing effort to improve reporting and data management.

Interest in the success of our LLMP participatory science research model has resulted in invited presentations at national conferences and provided the basis of a series of articles in the “Volunteer Monitor”, a national newsletter that had a distribution of over 10,000. To date, the approach and methods of the LLMP have been adopted by new or existing programs in twenty-four states and eleven countries. The key ingredients responsible for the success of the program include innovative cost share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

Participating groups in the LLMP include: Acton-Wakefield Watershed Alliance, Green Mountain Conservation Group, Little Island Pond Association, the Associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Conway Lake Conservation, Crystal Lake, Goose Pond, Governors Island, Great East Lake, Lake Kanasatka Watershed, Lovell Lake, Mendums Pond, Merrymeeting Lake, Milton Three Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee Watershed, Naticook Lake, Newfound Lake Region, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth Watershed Association and the towns of Alton, Amherst, Enfield, Gilford, Laconia, Madison, Meredith, Merrimack, Milton, Moultonborough, New Durham, Strafford, Tuftonboro and Wolfeboro.

Major collaborators with the UNH CFB also include the New Hampshire Lakes Association, New Hampshire Department of Environmental Services, Loon Preservation Committee, Dartmouth Hitchcock Medical Center and EPA Region 1.

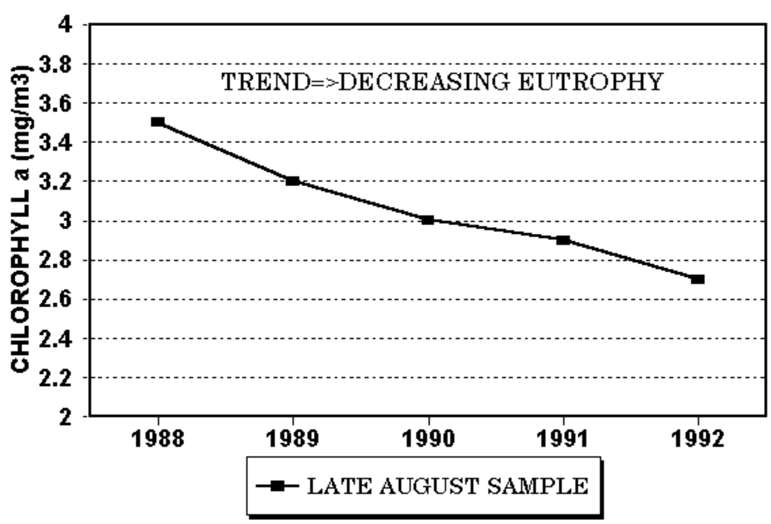
Importance of Long-term Monitoring

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, or 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 are 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.

Sampling frequency and seasonal changes are important to consider when assessing short and long-term water quality results. The Lakes Lay Monitoring Program results have indicated that there is quite a variation in water quality indicators through the open water season (typically April through November) on the majority of the sampled 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. However, this health assessment must be based on several other water quality parameters as well.

Consider the hypothetical data depicted in the "Algal Standing Crop" figure example. 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 term trend of the lake, increasing eutrophication, can only be clearly discerned by frequent sampling over a longer period of time with increased sampling frequency each year. In this instance, the information necessary to distinguish between short-term

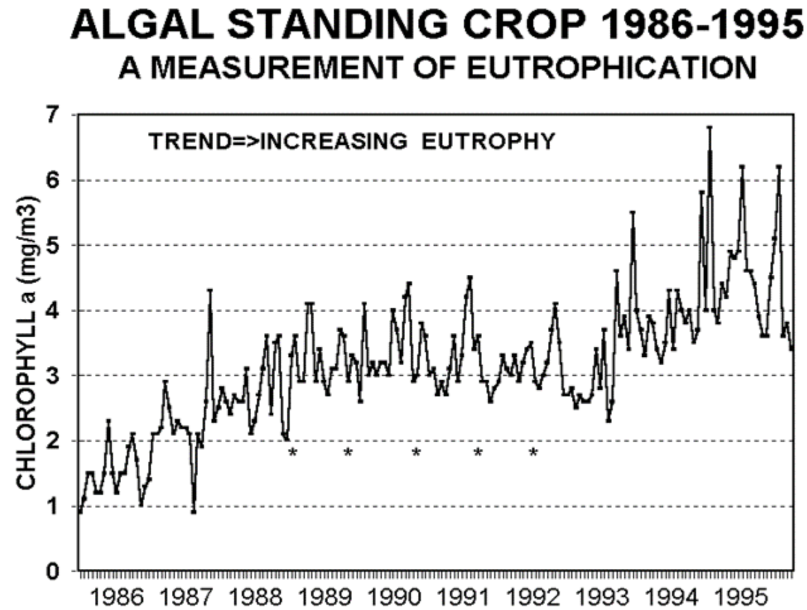
EXAMPLE



Algal Standing Crop measured via Chlorophyll a extractions between 1988 and 1992 from samples collected in late August suggest a trend of decreasing algal abundance and therefore decreasing eutrophy over a five-year period.

fluctuations, the "noise", and long-term trends, the actual "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 determining trends in water quality.

EXAMPLE



Algal Standing Crop measured via Chlorophyll a extractions between 1986 and 1995, with a higher sampling frequency each year, suggests a trend of increasing algal abundance and therefore increasing eutrophy over a nine-year period. The 5 asterisks mark the 1988-1992 data for comparison, suggesting a plateau rather than a decreasing trend during that time frame.

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, predictions of current and future trends can be made with greater confidence. 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. It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the Lakes Lay Monitoring Program. Many times, a monitor must brave inclement weather or heavy boat traffic to collect samples. We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the LLMP the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Effort

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 algal growth and increasing acid precipitation. If you have additional water quality concerns, we advise the lake association to contact our program staff to discuss additional monitoring options. When applicable we also strive to place the recent results into a historical context using past LLMP data as well as historical data from other sources. Sources of data compiled for New Hampshire lakes may include data collected by New Hampshire Department of Environmental Services, New Hampshire Fish and Game (surveys of the 1930's through the 1950's), The New Hampshire Water Supply and Pollution Control Commission and the UNH Center for Freshwater Biology surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to data gaps, methodological differences of the various analytical facilities and technological improvements in testing. This report aims to summarize the water quality findings and long-term trends for this individual lake to capture its historical story related to water quality conditions today.

LLMP OBJECTIVES

- *Lake and Stream Water Quality Monitoring*
- *Volunteer/Citizen/Lay Monitoring Training*
- *Students Trained in Field and Laboratory Practices*
- *Long-term Trends and Assessments of NH Water Quality*
- *Shoreline and Watershed Surveys*
- *Outreach and Education*
- *Community Engagement*

Little Island Pond Water Quality

Historical Records and Long-term Trends

The UNH Lakes Lay Monitoring Program had its first sampling season with Little Island Pond in 2022. However, UNH water quality data collections were also conducted in the late 1980s. Lake sampling has typically been collected from the deep site station (Figures 1 and 2). Preliminary findings from the sampling effort of LIPA and LLMP supported the conditions of a mesotrophic lake. While the lake has relatively clear waters, periodic cyanobacteria blooms have been observed, especially after rain events and towards the end of the summer. Continuous sampling is recommended to understand the seasonal dynamics of the lake and the long-term trends of the water quality parameters. Increased frequency in sampling can help identify patterns and possible sources of eutrophication for the pond. Awareness of the issues may also facilitate changes and best management practices in the watershed.

In 1949, the water clarity (as measured via the Secchi Disk (depth) (SDD) method) of Little Island Pond was noted to be 6.4 m. The LLMP highlights that this measurement can vary seasonally, while it often correlates with productivity (or chlorophyll a) and color. In 2022, average SDD readings were also 6.4 m, ranging from 4.8 to 8.5 m for the season. A survey in 2021 reported a 5 m SDD. The NH Department of Environmental Services (NHDES) measurements were recorded during the 1978, 1992 and 2001 trophic surveys with SDD at 5.5, 5.5, and 3.5 m, respectively (Figures 3-6). The lake was summarized as oligotrophic in these assessments.

On August 28, 1978, dissolved oxygen levels of 3.4 mg/L were measured at the lake bottom of 11.5 meters. On August 26, 2022, dissolved oxygen levels were recorded to be 0 mg/L (ppm). The late summer stratification with anoxic conditions of the hypolimnion are not uncommon, however, should be investigated further to understand the potential internal load of nutrients that could be supportive of algal and cyanobacterial blooms.

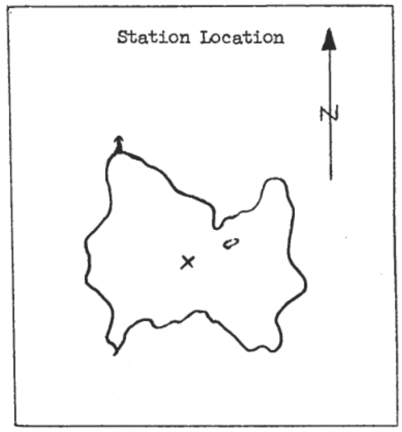
Nutrient concentrations are primarily reported as Total Phosphorus (TP) (ug/L or ppb). In 1978, surface water TP was 5 ppb, while the hypolimnion was slightly higher at 15 ppb. Since 1992, surace water TP has varied between 6 and 12 ppb (Figure 7). Further nutrient sampling was conducted in 2022 and will be discussed in the “2022 Water Quality Summary” section of this report.

1978 Water Quality Results

B. Summer Data:

Date 28 August 1978 Weather Light sprinkle; surface calm; 17.0° C

	Mid-ep	Mid-therm	Mid-hyp
Depth (m)	3.0	6.5	9.0
pH (units)	6.0	6.5	6.7
Alkalinity	6.0	5.0	5.0
PO_4-P	<.001	<.001	<.001
Total-P	.005	.005	.015
NO_2+NO_3-N	<.05	<.05	<.05
Kjeld-N	.28	.28	.25
Total Residue	27	29	32
Color (units)	20	15	20
Turb. (NTU)	4.7	5.0	4.1
Spec. Conduct. (μMhos/cm)	73.7	72.3	71.3
Tot. Org. Carbon	7.0	-	-
Chloride	12	12	11
Mg	.77	-	-
Ca	3.6	-	-
Na	7.1	-	-
K	0.8	-	-
[Mg+Ca] / [Na+K]	.55	-	-
Tot-N/Tot-P	-	-	-
NO_2+NO_3-N/PO_4-P	-	-	-



Bottom: Depth 11.5 m D.O. 3.4 % Sat. 32%

Epilimnetic alkalinity decrease -2.0

PO_4-P ratio: epi/hyp 1.00

Total-P ratio: epi/hyp .33

Secchi disk transparency (M) 5.5

% organic Matter sediment -

Vascular Plants Scattered
Dom. Vasc. Plants: 1. Pontederia
2. Juncus
3.

Ash-Free Dry Weight -
Chlorophyll a 3.18 (mg/m^3)
Tot. Zoopl. Cnts. 350 (cells/liter)
Dom. Phytopl. 1. Anabaena - 35%
2. Coelosphaerium - 20%
Dom. Zoopl. 1. Vorticella - 90%
2.

TROPHIC CLASSIFICATION 1978 :

	D.O.	S.D.	Vasc. Plants	Chl a	Total	Class.
Classification Points:	2	1	1	0	4	Oligo.

Figure 3. The chemical results summary and trophic classification of 1978 water quality data from NHDES for Little Island Pond.
https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Island%20Pond,%20Little,%20Pelham,%20NH,%20Hillsborough%20County%201978.pdf

1992 Water Quality Results

DEPARTMENT of ENVIRONMENTAL SERVICES
Water Supply & Pollution Control Division - Biology Bureau

LAKE TROPHIC DATA

MORPHOMETRIC:

Lake:	ISLAND POND, LITTLE	Lake Area (ha):	62.73
Town:	PELHAM	Maximum depth (m):	15.5
County:	Hillsborough	Mean depth (m):	5.5
River Basin:	Merrimack	Volume (m^3):	3466500
Latitude:	42°43'39" N	Relative depth:	1.7
Longitude:	71°17'21" W	Shore configuration:	1.00
Elevation (ft):	145	Areal water load (m/yr):	2.09
Shore length (m):	2600	Flushing rate (yr^{-1}):	0.40
Watershed area (ha):	284.9	P retention coeff.:	0.80
% watershed ponded:	0.0	Lake type:	natural w/dam

BIOLOGICAL:		24 February 1993	18 August 1992
DOM. PHYTOPLANKTON (% TOTAL)	#1	ASTERIONELLA 95%	MICROCYSTIS 40%
	#2		COELOSPHAERIUM 30%
	#3		BOTRYOCOCCUS 15%
PHYTOPLANKTON ABUNDANCE (cells/mL)			970
CHLOROPHYLL-A (µg/L)			2.92
DOM. ZOOPLANKTON (% TOTAL)	#1	NAUPLIUS LARVA 66%	NAUPLIUS LARVA 74%
	#2	CILIATE SPP. 43%	
	#3		
ROTIFERS/LITER		4	<1
MICROCRUSTACEA/LITER		26	18
ZOOPLANKTON ABUNDANCE (#/L)		35	19
VASCULAR PLANT ABUNDANCE			Sparse
SECCHI DISK TRANSPARENCY (m)			5.5
BOTTOM DISSOLVED OXYGEN (mg/L)		10.8	0.4
BACTERIA (E. coli, #/100 ml)	#1		
	#2		
	#3		

SUMMER THERMAL STRATIFICATION:

stratified

Depth of thermocline (m): 6.8
Hypolimnion volume (m^3) : 306000
Anoxic volume (m^3) : 9500

Figure 4. The NHDES trophic survey of 1992 for Little Island Pond.
https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Island%20Pond,%20Little,%20Pelham,%20NH,%20Hillsborough%20County%201992.pdf

2001 Water Quality Results

DEPARTMENT of ENVIRONMENTAL SERVICES
Water Division - Watershed Management Bureau

LAKE TROPHIC DATA

MORPHOMETRIC:

Lake: ISLAND POND, LITTLE
Town: PELHAM
County: Hillsborough
River Basin: Merrimack
Latitude: 42°43'39" N
Longitude: 71°17'21" W
Elevation (ft): 145
Shore length (m): 2600
Watershed area (ha): 284.9
% watershed ponded: 0.0

Lake Area (ha): 62.73
Maximum depth (m): 15.5
Mean depth (m): 5.2
Volume (m^3): 3248500
Relative depth: 1.7
Shore configuration: 1.00
Areal water load (m/yr): 2.09
Flushing rate (yr^{-1}): 0.40
P retention coeff.: 0.80
Lake type: natural w/dam

BIOLOGICAL:		3 July 2001
DOM. PHYTOPLANKTON (% TOTAL) #1		ANACYSTIS 35%
#2		MALLOMONAS 20%
#3		ANABAENA 10%
PHYTOPLANKTON ABUNDANCE (units/mL)		
CHLOROPHYLL-A (µg/L)		
DOM. ZOOPLANKTON (% TOTAL) #1		COLLOTHECA 34%
#2		NAUPLIUS LARVA 21%
#3		VORTICELLA 19%
ROTIFERS/LITER		69
MICROCRUSTACEA/LITER		46
ZOOPLANKTON ABUNDANCE (#/L)		150
VASCULAR PLANT ABUNDANCE		Scattered
SECCHI DISK TRANSPARENCY (m)		3.5
BOTTOM DISSOLVED OXYGEN (mg/L)		4.8
BACTERIA (E. coli, #/100 ml) #1		
#2		
#3		

SUMMER THERMAL STRATIFICATION:

stratified

Depth of thermocline (m): 6.6
Hypolimnion volume (m^3) : 317500
Anoxic volume (m^3) : None

Figure 5. The NHDES trophic survey of 2001 for Little Island Pond.
https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Island%20Pond,%20Little,%20Pelham,%20NH,%20Hillsborough%20County%202001.pdf

Long-term water quality data

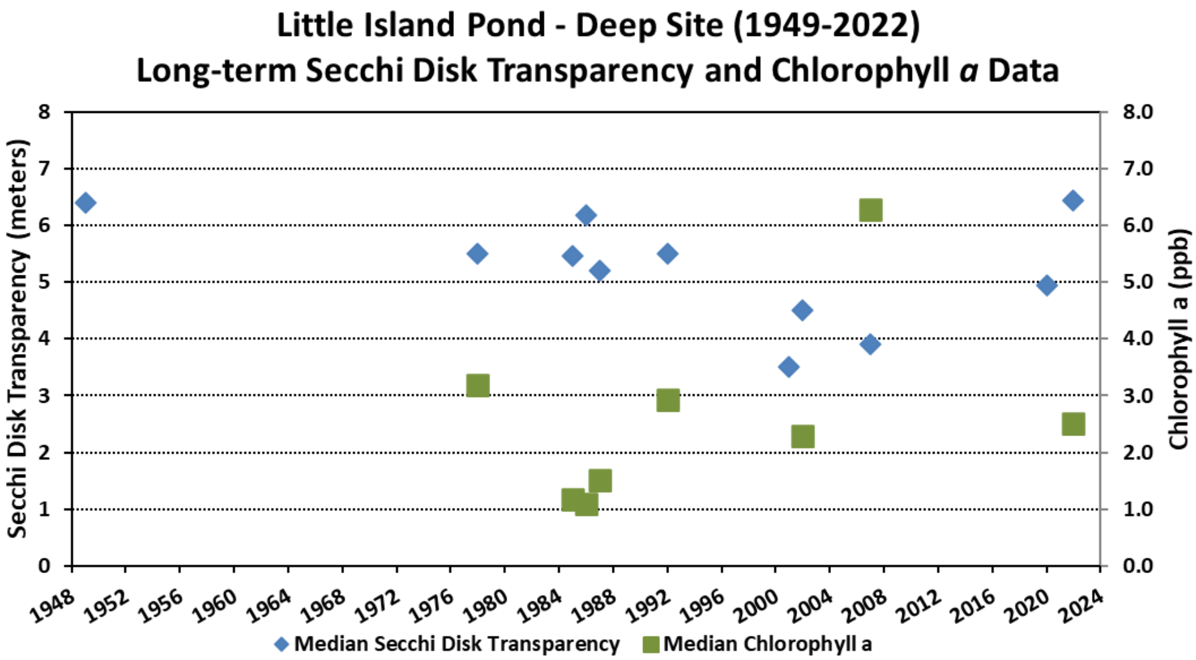


Figure 6. Historical data collection on water clarity (SDD in blue diamonds) and chlorophyll (green squares) for Little Island Pond (1949-2022).

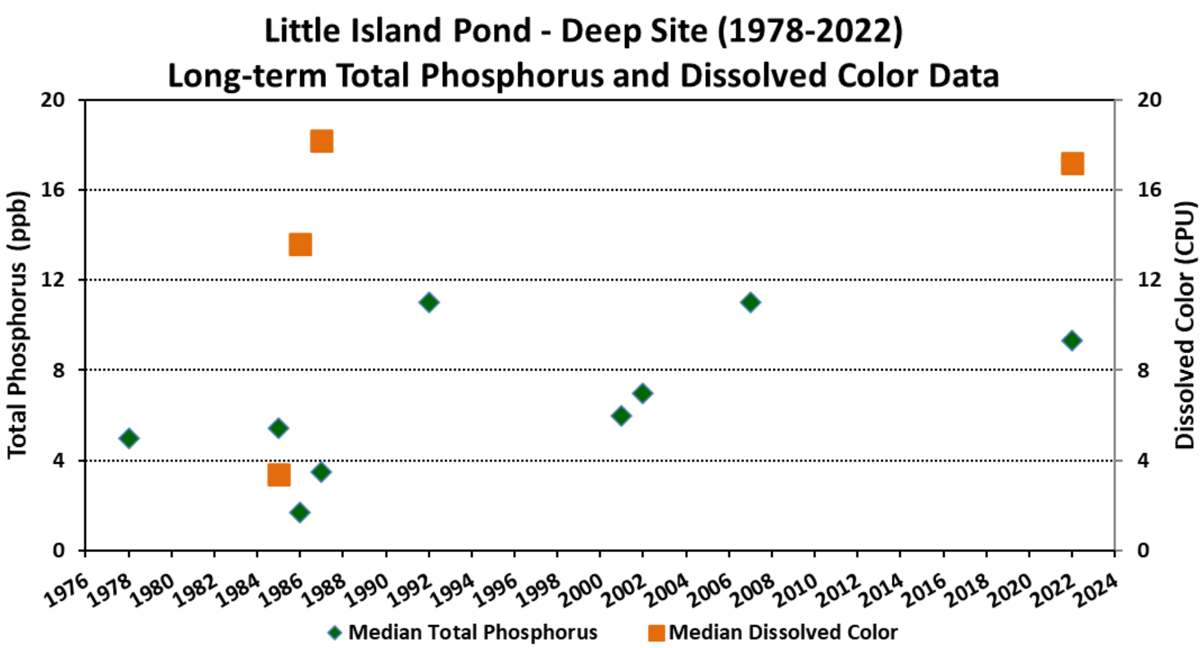
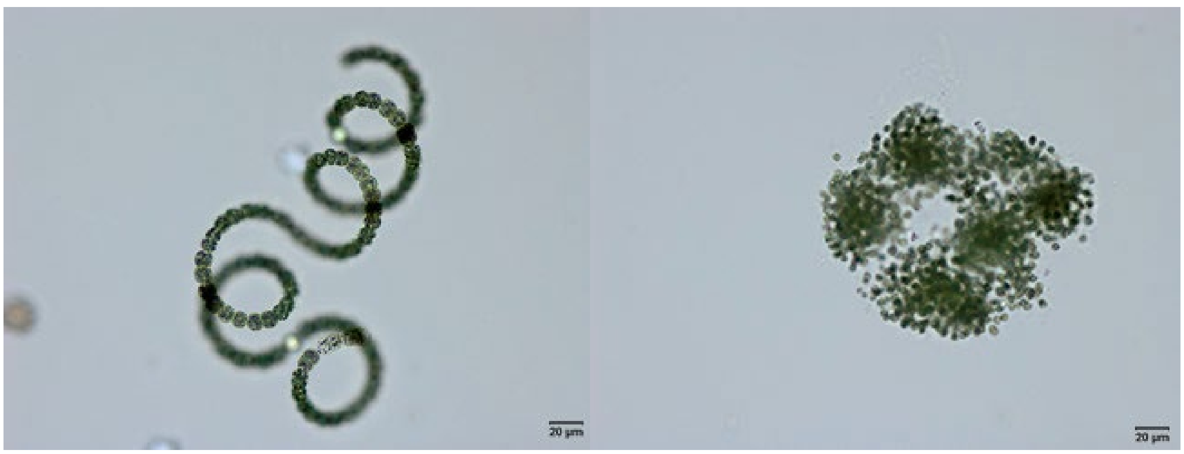


Figure 7. Median color (orange squares) and phosphorus (green diamonds) values for Little Island Pond (1978 – 2022).

Cyanobacteria Advisories/Observations

Noteworthy results from past surveys included a dominant population of "blue-green algae"; *Anabaena* and *Ceolosphaerium* in 1978. These names are now synonymous with cyanobacteria (formerly blue-green algae) *Dolichospermum* (formerly *Anabaena*) and *Woronichinia* (often confused with *Ceolosphaerium*). Again in 1992 and 2001, cyanobacteria taxa including *Anabaena*, *Microcystis*, *Anacystis* and *Ceolosphaerium* were noted. According to the NHDES advisory record, Little Island Pond has been under a cyanobacteria advisory in recent years; 2016, 2017 and 2022. Advisories have been due to elevated levels of *Dolichospermum* (*Anabaena*) and *Microcystis* (Table 2, Figures 8 & 9).



Figures 8-9. Cyanobacteria colonies of *Dolichospermum* (formerly *Anabaena*) (left) and *Microcystis* (right). http://cfb.unh.edu/CyanoKey/indexCyanoQuickGuide.html

Table 2. Advisories issued for Little Island Pond due to cyanobacteria exceedances.

Advisories are issued when cyanobacterial cell concentrations exceed 70,000 cells/mL or more than 50% of the sample is cyanobacteria

Date Advisory Issued	*Dominant Taxa*	Total Cell Count (cells/mL)	Number of Advisory Days
8/5/2016	*Anabaena*	542,392	5
7/31/2017	*Anabaena/Dolichospermum*	7,000,000	7
9/8/2022	*Microcystis, Dolichospermum*	435,800	14

Other Advisories/Observations

NHDES's lake info mapper lists observations of mercury in fish and the presence of invasive bivales, the Asian Clam and the Chinese Mystery Snail. Invasive and nuisance species can be detrimental to native aquatic life. Checking boats, rinsing and being diliget are recommened to slow the spread of such species. For more information, please visit:
https://nhdes.maps.arcgis.com/apps/webappviewer/index.html?id=1f45dc20877b4b959239b8a4a60ef540

Mercury in Fish (2003-current)

Table 3. There is a statewide advisory for mercury in fish tissue for New Hampshire. Little Island fish samples (Largemouth Bass (LMB)) were analysed in 2003, containing ~ 0.57 mg Hg/ kg tissue.

Year Collected	Common Name	*Scientific Name*	Length (cm)	Weight (g)	Hg (mg Hg/ kg tissue)
2003	Largemouth bass	*Micropterus salmoides*	34.3	525	0.569
2003	Largemouth bass	*Micropterus salmoides*	35.2	591	0.58

Note: Raw Hg values are presented. 1 foot = ~30.5 cm. 1 oz = ~28 g.

Asian Clam (2017-current)

Figure 10. According to NHDES, Asian Clam have been noted in the pond as of 2017. To learn more about these invasive species, please visit; https://yates.cce.cornell.edu/environment/invasive-species/aquatic-invasives/asian-clam

Chinese Mystery Snail (2022- current)

Figure 11. According to NHDES, Chinese Mystery Snails have been noted in the pond as of 2022. LIPA notes seeing it earlier. To learn more about these invasive species, please visit; https://yates.cce.cornell.edu/environment/invasive-species/aquatic-invasives/chinese-mystery-snail

CFB Site Visit - Summary

The UNH LLMP samples lakes with volunteers across the State of New Hampshire. A “CFB Site Visit” occurs when our team comes to the lake with supplemental resources for profiling and sampling the lake water. These profiles and extra sampling efforts can reveal more detail about what is going on within the water column. Depending on the goals for water quality sampling, the CFB Site Visit can also be an opportune time to collect additional water samples for nutrient analyses, biological/microscopic identifications, and/or parameters that can be recorded with meters and dataloggers by the CFB staff. A CFB Site Visit was conducted on August 26, 2022 at Little Island Pond.

Temperature, dissolved oxygen and pH profiles in 2022

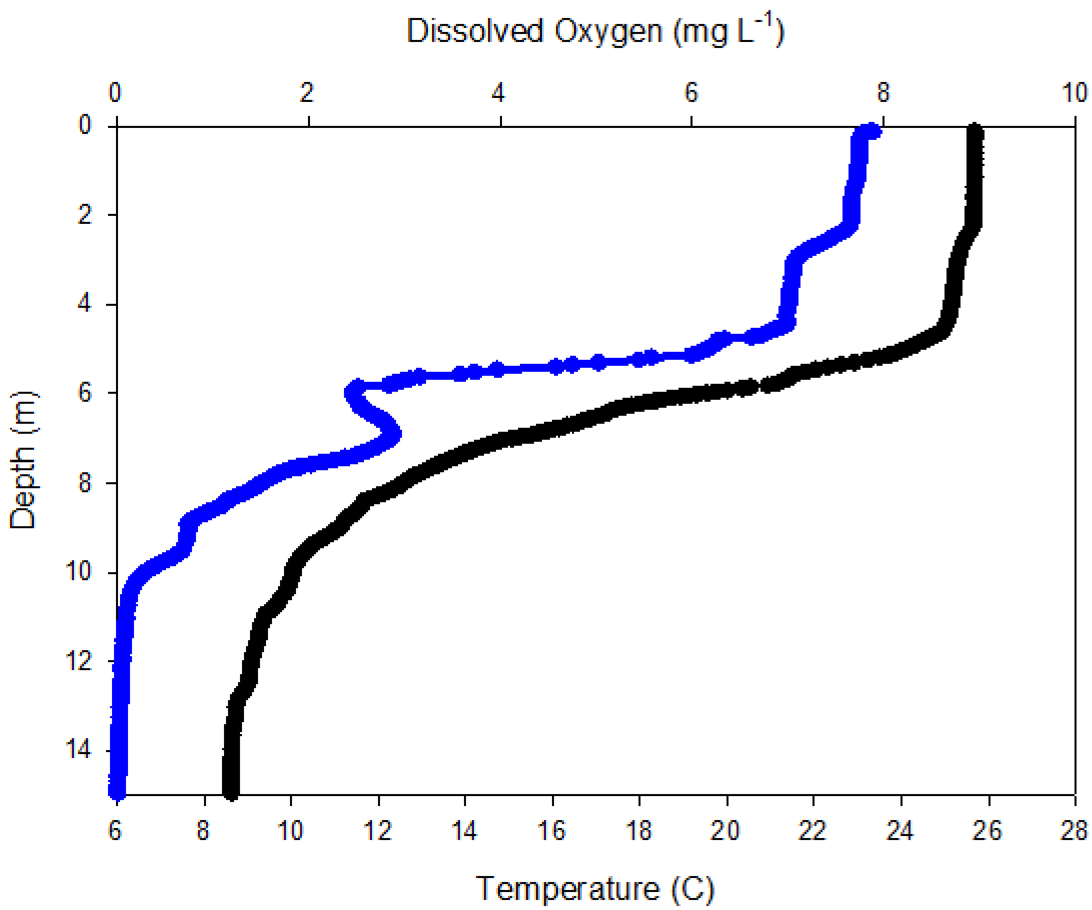


Figure 12. Late summer stratification was strong in August. The epilimnion (~0-5 m), the metalimnion (~5-10 m) and the hypolimnion (~10-15 m) were clearly defined on August 26. An oxygen profile was collected in tandem with temperature, revealing a metalimnetic pulse in oxygen that is indicative of productivity at around 7 m. The hypolimnion was anoxic during this time.

Temperature profile - Temperature profile (collected by the CFB team and volunteer monitors) indicate Little Island Pond became stratified into three distinct thermal layers during the summer months; a warm upper water layer, the **epilimnion**, overlaid a deep cold-water layer known as the **hypolimnion**. The two layers were separated by a layer of rapidly decreasing temperatures known as the **metalimnion**. During the August 26th survey, surface waters were about 25 C, while bottom waters were 8-10 C (Figure 12).

Dissolved oxygen profile - 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. During the August 26th survey, surface waters were well oxygenated, while bottom waters were anoxic below 10 m. An oxygen pulse was observed around 7 meters, which is often indicative of metalimnetic algal growth (Figure 12).

Lake acidity (measured as pH) - The Little Island Pond pH data averaged 6.9 units in 2022. Results in the surface waters are within the tolerable range for most aquatic organisms (Figure 13). These pH values are notably higher in recent years, as NHDES listed this pond on the acid-impaired lakes list in 2007.

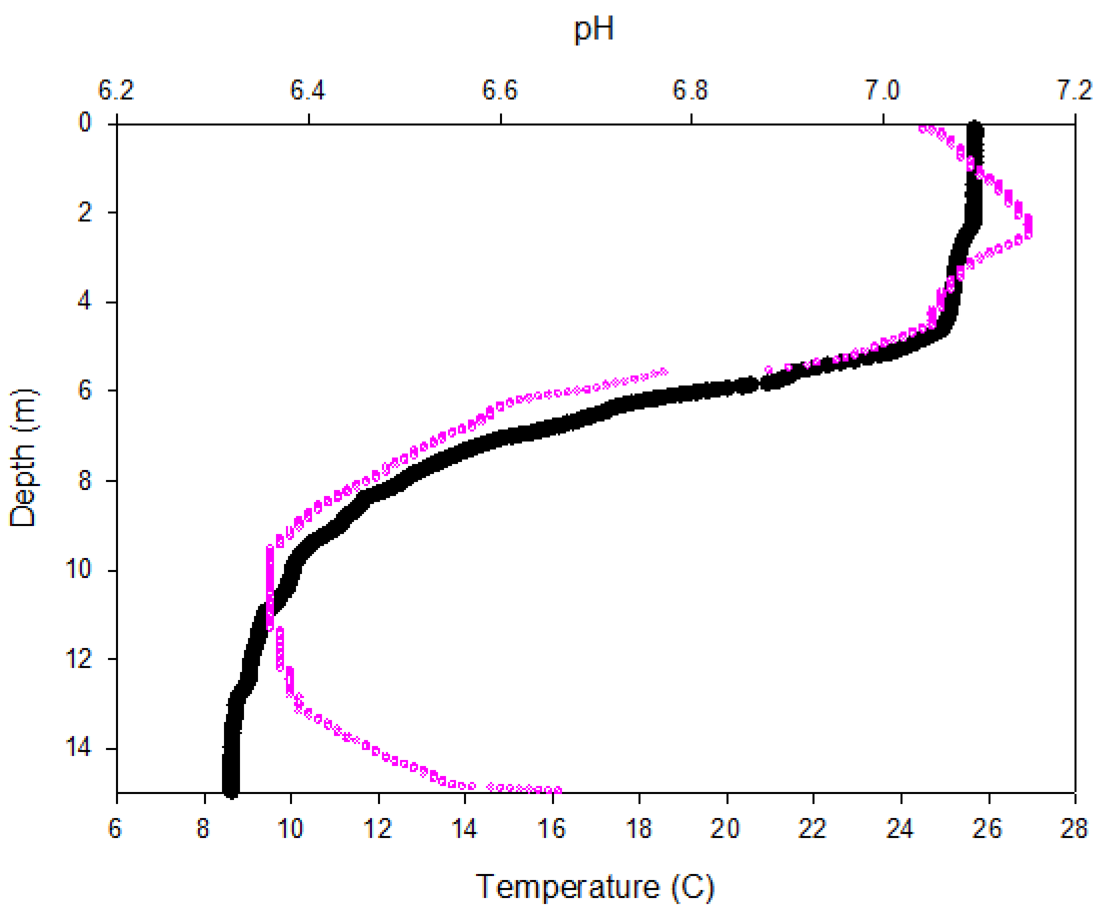


Figure 13. During the August 26th survey, surface waters ranged between 7 and 7.2, and a steady decline was observed throughout the metalimnion. The slight increase in pH in the bottom waters could be indicative of benthic cyanobacteria in this pond.

Specific conductance in 2022

Dissolved salts: measured as specific conductivity – Specific Conductivity levels were documented in the Little Island Pond water column. Measured by staff during a CFB Site Visit, conductivity values ranged from ~200-215 micro-Siemans (µS) per centimeter (cm) at the deep site in recent years. It is also noteworthy that conductivity was recorded as 70-80 µS/cm in 1992. Higher specific conductivity values can be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications, and sedimentation contribute “excessive” nutrients that make their way into the lake. These measurements may also be correlated to chloride levels. High specific conductivity values can also be associated with excessive road salt applications within the Little Island Pond watershed.

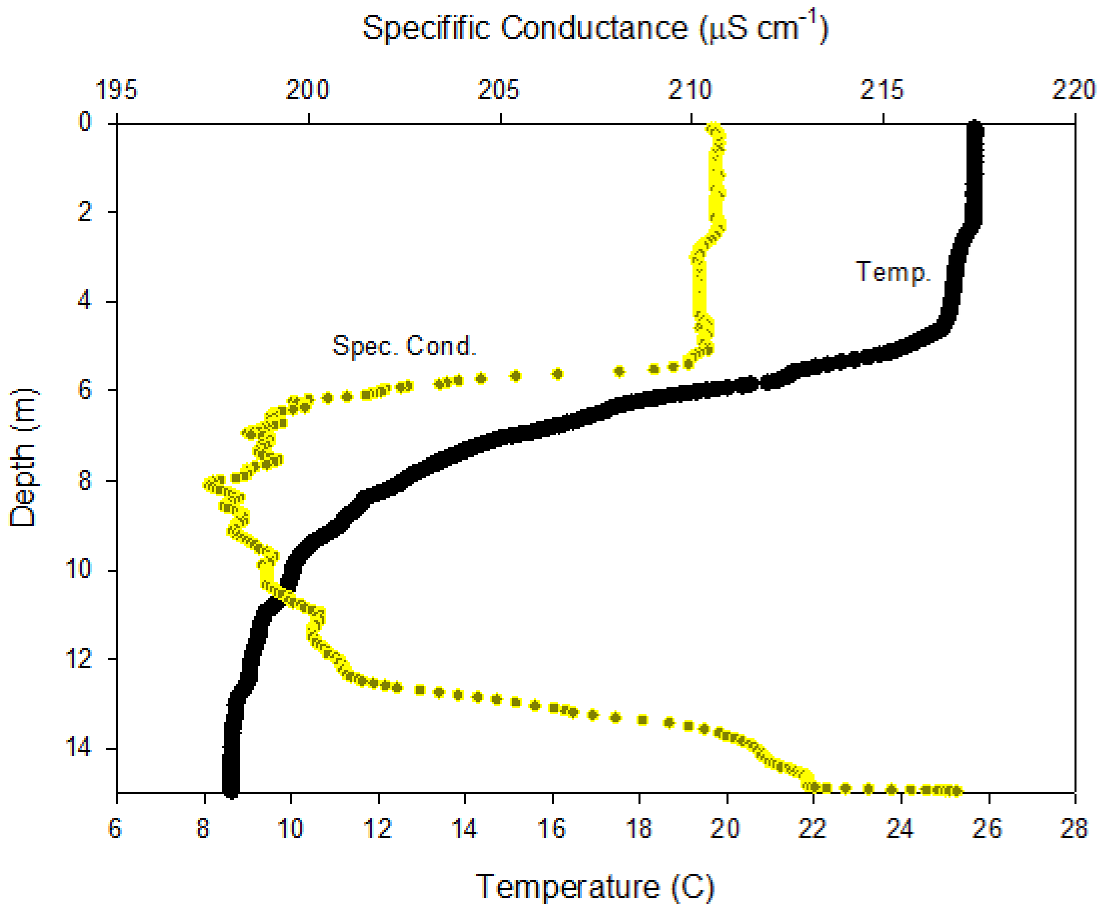


Figure 14. Specific Conductivity levels were documented on August 26, 2022, from the Little Island Pond water column. Levels ranged from ~ 200 to 215 µS cm^{-1}. Earlier trophic survey findings from the 1970’s and 1990’s were recorded as ~ 70-80 µS cm^{-1}.

Turbidity, chlorophyll and phycocyanin fluorescence in 2022

In 2022, vertical profiles revealed the distribution of phytoplankton using the fluorescence of pigments including chlorophyll *a* and phycocyanin. These quick measurements are a different approach than chlorophyll extractions from filters and should not be directly compared to the chlorophyll results presented in Table 4. This in vivo device identifies fine differences within the water column to help characterize the distribution of total algal/cyanobacterial abundances. During the August 26 survey, surface water observations resulted in relatively low levels of pigments associated with productivity. Chlorophyll, turbidity and dissolved oxygen, between 6 and 8 meters, correlate indicating a metalimnetic population of photosynthetic growth. This layer could support cyanobacteria populations that may rise to the surface under calm conditions. However, phycocyanin values were non-detectable in the surface waters, suggesting there was not a strong cyanobacteria presence in the water column on August 26, 2022. Fluorescence signals in the hypolimnion could represent algal growth at the lake bottom where plenty of sun may reach as Secchi disk depths were nearly 7.5 meters during this time. Phycocyanin increases at the bottom, indicative of benthic mats or cyanobacteria settling. A noteworthy spike in turbidity was observed between 12 and 14 meters. This does not correlate with algal pigments but could be related to the increased specific conductance at this depth (Figure 15).

Cyanobacteria pigments

Cyanobacteria are a growing concern worldwide and LLMP recognizes the need to monitor these organisms due to their toxic properties and aesthetically displeasing nature. Blooms are the rapid growth of algae and cyanobacteria, however not all waterbodies will experience a visible bloom. The cyanobacteria often live throughout the water column as microscopic colonies. As they rise to the surface, they accumulate to a visual surface scum. Not all lakes will have an obvious population of cyanobacteria, however most lakes do harbor at least some type and abundance of cyanobacteria. Little Island Pond samples indicate some signal of pigments for cyanobacteria in 2022 (Figure 15). A significant correlation between chlorophyll and phycocyanin is also suggestive of a cyanobacteria dominant population (Figure 16). While some colonies were observed in the water column on August 26, very little phycocyanin was measured until reaching the hypolimnion. An advisory was later issued by NHDES on September 8, 2022 for elevated concentrations of *Microcystis* and *Dolichospermum*.

These naturally occurring cyanobacteria are an integral part of lake ecosystems. However, when their growth is prolific, they can be a nuisance to humans and wildlife. The LLMP is working with our CFB partners to understand the use of cyanobacterial pigments to help us monitor their abundance and, possibly, toxicity. A variety of devices and tools are commercially available for measuring the pigments associated with cyanobacteria, such as phycocyanin and chlorophyll. The LLMP continues to follow the evolving methods and findings in collaboration with our CFB partners.

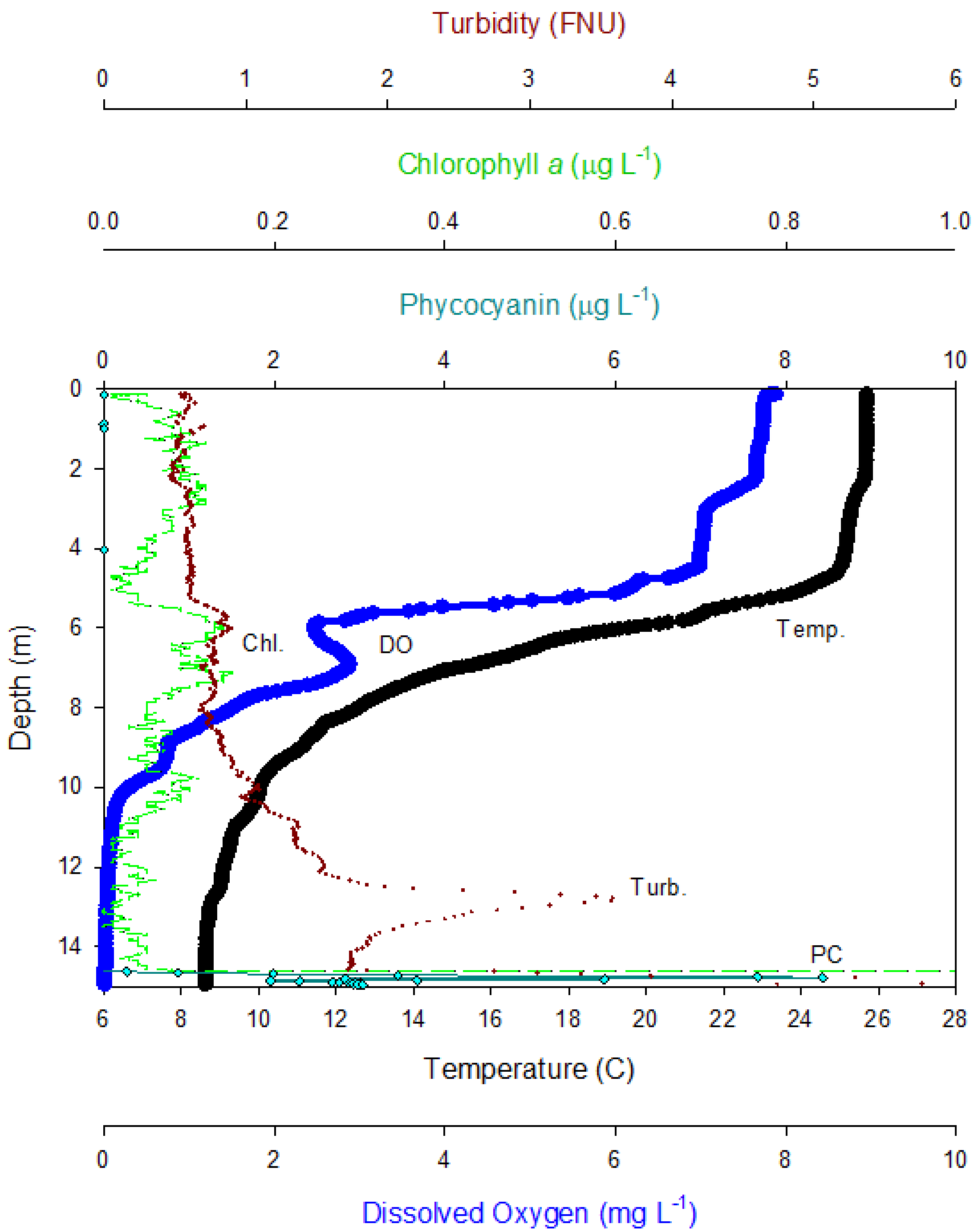


Figure 15. A variation in algal and cyanobacterial pigment abundance (µg/L or ppb) was observed in 2022. A microscopic assessment of which type of cyanobacteria are dominant would be interesting to correlate with such pigments in the future. The correlation between phycocyanin and chlorophyll fluorescence suggests a dominance of cyanobacteria present at the time of sample.

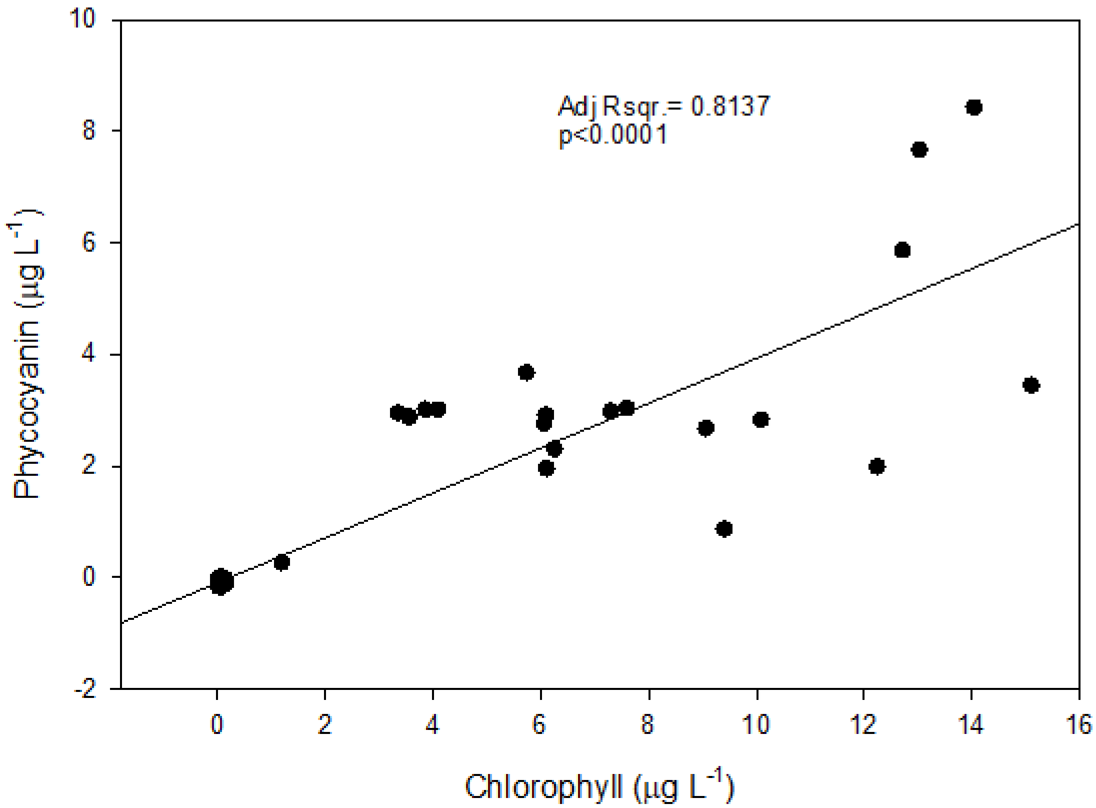


Figure 16. Surface water and the majority of the water column contained little to no presence of phycocyanin. However, a bottom layer of these pigments hovered over the sediment-water interface. The correlation of phycocyanin and chlorophyll supports that the photosynthetic activity at the lake bottom is likely cyanobacteria.

Little Island Pond
2022 Water Quality Summary

Water quality data were collected by the Little Island Pond Association and volunteer monitors between May 14 and October 2, 2022. Sampling was mainly conducted at the "Deep Site Station". The 2022 Little Island Pond seasonal water transparency ranged between 4.8 and 8.5 meters with an average measure of 6.4 meters (Table 4, Figures 17 & 18). Extracted chlorophyll values varied over time, averaging 2.5 ppb over the season, with a peak of 3.4 ppb occurring at the end of May and June (Table 4, Figures 17 & 18). Total phosphorus (nutrient) concentrations ranged from 6.8 to 12.8 ppb and averaged 9.3 ppb for the season. These water quality parameters generally reflected the conditions considered typical of a mesotrophic New Hampshire Lake (Table 4).

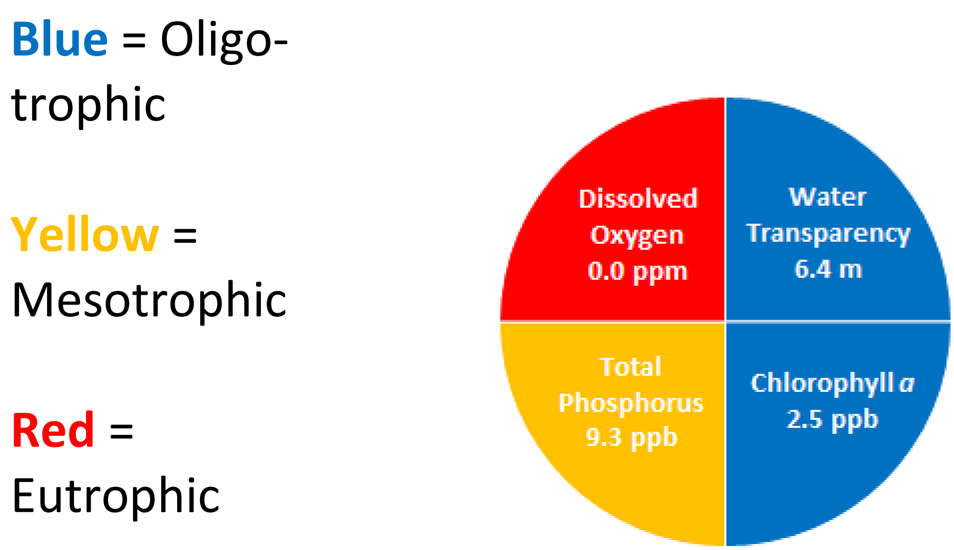


Figure 17. The annual summary of major parameters included water transparency, chlorophyll a, and total phosphorus for Little Island Pond in 2022. *Dissolved Oxygen data are highlighted from the hypolimnion, collected on August 26.

Table 4: 2022 Little Island Pond Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Excellent"	Mesotrophic "Fair"	Eutrophic "Poor"	Little Island Pond Average (range)	Little Island Pond Classification
Water Clarity (meters)	4.0 – 7.0	2.5 - 4.0	< 2.5	**6.4** meters (4.8 – 8.5)	**Oligotrophic**
Chlorophyll *a* [1] (ppb)	< 3.3	> 3.3 – 5.0	> 5.0 – 11.0	**2.5** ppb (2.0 – 3.4)	**Oligotrophic**
Total Phosphorus [1] (ppb)	< 8.0	> 8.0 – 12.0	> 12.0 – 28.0	**9.3** ppb (6.8 – 12.8)	**Mesotrophic**
Dissolved Oxygen (ppm)	5.0 – 7.0	2.0 – 5.0	<2.0	**0.0** ppm (0.0 – 0.1) *	**Eutrophic**

*Dissolved oxygen concentrations were measured between 10.0 and 15.0 meters, in the bottom water layer, on August 26, 2022.

Water Clarity (Secchi Disk transparency)

The 2022 Little Island Pond water clarity values were deeper than 4 meters throughout the sampling season (Figure 18). This range of transparency values is characteristic of an oligotrophic system (Table 4). It is important to note that the size of particles in the water are related to transparency. Large colonies of phytoplankton and cyanobacteria are less obstructive than small colonies that create more turbid conditions. The SDD reached 7.5 m on August 26th. This coincides with an increase in chlorophyll turbidity and oxygen. While surface waters may be clear, deeper populations of phytoplankton and cyanobacteria may be looming.

Microscopic plant abundance "greenness" (chlorophyll *a*)

The 2022 Little Island Pond seasonal chlorophyll *a* measurements consistently remained below the threshold of 3.3 parts per billion (ppb); that is considered the boundary between a nutrient poor and more nutrient enriched "greener" lake. On May 29 and June 26, levels peaked at 3.4 ppb, with very little effect on the water transparency during those times (Figure 18). These chlorophyll values are characteristic of an oligotrophic system (Table 4).

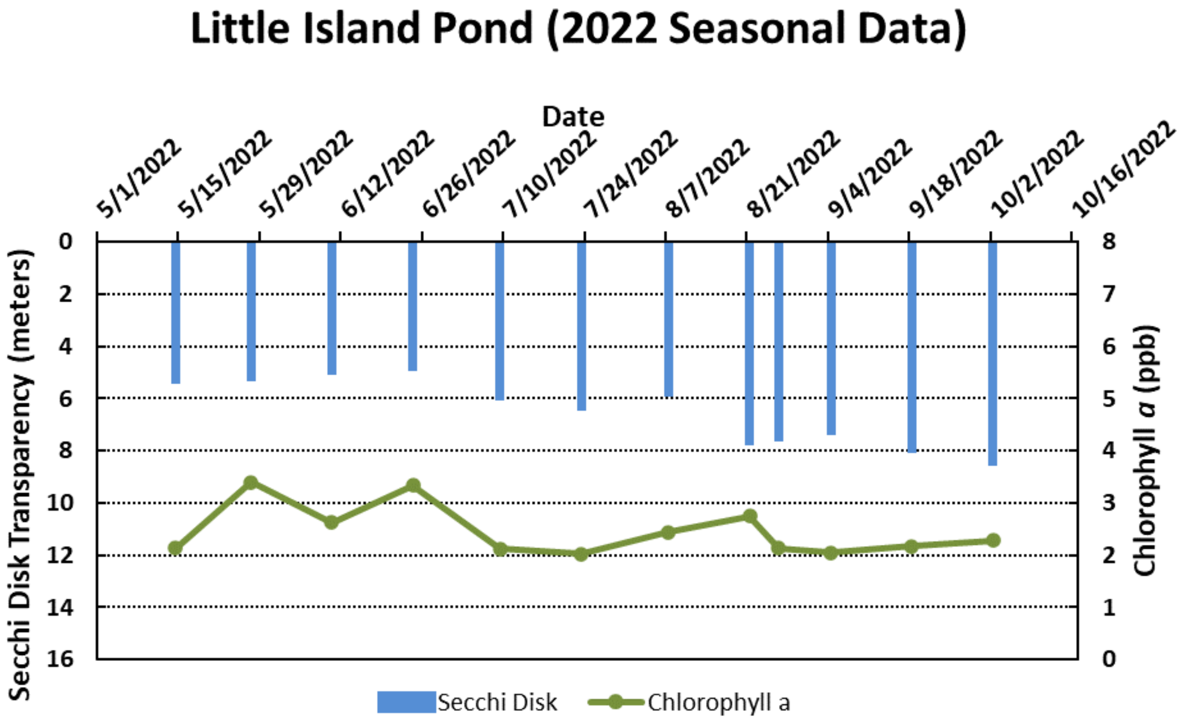


Figure 18. Secchi disk depth and chlorophyll values for each sample date in 2022.

Colored Dissolved Organic Matter (background (dissolved) water color, often perceived as "tea colored" in more highly stained lakes

Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a byproduct of microbial decomposition of soils and plants) (Table 5). Small increases in water color from the natural breakdown of soils and plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Additionally, recent studies have shifted focus to "lake browning", a condition also related to humic-stained lakes. Browning may contribute to increased surface water temperatures, which may increase with climate change.

The 2022 Little Island Pond seasonal average dissolved color concentration measured 17.2 chloroplatinate units (CPU) and fell within the classification of a "slightly tea colored" lake (Tables 5 and 6). The color peaked on May 15 and August 21 at around 26 CPU (Figure 19). Noticeable increases in color may follow rain events. Paying attention to these events may also help identify sources of external nutrients to the pond.

Table 5. 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

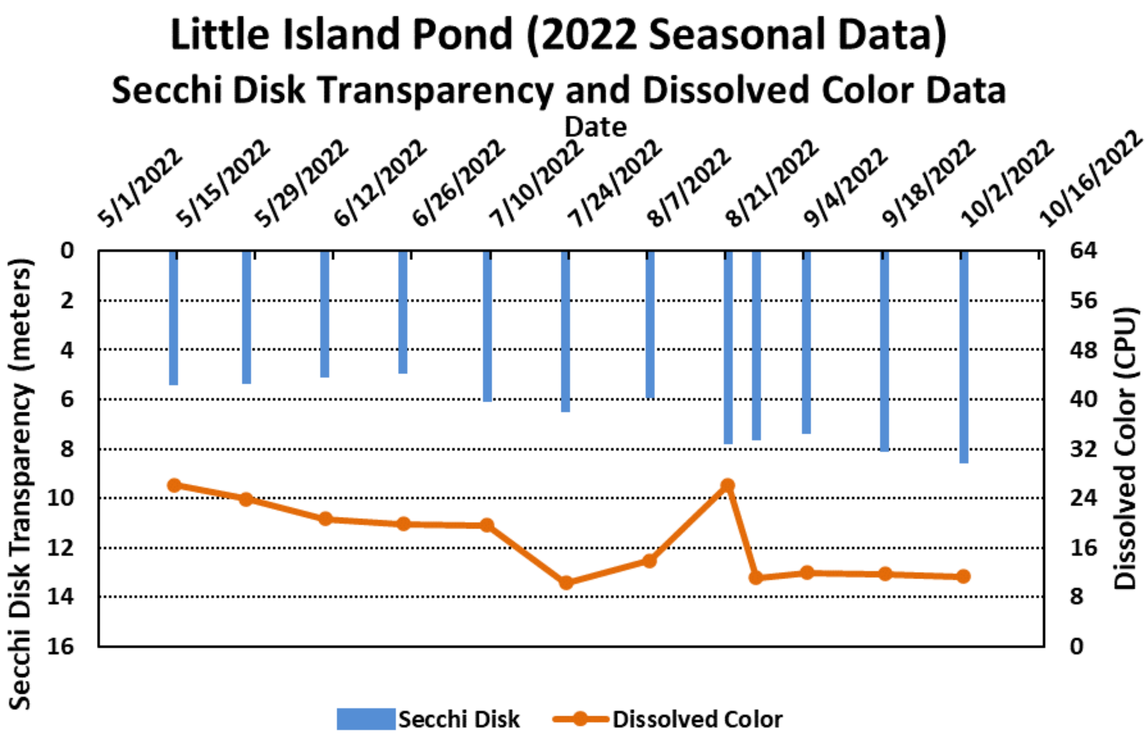


Figure 19. Secchi disk depth and color values for each sample date in 2022.

Resistance against acid precipitation (total alkalinity)

The 2022 Little Island Pond alkalinity of 13.6 milligrams per liter (mg/l) is characteristic of lakes with low vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Tables 6 and 7). Generally speaking, the geology of the region does not contain the mineral content (e.g. limestone) that increases the buffering capacity in our surface waters. Thus, many NH lakes in the vicinity have naturally low alkalinities. While low, the 2022 Little Island Pond alkalinity remained sufficient to neutralize acid inputs and to avoid large pH reductions (i.e. more acidic water) that are stressful to aquatic organisms.

Table 6. Color and Alkalinity Assessment Criteria for New Hampshire.

Parameter	Assessment Criteria					Little Island Pond Average (range)	Little Island Pond Classification
Color (color units)	**< 10 uncolored**	**10 – 20 slightly colored**	**20 – 40 lightly tea colored**	**40 – 80 tea colored**	**> 80 highly colored**	**17.2** color units (range: 10.3 – 26.1)	**Slightly tea colored**
Alkalinity (ppm)	**< 0.0 acidified**	**0.1 – 2.0 extremely vulnerable**	**2.1 – 10 moderately vulnerable**	**10.1 – 25.0 low vulnerability**	**> 25.0 not vulnerable**	**13.6** ppm (range: 13.0 – 14.2)	**Low vulnerability**
pH (std units)	**< 5.5 suboptimal for successful growth and reproduction**		**6.5 – 9.0 optimal range for fish growth and reproduction**			**6.9** standard units (single value)	**Optimal range for fish growth and reproduction**
Specific Conductivity (*u*S/cm)	**< 50 *u*S/cm Characteristic of minimally impacted NH lakes**		**50-100 *u*S/cm Lakes with some human influence**	**> 100 *u*S/cm Characteristic of lakes experiencing human disturbances**		**204.1** *u*S/cm (single value)	**Characteristic of lakes experiencing human disturbance**

Table 7. 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

Total Phosphorus: the nutrient considered most responsible for elevated microscopic algal and cyanobacterial growth in New Hampshire Lakes

Total phosphorus samples, were collected May 14 to October 2, 2022, ranging from 6.8 to 12.8 parts per billion (ppb) or microgram/L (ug/L), averaging 9.3 ppb, a level associated with a mesotrophic lake status in New Hampshire. On August 26, 2022, water samples were collected from the epilimnion, mid-epilimnion, mid-metalimnion, and from the hypolimnion. The surface water TP was compared to the bottom water TP to identify nutrient distribution in the pond. As noted, the water was heavily stratified during this CFB Site Visit. While surface water TP did not exceed 12.8 ppb, deeper water of the metalimnion increased the range to 14.6 ppb. The hypolimnion resulted in 34.2 ppb (Figure 20). This bottom water zone also had some evidence for increased cyanobacteria activity and anoxia. These results could be indicative of cyanobacteria falling to the benthos and decomposing, reducing oxygen and increasing nutrients.

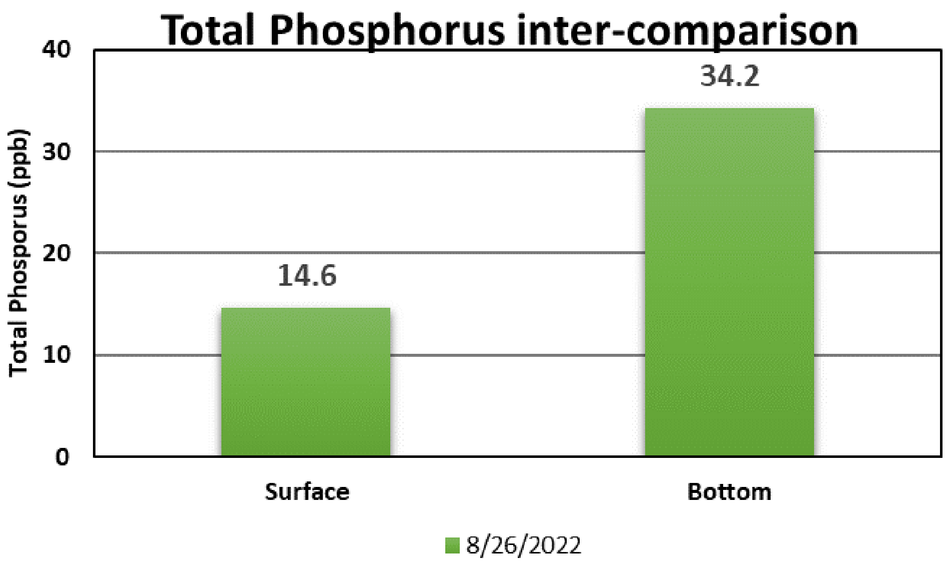


Figure 20. Comparison of Total Phosphorus values in the water column of Little Island Pond on August 26, 2022. Bottom water TP was more than double the TP values of the surface waters. Low DO and high TP of the hyoplimnion may suggest internal nutrient loading, which should be further investigated.

2022 Precipitation & Temperature Overview

Based on measurements collected at the Lakeport 2 Climatological sampling station located in Laconia, New Hampshire: 43.5491°N and -71.4646°W

Precipitation (2022)

The 2022 annual precipitation (reported as "rainfall" water equivalent) measured 49.42 inches and was approximately four inches above the 44 year (1979-2022) average of 44.21 inches. Following below average January precipitation, the 2022 monthly precipitation totals were above average during the months of February, March and April. Unusually dry conditions persisted during the months of May and June while July through September exhibited above average precipitation. Significantly below average precipitation characterized October followed by near normal November precipitation and significantly above average December precipitation to end the year (Figures 21 & 22).

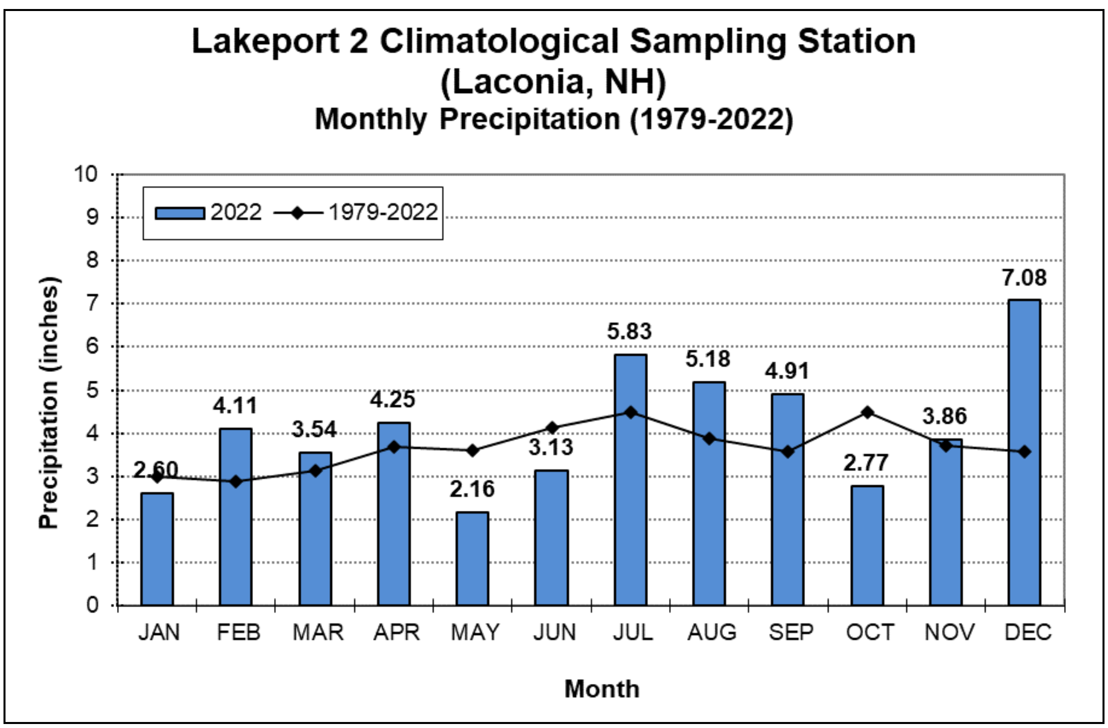


Figure 21. Monthly precipitation in 2022 compared to the overall average monthly precipitation between 1979 and 2022.

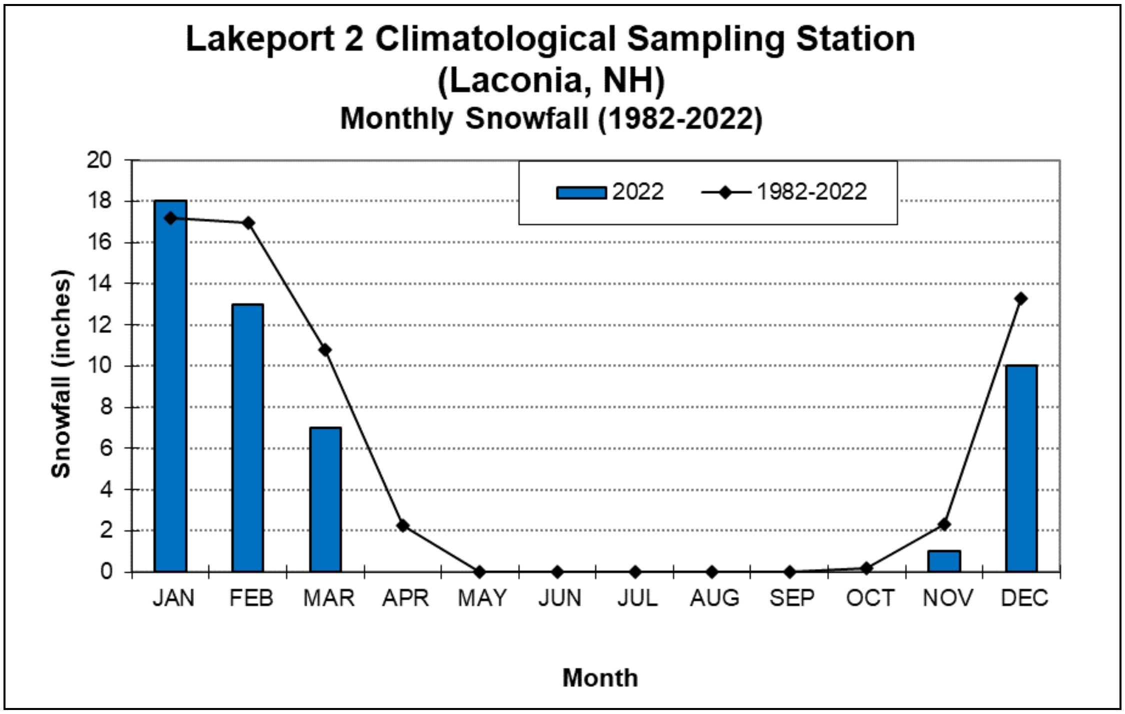


Figure 22. Monthly snowfall in 2022 compared to the overall average monthly snowfall between 1979 and 2022.

Snowfall and Snowpack (2022)

The 2022 snowfall was below average for the year and, with the exception of January, the 2022 monthly snowfall totals, during the colder months, were consistently below average. Sustained near/sub-zero weather in January through early February resulted in sustained snowpack accumulations of 8 inches and greater for most of that period (Figures 23 & 24). A rapid melt occurred in late February, when the snowpack disappeared, while a couple of late February snowfall events restored a blanket of snowpack that melted away by mid-March, as daytime temperatures neared/exceeded 50°F.

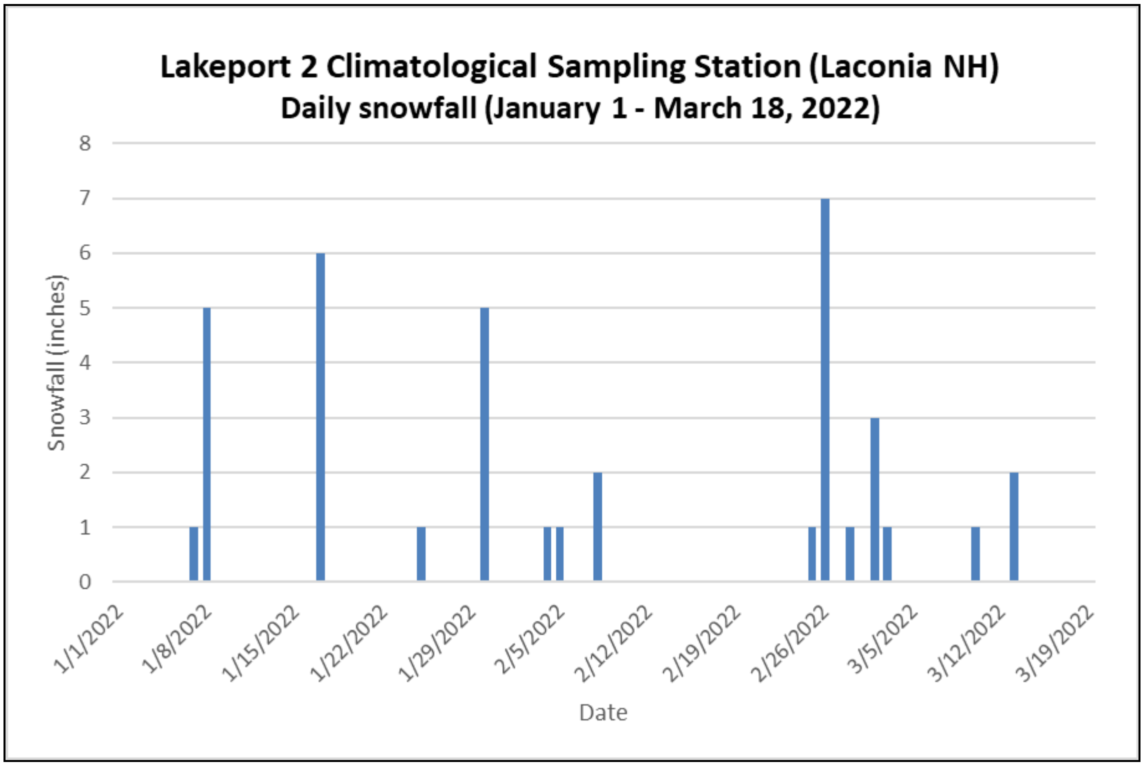


Figure 23. Daily snowfall in 2022.

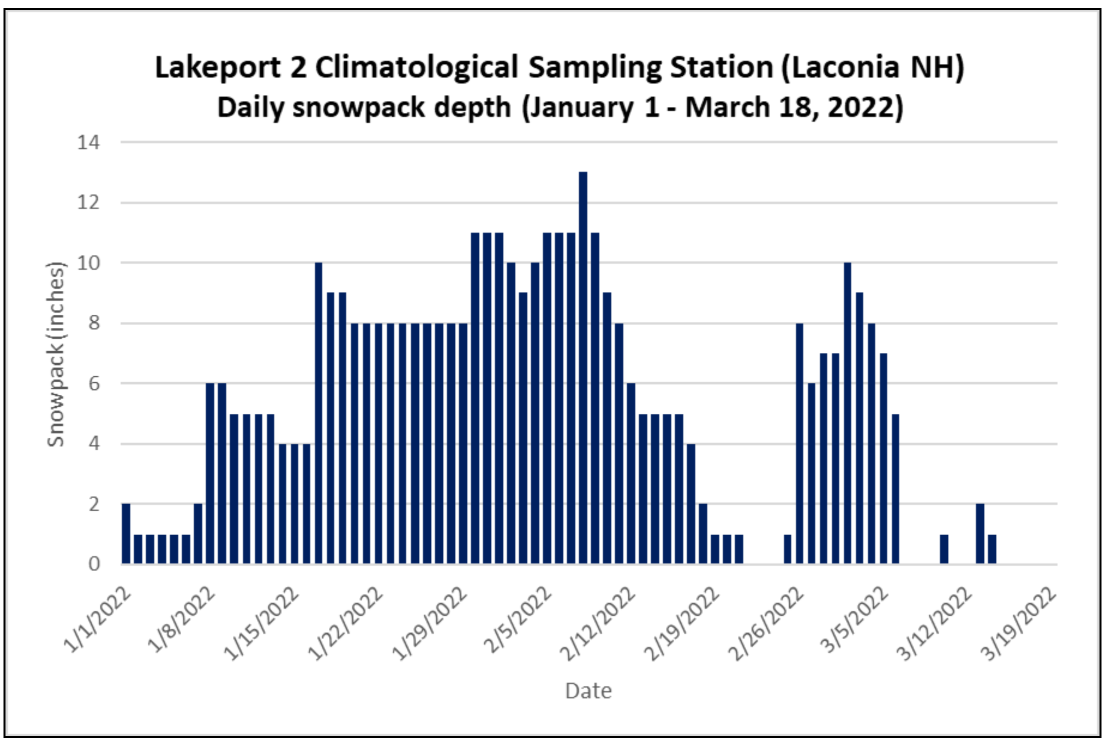


Figure 24. Daily snowpack depth in 2022.

Temperature (2022)

The 2022 temperature ranges began with below average temperature for the month of January. However, the remainder of the year was characterized by near to above average monthly temperatures that were most pronounced during the months of May, August and November. An above average February temperature limited spring snowpack accumulation while unusually warm weather in July and August contributed to a warm summer (Figures 25 & 26).

Note: longer-term weather patterns, such as drought conditions, that characterized much of New Hampshire between 2020 and 2022, were not considered in this Precipitation and Temperature Overview section but may have implications on water movement (e.g. overland runoff and groundwater recharge).

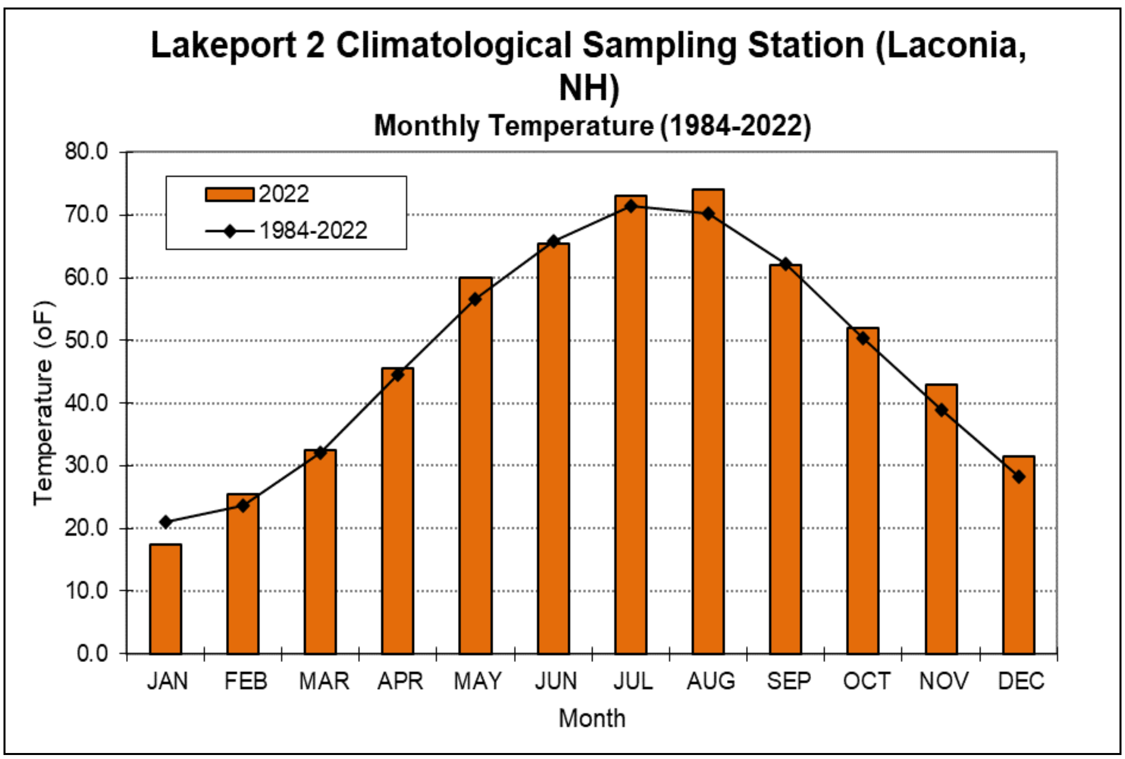


Figure 25. Monthly temperatures in 2022 compared to the overall average monthly temperatures between 1984 and 2022.

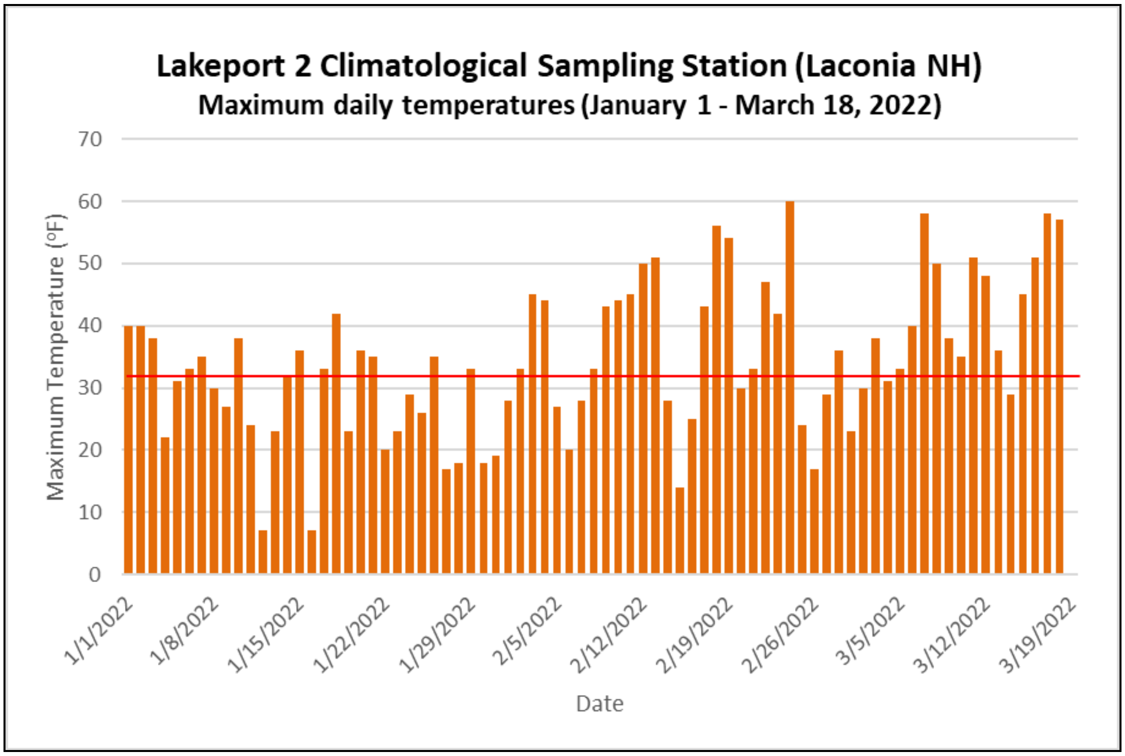


Figure 26. Maximum daily temperatures in winter of 2022.

Water Quality Implications:

- **Total Phosphorus** – Phosphorus is oftentimes flushed into lakes and ponds during, or immediately following, heavy rainfall periods. Dry periods, on the other hand, oftentimes limit the amount of phosphorus that enters lakes through channelized (e.g. streams and drainage culverts) and sheet flow, that flows in a thin layer over the ground, runoff. The unusually dry spring favored low phosphorus concentrations in many of our New Hampshire lakes while the atypically wet July rainfall events were associated with short-term phosphorus pulses. *Note: localized, and unusually intense, short-term rainfall events during the 2022 were also associated with short-term washout/nutrient loading events. Such events can be associated with unusually high total phosphorus and particulate (reflected in Secchi Disk transparency and turbidity measurements).*

- **Secchi Disk Transparency** – Water transparency (measured with the Secchi Disk) can be heavily impacted by the amount of algal growth (measured as chlorophyll a concentrations), the amount of suspended particles (both organic and inorganic) and the amount of dissolved color compounds, many of which are naturally occurring and are associated with decaying vegetation and surrounding wetland complexes. Generally speaking, dry periods oftentimes favor clearer water while wetter periods are oftentimes associated with reduced water transparencies.

- **Chlorophyll a** (surrogate for algal/cyanobacteria growth) – Algal and cyanobacteria populations can be heavily influenced by water temperatures, the amount of light penetration into the water column and nutrient concentrations. Thus, there are multiple factors that could influence the chlorophyll content. In general, wet periods are oftentimes associated with increased algal/cyanobacteria growth that take advantage of nutrients that are flushed into our lakes. On the other hand, dry periods can be associated with lower algal/cyanobacteria levels in our lakes. There is a natural progression of different algal/cyanobacteria forms that occur annual. In general, nuisance algal/cyanobacteria forms tend to flourish in warmer water temperatures that are associated with annual cycles (e.g. warm July and August water temperatures), as well as, unusually warm short-term periods, when the water temperatures rapidly increase in a lake's surface waters.

- **Turbidity** – Turbidity is a measure of the scattering of light and is associated with particles in the water. Since wet periods are oftentimes associated with displacement of fine sediments into our lakes, higher turbidity levels are frequently associated with unusually wet periods while lower turbidity levels are frequently associated with dry periods. Algal/cyanobacteria levels, discussed above, can also impact turbidity by increasing/decreasing the number of cells in the water.

- **Dissolved Color** – Dissolved color, a byproduct of microbial decomposition of soils and plants, varies among lakes as well as seasonally. Dissolved color concentrations tend to be lower during dry period while wet periods, when highly colored water from the surrounding wetlands is flushed into our lakes, tend to be associated with elevated dissolved color concentrations.

Climatic Considerations

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 that is referred to 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 such as precipitation and temperature fluctuations as well as variations, in sunlight intensity which can accelerate or suppress the photosynthetic process.

Climatic "swings" can have a profound effect on water quality, both positive and negative. For instance, 2008 was a wet year relative to other years of LLMP water quality monitoring. The wet conditions 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 water clarities and elevated algal abundance (greenness) during these periods that is supported by historical monitoring through the NH LLMP. Similarly, short-term storm events can have a substantial effect on the water quality. Take, for instance, Tropical Strom Irene (August 30, 2011) that moved through New Hampshire and included intense periods of rainfall in excess of one inch per hour. The water quality monitoring that followed Irene consistently documented significantly reduced water transparency measurements, relative to measurements recorded prior to Irene. While events such as these are short lived, they can affect our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake. These intense rainfall events emphasize the importance of adequate stormwater management practices that minimize the erosion, sediment and nutrient runoff that are commonly associated with intense storm events.

The 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. Dry years, characterized by reduced pollutant transport into the lakes, oftentimes correspond to higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. These observed patterns suggest the importance of watershed management and reducing external nutrient inputs from runoff.

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 nutrient enriched lakes remain more susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems. The few NH lakes and ponds that do not have significant surface inflows and outflows may also show water quality improvement in wet years due to greater flushing by groundwater seepage.

Climatic Impacts on Water Quality

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), however, 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 that occur in 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 shoreline 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 other land clearing can also increase sediment displacement during and following heavy storm events throughout the year. As sediment is transported into surface waters it 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 lake-bottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as variable 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 forms of contaminants 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 lake-bottom, 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 lake-bottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lake-bottom one 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 typically most evident in 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." 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). Increased cyanobacteria abundances can 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 documented to increase during warmer temperatures. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lake-bottom 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 some 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. There has been an increase in the number of reported blooms related to microscopic organisms, algae, cyanobacteria, and plant growth according to NHDES. A fact sheet on green filamentous algae can be found at des.nh.gov.

COMMENTS AND RECOMMENDATIONS

An important step towards preserving and possibly improving the Little Island Pond water quality is to take action at the local level for all to do their part to minimize the number of pollutants (particularly sediment, salts and the nutrient - phosphorus) that enter the lakes.

Based on the current and historical water quality data, Little Island Pond would be considered a relatively clear and unproductive lake that is bordering the conditions considered characteristic of a mesotrophic or moderately nutrient enriched lake reflected in sample results collected in 2022. Overall conditions suggest a trend of improving water quality since 2007 when chlorophyll levels peaked at over 6 ppb (eutrophic) from samples collected by the NHDSE Volunteer Lakes Assessment Program (June 19, 2007). With similar transparencies observed in 2022 to that observed in 1980s (and earlier) and data gaps, we cannot identify significant trends at this time.

In 2022, water quality parameters were indicative of a meso-oligotrophic lake. Total phosphorus (nutrient) concentrations ranged from 6.8 to 12.8 ppb and averaged 9.3 ppb for the season. These water quality parameters generally reflected the conditions considered typical of a mesotrophic New Hampshire Lake. These results represent the limiting nutrient in lakes which support the growth of plants, algae and cyanobacteria. Total phosphorus ranging 8 - 12 ppb are typical of mesotrophic lakes. Values approaching 10 ppb are often correlated with increased populations of cyanobacteria. During rainy summers, as we experienced in 2022 (especially in July), it is not surprising to see immediate effects from runoff, suggesting conditions were worsening. Runoff may have provided quick surges of external nutrients affecting these parameters and the overall water quality for that summer.

Refer to the following informational sections: “10 Recommendations for Healthy Lakeshore and Streamside Living”, “Go with the Flow: Understanding how water moves onto, through and away from your house site” and “Lake Friendly Lawn Care”, that discuss measures landowners can take to preserve water quality.

Specific Recommendations

1) LLMP recommends that each participating lake association, including the Little Island Pond community, 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 Little Island Pond while continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) LLMP suggests the Little Island Pond monitors continue to monitor the deep site into mid-late April/early May that will document Little Island Pond's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Expanding the near-shore sampling could focus on the collection of total phosphorus and conductivity samples where inlets or areas of concern may be addressed.

3) Frequent "weekly" or "bi-weekly" water quality samples, necessary to assess the current condition of Little Island Pond, should continue to be collected whenever possible at the deep sampling station. Continued sampling of chlorophyll *a*, Secchi Disk transparency, dissolved color, alkalinity and total phosphorus samples will be useful to track variations in nutrient loading during the summer months.

4) **Implement Best Management Practices** within the Little Island Pond watershed to minimize the adverse impacts of polluted runoff and erosion in Little Island Pond. Refer to "Landscaping at the Water's Edge: An Ecological Approach" and "New Hampshire Homeowner's Guide to Stormwater Management: Do-It-Yourself Stormwater Solutions for Your Home" for more information on how to reduce nutrient loading caused by overland run-off.

- https://extension.unh.edu/resources/files/Resource004159_Rep5940.pdf
- https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/homeowner-guide-stormwater.pdf

5) While cyanobacteria may not always be apparent, it is their sudden growth that can be unpredictable and concerning. LLMP recommends always being on the lookout for cyanobacteria or surface scums wherever you recreate. If interested in cyanobacteria-specific monitoring, please contact Amanda McQuaid @ Amanda.McQuaid@unh.edu.

6) If you are interested in discussing additional water quality monitoring options that would meet your needs, please contact Bob Craycraft @ 862-3696 or Bob.Craycraft@unh.edu.

10 Recommendations for Healthy Lakeshore and Streamside Living

1. Encourage shoreside vegetation and protect wetlands - Shoreside vegetation (also 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. Tall shoreline vegetation will also discourage geese invasions and shade the water reducing the possibility of aquatic weed recruitment including the dreaded invasive milfoil.

2. Limit 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 and can also produce 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. Use low maintenance grasses such as fescues that require less nutrients and water to grow. Do not apply any fertilizers until you have had your soils tested. Oftentimes a simple pH adjustment will help the issue and release nutrients already in the soils. After a lawn is established a single application of fertilizer in the late fall is generally more than adequate to maintain a healthy growth from year to year.

3. Prevent organic matter loading - Excessive 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 leeches and other potentially undesirable organisms in swimming areas.

4. Limit the 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, limit the effectiveness

of nature's water purification system, our soils. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes of soil organisms and plants detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities, which favor the transport of a greater load of suspended and dissolved pollutants into your lake.

5. Follow the Flow - 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 for your well.

6. Discourage the feeding of ducks and geese - Ducks and geese that are locally fed tend to concentrate in higher densities around the known food source and can result in localized water quality problems. Waterfowl quickly process food into nutrients that are capable of stimulating microscopic plant ("algal") growth. Ducks and geese are also host to the parasite responsible for swimmers itch. While not a serious health threat, swimmers itch is very uncomfortable especially for young children.

7. Maintain septic systems - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes in the summer. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly. Inspect your system on a timely basis and pump out the septic tank every three to five years depending on tank capacity and household water use. Since the septic system is such an expensive investment often costing a minimum of $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 lake and ground water quality degradation.

8. Take care when using and storing pesticides, toxic substances and fuels as it only takes a small amount to pollute lake, stream and ground water. Store, handle and use with attention paid to the label instructions.

9. Stabilize access areas and beaches - Perched beaches (cribbed areas) that keep sand and rocks in-place are preferred if you have to have that type of access. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in the lake as it gets transported away by currents and wind and encourages invasive plants and algal blooms), particularly if the sand disappears with time.

10. Review the Shoreland Water Quality Protection Act (SWQPA) if you have shoreland property, http://des.nh.gov/organization/divisions/water/wetlands/cspa/. The SWQPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the Act you can contact the New Hampshire Department of Environmental Services Shoreland Program at 271-2147 or shoreland@des.nh.gov

Note: The materials listed below offer more detailed guidance on assessing and implementing corrective actions that can maintain or improve the quality of surface and subsurface (septic) runoff that may otherwise impact water quality.

- Landscaping at the Water's Edge: an Ecological Approach. University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. http://extension.unh.edu/resources/files/Resource004159_Rep5940.pdf -
- Integrated Landscaping: Following Nature's Lead. University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. https://extension.unh.edu/resource/integrated-landscaping-following-natures-lead-book
- The Best Plants for New Hampshire Gardens and Landscapes - How to Choose Annuals, Perennials, Small Trees & Shrubs to Thrive in Your Garden. University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. https://extension.unh.edu/resource/best-plants-nh-gardens-and-landscapes-book
- New Hampshire Homeowner's Guide to Stormwater Management: Do-It-Yourself Stormwater Solutions for Your Home. March 2011. New Hampshire Department of Environmental Services. 29 Hazen Drive. Concord NH 03301. https://www.des.nh.gov/water/stormwater
- New Hampshire Department of Environmental Services (NHDES) Soak up the Rain facts: https://www4.des.state.nh.us/SoakNH/resources-2/diy-fact-sheets/
- Are you Lake Smart? https://nhlakes.org/

Trophic surveys by NHDES:

- https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Island%20Pond,%20Little,%20Pelham,%20NH,%20Hillsborough%20County%201978.pdf
- https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Island%20Pond,%20Little,%20Pelham,%20NH,%20Hillsborough%20County%201992.pdf
- https://www4.des.state.nh.us/onestoppub/TrophicSurveys/Island%20Pond,%20Little,%20Pelham,%20NH,%20Hillsborough%20County%202001.pdf

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APPENDIX A STATISTICAL DEFINITIONS

Little Island Pond line graphs display the median Secchi Disk transparency, chlorophyll *a,* total phosphorus and dissolved color concentrations. Regression lines are included in the graphs to display the long-term trend for each parameter; the steeper the slope, the more rapid water quality changes are occuring. Solid regression lines indicate statistically significant (P-value $\leq$ 0.05) trendlines, while dashed lines indicate trendlines that are not considered statistically significant (P-value $\geq$ 0.05).

Long-term trend analysis using linear regressions

A linear, bivariate regression allows us to identify the relation of two or more variables by producing a single line that best represents the distribution of points in a data set. The linear regression is calculated by a simple mathematical equation, $y = mx + b$, that creates a line that best describes the overall trend in the data; where x = the independent variable, y = the dependent variable, b = y-intercept (the value of y when x is zero) and m = the slope of the line. Ultimately, the slope of the line exemplifies the relationship between the two variables being studied. The distance between the line and the points ("standard error") describes the strength of the relationship. The closer the line is to the data points, the stronger the relationship is; whereas the farther away the points are, the weaker the relationship.

While linear regressions help distinguish patterns in data sets, the relationships or correlations identified do not necessarily mean that one variable is the cause of another, even when the line indicates a strong fit with the data points. In other words, there may be a strong relationship between water clarity (Secchi disk depth) and chlorophyll *a*. However, this does not necessarily mean that the clarity of the water is driven by the algal growth associated with high chlorophyll *a* concentrations. Water clarity can fluctuate due to land use changes, storm events, shoreline erosion, etc. causing changes in not only chlorophyll *a*, but in turbidity and color, which can also drive a decrease in clarity. In order to truly understand a trend, such as a change in water clarity, it is crucial to think about all the factors that play into the change in water quality conditions. Linear regression analysis is the first step to identify the areas that need a closer look by providing connections between variables. However, more vigilant observation and analysis is required to determine a true cause-and-effect relationship.

Understanding P-values

A P-value is a number between 0 and 1 used in statistics to decide whether or not to take the null hypothesis while making a prediction based on collected data. The **null hypothesis (H_O)** is the prediction that there is no difference in the data and that there is virtually no change in the parameter, or the question being studied. For example, the null hypothesis of this study is that there has been no change in water quality over a specified amount of time. If the null hypothesis is not taken and is proven to be untrue, then you take the **alternative hypothesis (H_A),** which is there has been a change in the data and the change in water quality is significant. A P-value identifies the confidence one has to reject the null hypothesis. Numbers closer to 0 indicate strong evidence to reject the null hypothesis and accept the alternative hypothesis; while numbers closer to 1 infer weaker evidence that the null hypothesis should be rejected. Generally, significant P-values are identified as **0.05**, **0.01**, and **0.001**.

For our purposes, a **P-value ≤ 0.05** indicates strong evidence to reject the null hypothesis and accept the alternative hypothesis, which is there has been a change in water quality conditions. A **P-value ≥ 0.05** indicates weaker evidence and therefore the null hypothesis of no change or difference is accepted, while the alternative hypothesis is rejected. It is important to understand that while a relationship with P-values ≥ 0.05, do not display "statistical significance", it does not mean that there is no importance in what the data is suggesting, just not enough to reject the null hypothesis. The same goes for a P-value ≤ 0.05. Although the trend is considered "significant" it does not mean it is the only important, suggestive changes in water quality conditions. Again, it is important to consider all factors that play into water quality changes and decide which influences play the largest role.

Multiparameter Sonde

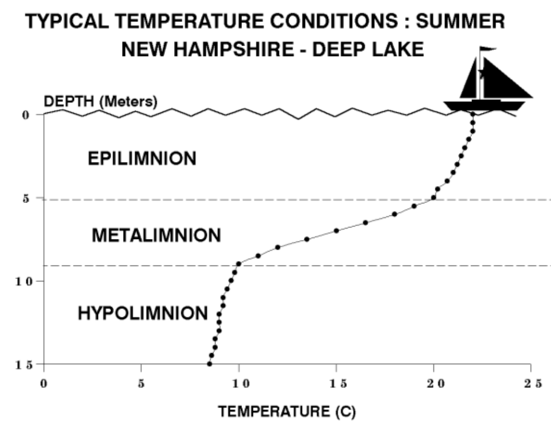
The water quality profile data were collected in situ with a Yellow Springs Instruments model EXO2 Sonde equipped with a pressure (depth) sensor, total chlorophyll fluorescence probe that measures both phycocyanin and chlorophyll, temperature/conductivity probe, optical oxygen sensor, and a combination low ionic strength pH/redox probe. The chlorophyll *a* and phycocyanin fluorescence data are reported as relative fluorescence units and are used to characterize the vertical variability within the water column. All profiling data were digitally logged onto a data logger and subsequently downloaded onto a personal computer for further data analysis. The YSI profile data were recorded at three second intervals by slowly lowering the Sonde into the water column at an approximate rate of two centimeters per second.

APPENDIX B DEFINITIONS OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Certain tests or sampling performed at the time of the optional **Center for Freshwater Biology** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion**. Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion before reaching the lake bottom.



Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance to the observer, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic 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 5 milligrams chlorophyll per cubic meter of water (mg m^3), equivalent to 5 parts chlorophyll *a* per billion parts water (ppb) or 5 micrograms chlorophyll per liter of water (µg/L). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3.3 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 3.3 mg m^3 and 5 mg m^3. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline (metalimnion) and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline by volunteers or CFB staff is often compared to the integrated epilimnetic sample. Greater chlorophyll levels of that point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), can confirm the presence of such a population of algae and if they are a nuisance species. These populations should be carefully monitored as they may be an early 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 runoff 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 generally 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 a lake's typical level of 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 wetland areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, <u>both</u> dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency to infer whether or not significant quantities of suspended sediment may be present.

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit (cpu 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 in lakes, 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 (ppb) or 10 micrograms per liter (µg/L) 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.

Soluble Reactive Phosphorus *

Soluble reactive phosphorus is a fraction of the (total) phosphorus that consists largely of orthophosphate, the form of phosphorus that is directly taken up by algae and that stimulates growth. Soluble reactive phosphorus is obtained by filtering a water sample through a fine mesh filter, generally a 0.45 micron membrane filter, which effectively removes the particulate matter from the sample. Soluble reactive phosphorus concentrations are thus less than, or equal to, the measured total phosphorus concentrations for a water sample.

Soluble reactive phosphorus typically occurs in trace concentrations while applications of fertilizers as well as septic system effluent can be associated with elevated concentrations. Knowledge of both the total phosphorus and the soluble reactive phosphorus is important to understanding the sources of phosphorus into a lake and to understanding the lake's response to the phosphorus loading. For instance, a lake experiencing soluble reactive phosphorus runoff from a fertilized field may exhibit immediate water quality decline (i.e. increased algal growth) while lakes experiencing elevated total phosphorus concentrations associated with sediment washout may not exhibit clear symptoms of increased nutrient loading for months to years.

Streamflow

Streamflow, when collected in conjunction with stream channel 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 alkalinity 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, performed by Schindler and his colleagues in 1985, 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 that are comparable to the currently preferred Acid Neutralizing Capacity (ANC) test results, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates alkalinity values that are similar to those 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 (uS). Specific conductivity implies the measurements are standardized to the equivalent room temperature reading as conductivity will increase with increasing temperature.

Sodium and Chloride *

Low levels of sodium and chloride are found naturally in some freshwater and groundwater systems while high sodium and chloride concentrations are characteristic of the open ocean and are elevated in estuarine systems as well. Elevated sodium and chloride concentrations in freshwater or groundwater systems, that exceed the natural baseline concentrations, are commonly associated with the application of road salt. Sodium and particularly chloride are highly mobile and move into the surface and groundwater relatively unimpeded. Sodium and chloride concentrations can become elevated during periods of heavy snowpack melt when the salts are flushed into surface waters and have also been observed in elevated concentrations during the summer months when low flow conditions concentrate the sodium and chloride.

Road salt runoff is known to adversely impact roadside vegetation as is oftentimes evidenced by bleached (discolored) leaves and needles and in more extreme instances dead trees and shrubs. The United States Environmental Protection Agency (EPA) has set the standard for protection of aquatic life, both plants and animals, at 230 milligrams per liter (mg/l). The EPA has also established a secondary maximum contaminant level of 250 mg/l for both sodium and chloride, predominantly for taste, while the sodium advisory limit for persons with hypertension is 20 mg/l.

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 unoxygenated 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 waterproofed!). 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 irradiance 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 lake water.

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 provide 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 offerings 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 blue-green 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 can be 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**.

Macrozooplankton 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 mayfly 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, particularly for stream sampling, contact the **LLMP** coordinator.

Cyanobacteria (*optional program*)

Cyanobacteria, formerly known, as "blue-green algae" are a potentially toxic bacterium found in all lakes, which become prominent in the summer and fall months when algal "blooms" are present. Cyanobacteria have the ability to dominate over other algae in the water column due to adaptations, such as nitrogen-fixing heterocysts and buoyancy adjustment. The presence of cyanobacteria blooms can decrease overall water quality and produce foul smelling scums when they rise to the surface of the water. Furthermore, many species have the potential to produce hepatotoxins and neurotoxins such as microcystins and anatoxins, making these organisms a concern for public health. The N.H. Department of Environmental Services posts annual advisories for lakes when levels rise above the threshold that is considered "harmful".

Collecting cyanobacteria water samples throughout the summer and fall months can give insight to how these populations are distributed throughout the seasons and when they are most likely to reach harmful levels. In order to better understand the ecological functions of cyanobacteria, qualitative and quantitative analysis, coupled with long-term cyanobacteria data collection, is imperative to identify patterns and changes in populations and the lake's overall water quality. Short-term results can be used to alert officials and the public when levels are at most risk in terms of public safety.

APPENDIX C 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 lake water 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 lake water. Generally the most abundant ion in New Hampshire lake water, 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 lake water 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 lake water 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 CO_2- 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 lake water 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 lake water 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 aesthetically "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 lake water 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. Aesthetically 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 lake water. 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 lake water, 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 lake water. 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 lake water 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 lake water. 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*.

APPENDIX D LIMNOLOGICAL DATA

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

Source	Date	Secchi Disk w/o scope (meters)	Secchi Disk Scope (meters)	Epilimnetic Chlorophyll a Surface (ug/l)	Epilimnetic Total Phosphorus Surface (ug/l)	Epilimnetic Specific Conductivity (uS/cm)	Epilimnetic Chloride (mg/l)	Comments
NH F&G	6/23/1949	6.4						No biological or chemistry data
NH DES	8/28/1978	5.5		3.2	5.0	71.3		
UNH	1985		5.5	1.2	5.5			seasonal average
UNH	1986		6.2	1.1	1.7			seasonal average
UNH	1987		5.2	1.5	3.5			seasonal average
NH DES	8/18/1992	5.5		2.9	11.0	111.9		
NH DES	7/3/2001	3.5			6.0	133.5	26.0	chl not processed
NH DES	6/19/2002	4.5		2.0	9.0	129.3		
NH DES	8/6/2002	4.5		2.6	5.0	146.9		
NH DES	6/19/2007	3.6	3.9	6.3	11.0	133.3		
NH DES	3/12/2020	3.75	4.5	3.2	9.7	149.9		
Aquatic Ecosystem Research	7/20/2020	4.9						Chl and TP data are suspect, not used
NH DES	8/31/2022	5.2	5.9	2.5		191.5	56.9	
UNH	2022		6.4	2.5	9.3	204.1		seasonal average

Lake	Site	Date	SDD	CHL	Color	TP	Alkg	Alkp	SPCD	Depth	pH	CO2
Little Island Pond	2 Deep	7/12/1985	6.8	1.0		8.4				0-4.5		
Little Island Pond	2 Deep	7/12/1985					5.8	6.2	87.5	0.5	7.1	0.3
Little Island Pond	2 Deep	7/12/1985					5.6	5.9	82.5	4	6.9	0.4
Little Island Pond	2 Deep	7/12/1985					5.7	6.2	82.5	9	6.2	3.4
Little Island Pond	2 Deep	7/12/1985					5.8	6.1	80.3	14	6.0	5.1
Little Island Pond	2 Deep	7/20/1985	5.90		5.15							
Little Island Pond	2 Deep	7/27/1985	5.70		3.44							
Little Island Pond	2 Deep	8/4/1985	4.80	1.40	5.15							
Little Island Pond	2 Deep	8/11/1985	5.50	1.20	2.58							
Little Island Pond	2 Deep	8/18/1985	5.10	0.70	2.58							
Little Island Pond	2 Deep	8/28/1985	4.80	0.90	3.44							
Little Island Pond	2 Deep	9/2/1985	5.10	1.80	1.72							
Little Island Pond	2 Deep	9/14/1985				2.50						
Little Island Pond	2 Deep	7/20/1986	5.70	1.10	22.33	1.40						
Little Island Pond	2 Deep	8/4/1986	4.30	1.80	16.32		6.50	7.50				
Little Island Pond	2 Deep	8/24/1986	5.00	1.00	12.89		6.70	7.60				
Little Island Pond	2 Deep	8/31/1986	6.30	0.80	11.17		7.60	8.50				
Little Island Pond	2 Deep	9/13/1986	6.00	0.80	9.45		7.90	8.70				
Little Island Pond	2 Deep	9/27/1986	7.50	1.10	9.45		7.50	8.40				
Little Island Pond	2 Deep	10/13/1986	7.30	1.10	17.18		7.10	7.90				
Little Island Pond	2 Deep	10/25/1986	7.30	1.10	10.31	2.00	6.90	7.40				
Little Island Pond	2 Deep	6/7/1987	4.20	1.30	21.48		6.40	7.10				
Little Island Pond	2 Deep	6/20/1987	4.70	0.90	17.18	2.70	6.80	7.50				
Little Island Pond	2 Deep	7/5/1987	4.80	1.60	16.32		6.40	7.20				
Little Island Pond	2 Deep	7/19/1987	5.50	0.90	18.90		7.00	7.70				
Little Island Pond	2 Deep	8/2/1987	6.20	1.60	14.60		7.40	7.80				
Little Island Pond	2 Deep	8/15/1987	6.00	1.10	12.89		6.20	7.10				
Little Island Pond	2 Deep	9/7/1987	5.10	1.60	24.05	4.30	6.10	6.90				
Little Island Pond	2 Deep	9/27/1987	5.10	3.10	19.76		6.00	6.80				
Little Island Pond	2 Deep	5/14/2022	5.30	2.14	26.10	9.10	13.00	14.30				
Little Island Pond	2 Deep	5/27/2022	5.20	3.39	23.90	11.10	13.10	14.00				
Little Island Pond	2 Deep	6/10/2022	4.97	2.63	20.70	8.50	13.80	14.60				
Little Island Pond	2 Deep	6/24/2022	4.80	3.34	19.80	10.50	13.60	14.70				
Little Island Pond	2 Deep	7/9/2022	5.95	2.13	19.60	8.00	13.80	14.50				
Little Island Pond	2 Deep	7/23/2022	6.35	2.02	10.30	7.60	13.60	14.20				
Little Island Pond	2 Deep	8/7/2022	5.80	2.44	13.90		14.20	15.20				
Little Island Pond	2 Deep	8/21/2022	7.65	2.75	26.10	6.80	13.50	14.60				
Little Island Pond	2 Deep	8/26/2022	7.5	2.1	11.1	12.1	14.0	14.6	204	0-4.5	6.9	
Little Island Pond	2 Deep	8/26/2022		2.1	11.3		13.7	14.2	205	0.5	7.0	2.2
Little Island Pond	2 Deep	8/26/2022					13.5	14.2		2		2.5
Little Island Pond	2 Deep	8/26/2022		2.2	17.9	9.4	13.8	14.4	194	9.5	6.3	13.8
Little Island Pond	2 Deep	8/26/2022				34.2	20.7	21.5	201	14	6.3	14.0
Little Island Pond	2 Deep	9/4/2022	7.26	2.05	11.90	8.10	13.80	14.60				
Little Island Pond	2 Deep	9/18/2022	7.95	2.16	11.70	12.80	13.20	14.10				
Little Island Pond	2 Deep	10/2/2022	8.45	2.28	11.30	7.70	13.00	13.40				