A Survey of the Nation's Lakes – EPA's National Lake Assessment

and

Survey of Vermont Lakes

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January 2009

Table of Contents

List of Tables and Figures

Introduction

In the summers of 2007 and 2008, Vermont's Agency of Natural Resources (VTANR), Department of Environmental Conservation (VTDEC) contributed to an initiative called the National Lake Assessment (NLA) set forth by the United States Environmental Protection Agency (EPA). The goal of the survey was to collect extensive data from lakes across the lower 48 states in order to assess the condition of the nation's lakes. EPA intends to repeat the assessment on a five-year, rotating schedule, with the next nationwide survey scheduled for 2012. The goals of the survey include:

1) Estimating the percentage of lakes that are in good, fair or poor condition, with respect to ecological integrity, water quality, and recreational suitability;
2) Examining the key stressors (e.g. nitrogen, phosphorus, acidification, aquatic invasive species) threatening lakes across the nation, establishing a baseline for future monitoring of lakes;
3) Assessing trends in lake status since the last national lake assessment (National Eutrophication Study of 1972); and
4) Helping state and other organizations better monitor and assess their lakes and promoting cooperation between jurisdictional boundaries.

For the survey, 1,000 lakes (909 unique lakes, plus 91 repeats) were randomly selected using a probability survey design serving two purposes: 1) to allow results from sampled lakes to be projected to the larger target population; and 2) to represent the population of lakes in their respective "ecoregion" – the geographic area in which climate, ecological features, and plant and animal communities are similar (Figure 1). Vermont's contribution to the national assessment included nine lakes and one repeat lake. However, to meet the goals laid out above specifically for Vermont, VTDEC augmented the sampling to visit 50 lakes state-wide (Figure 2), permitting a statistically-valid assessment of lakes for Vermont. Upon completion of the survey, 12 lakes were surveyed for the National assessment, and 40 more for the statewide assessment. For more information about how lakes were selected for this survey, please refer to: Site Selection for the Survey of the Nation's Lakes Fact Sheet[1].

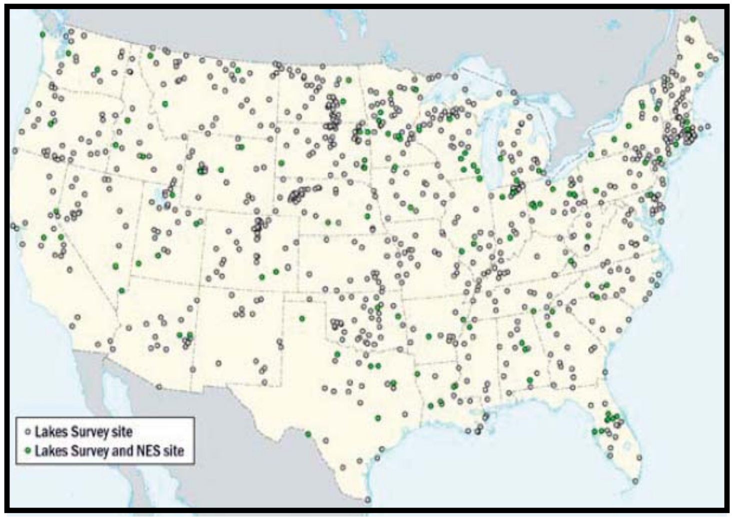


Figure 1. Distribution of lakes nationwide included in the survey (www.epa.gov).

The 52 Vermont lakes included the twelve core National Lake Assessment lakes, and only these will twelve lakes contribute to the overall nation-wide survey. The fifty selected lakes were sampled in the summers of 2007 and 2008 by staff scientists and field technicians from the Water Quality Division of VTDEC. The chosen lakes sampled for the study are listed in Table 1 and located in Figure 2. Clicking on the lake names will lead you to Water Quality Summary Reports that include data from historical and on-going State monitoring and assessment initiatives of the Lakes and Ponds Program (but not data from the NLA).

The purpose of this report is to describe the condition of lakes in Vermont using several types of indicators as described in the following sections. In addition, information is provided about the utility and meaning of each indicator. This information therefore serves as a guide to understanding how scientists describe the quality of lakes and ponds using measurements of these indicators. The figures provided display results for each sampled lake for each indicator. The pie charts associated with each graph show the weighted percentages of lakes in each category. The numeric weight given to each lake is a key component of the statistical survey design. Weights are assigned relative to the size of the individual waterbody and the density of lakes in the area near the selected lake. For example, in Vermont, the smallest survey lakes (e.g. Lily Pond and Little Rock Pond) have high weights because although there are few small lakes in the survey, there are many more small lakes on the Vermont landscape. Therefore, these two small lakes selected in the survey are representative of a large number of lakes in VT. Conversely, large-area lakes such as Bomoseen and Seymour are weighted lower because there are fewer large lakes in Vermont. These weight associations are the tool that permit the estimation of a Vermont-wide condition from the sampled set of lakes and make comparisons to national conditions statistically valid.

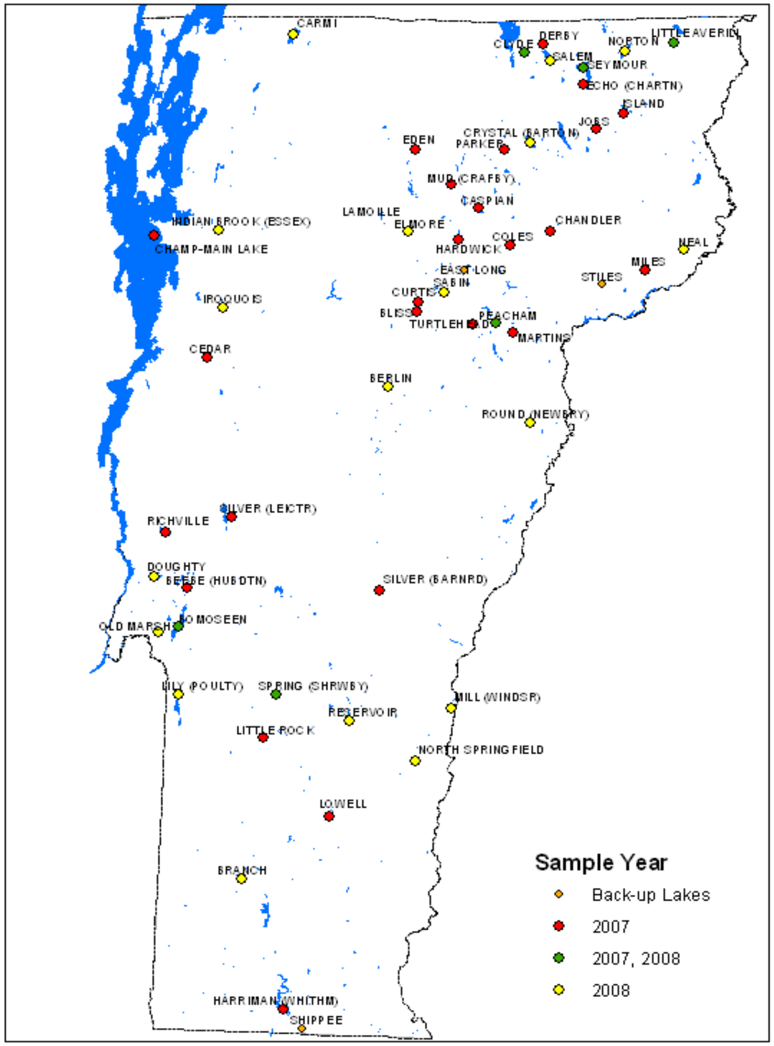
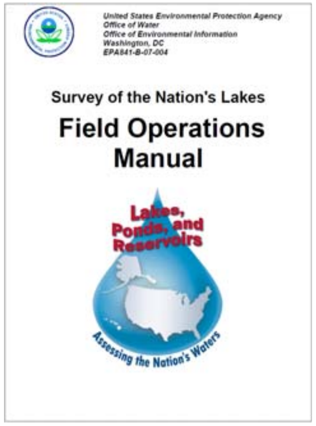


Figure 2. Distribution of Vermont lakes from the random selection provided by the National Lake Survey.

Table 1. Vermont lakes (n=52) included in the National Lake Survey. *Asterisk indicates Core NLA lakes.

Sampling Year	Lake Name (click for more information)	Town	Area (hectares)	Sampling Year	Lake Name (click for more information)	Town	Area (hectares)
2007	*Beebe Pond	Hubbardton	38.46	2007	Silver Lake	Barnard	34.05
2007	Bliss Pond	Calais	12.09	2007	*Silver Lake	Leicester	41.13
2007	Lake Bomoseen	Castleton	943.83	2007	*Spring Lake	Shrewsbury	26.22
2007	*Caspian Lake	Greensboro	306.67	2007	*Turtlehead Pond	Marshfield	27.83
2007	*Lake Champlain	Main lake off Burlington	66,414.37	2007	Seymour Lake	Morgan	667.57
2007	Cedar Lake	Monkton	50.14				
2007	Chandler Pond	Wheelock	23.81	2008	Berlin Pond	Berlin	115.81
2007	Clyde Pond	Derby	59.53	2008	Branch Pond	Sunderland	20.12
2007	Coles Pond	Walden	44.08	2008	Lake Carmi	Franklin	541.22
2007	Curtis Pond	Calais	35.06	2008	Crystal Lake	Barton	274.4
2007	*Lake Derby	Derby	76.20	2008	Doughty Pond	Orwell	301.5
2007	Echo Lake	Charleston	191.71	2008	East Long Pond	Woodbury	76.08
2007	Lake Eden	Eden	71.43	2008	Lake Elmore	Elmore	79.19
2007	Hardwick Lake	Hardwick	79.75	2008	Indian Brook Reservoir	Essex	21.63
2007	Harriman Reservoir	Whitingham	812.42	2008	Lake Iroquois	Hinesburg	96.52
2007	*Island Pond	Brighton	220.65	2008	Lily Pond	Poultney	7.2
2007	*Jobs Pond	Westmore	12.55	2008	Mill Pond	Windsor	32.37
2007	Little Averill Pond	Averill	177.56	2008	Neal Pond	Lunenburg	72.28
2007	Little Rock Pond	Wallingford	5.47	2008	North Springfield Reservoir	Springfield	53.37
2007	Lowell Lake	Londonderry	44.1	2008	Norton Pond	Norton	216.56
2007	*Maidstone Lake	Maidstone	301.5	2008	Old Marsh Pond	Fair Haven	50.64
2007	Martins Pond	Peacham	31.88	2008	Reservoir Pond	Ludlow	13.87
2007	*Miles Pond	Concord	82.16	2008	Round Pond	Newbury	11.05
2007	Mud Pond	Craftsbury	10.88	2008	Sabin Pond	Calais	51.1
2007	*Lake Parker	Glover	83.35	2008	Lake Salem	Derby	52.34
2007	Peacham Pond	Peacham	136.92	2008	Shippee Pond	Whitingham	10.90
2007	Richville Pond	Shoreham	61.35				

What We Measured



In the summers of 2007 and 2008, field crews collected over 10,000 individual datapoints from the survey lakes in Vermont. Consistent methods and procedures were employed at all lakes within the state and across states so that results can be compared across the country. Five groups of indicator measurements were collected at each lake: 1) water quality and trophic status, 2) acidification, 3) ecological integrity, 4) nearshore habitat and 5) recreational integrity. These five groups are described in detail below. Parameters denoted by an asterisk were collected only at the twelve core NLA lakes.

Water Quality and Trophic Status Indicators: Lakes are often classified according to their water quality and trophic state. "Trophic" means nutrition or growth and pertains to the amount of biological material present in a waterbody (nutrient concentrations and degree of plant growth). Trophic state refers to a lake's position along a gradient of very low-nutrient, and poorly productive lakes to very high-nutrient, and over productive lakes. Refer to Table 2 below for descriptions of trophic states for lakes. The following water chemistry and trophic indicators were measured:

- Temperature, pH, dissolved oxygen, nutrients (total phosphorus, total nitrogen, nitrate and sulfate, silica), metals, chlorides, water clarity (Secchi transparency), turbidity, total suspended solids, and water color;

Three variables, chlorophyll-*a*, Secchi disk transparency, and total phosphorus, are commonly used characterize the trophic status of a particular lake, or to estimate algal growth (see Table 2 below). Vermont's specific numeric guidelines for determining trophic state are shown on each figure illustrating the results of the specific chemistry tests in the "What we found" section of this report.

Acidification Indicator: Alkalinity is a measure of sensitivity to acid rain.

- Alkalinity

Ecological Integrity Indicators: Ecological integrity indicators describe the ecological condition of a lake by focusing on the various assemblages of the aquatic communities and their physical habitat.

- *Phytoplankton and zooplankton (microscopic aquatic animals and plants)
- Aquatic macroinvertebrates (insects, snails, mussels, etc.)
- *Sediment diatoms (microscopic algae)
- Sediment mercury

Nearshore Habitat Indicators: Measurement of nearshore and in-lake littoral conditions provides an evaluation of ecological condition and degradation due to anthropogenic impacts.

- Shoreline condition
- Littoral-zone condition

Recreational Integrity Indicators: Recreational indicators address the ability of a lake to support recreational activities

- *Bacteria (*Entercocci* from fecal contamination);
- *Algal toxins from cyanobacteria (microcystins).

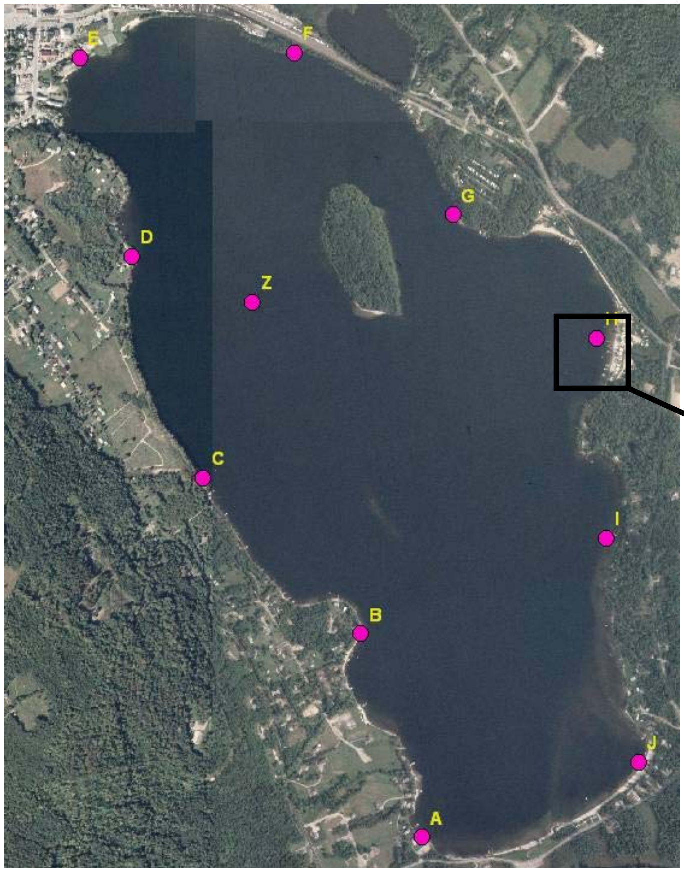
There were eleven sampling stations at each lake. The Index Site is the deepest point in the lake and is intended to capture general water quality conditions in the lake. This is the location where a majority of the samples are collected (water chemistry, chlorophyll-*a*, phytoplankton, algal toxins, zooplankton, sediment diatoms, and sediment mercury). The ten physical habitat sampling stations are randomly selected *a priori* and are evenly spaced along the periphery of the lake. At each of the ten physical habitat stations the following information is collected: measures of the littoral and riparian physical habitat structure, observations of invasive plants, sampling of benthic macroinvertebrates composited into a single sample, and collection of a water sample at one physical habitat station for fecal indicator (*Enterococci*) analysis.

Table 2. Description of trophic states for Vermont lakes (adopted from the Vermont Volunteer Surface Water Monitoring Guide).

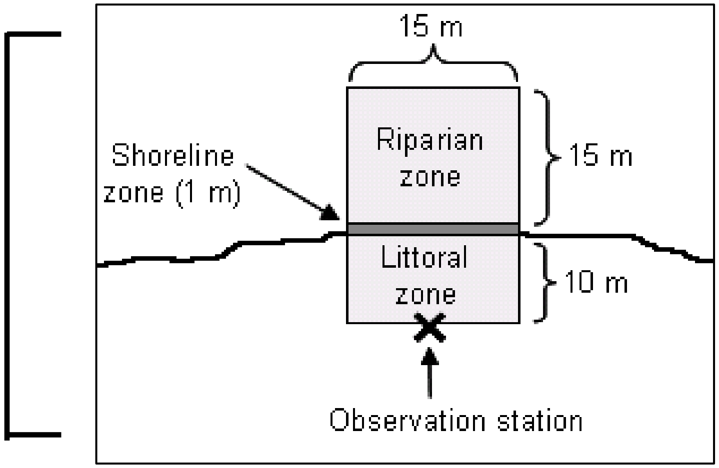
Oligotrophic – Referred to as "young" lakes, characterized by deep, clear water; low nutrient enrichment; little algae growth (low productivity); few aquatic plants; bare sand or rock along most of the shoreline (little mud); and often supporting coldwater fish species.
Mesotrophic – Referred to as "intermediate" lakes, characterized by moderate nutrient enrichment; moderate algae growth, moderate aquatic plant growth; moderate sediment accumulation over the lake bottom; and usually supporting warmwater fish species.
Eutrophic – Referred to as "old" lakes, characterized by high nutrient enrichment, abundant algae growth (high productivity); extensive aquatic plant beds; extensive sediment accumulation on the lake bottom; and supporting exclusively warmwater fish species.
Dystrophic – Lakes that are "stained" brown by dissolved organic material from the surrounding watershed, these lakes exhibit water quality characteristics similar to oligotrophic lakes, although occasionally a dystrophic lake may have characteristics closely aligned with mesotrophic or eutrophic conditions.

Before leaving the lake, other observations and impressions regarding lake and watershed activities and disturbances, general lake information (house and motor boat density, type of dam) and general shoreline characteristics are recorded. This type of categorical information will be useful for the ecological value assessment and the development of associations and stressor indicators.

The large amount of data that was collected at each lake was simplified with the help of electronic data capture – convenient, resilient computers aided in data and field note organization and storage. If you are interested in the details of field protocols, please refer to the Survey of the Nation's Lakes Field Operations Manual[2].



An example of the 10 randomly selected physical habitat locations and the Index (Z) Site, at Island Pond in Brighton.



Schematic of a physical habitat and benthic sampling station. The observation station is located on the lake, 10 meters from shore. (Survey of the Nation's Lakes Field Operations Manual)

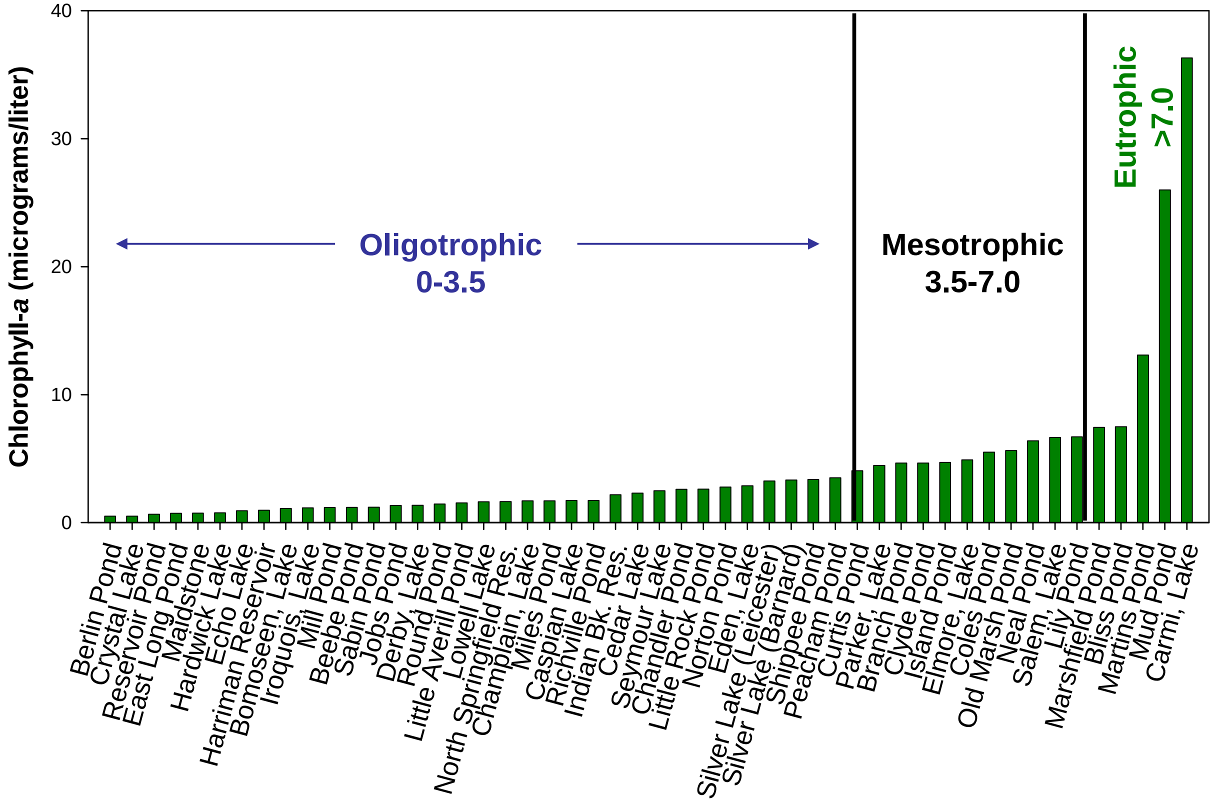
What We Found

The following section includes reported values and graphs of five key lake parameters (chlorophyll-*a*, Secchi disk transparency, total phosphorus, total nitrogen, and alkalinity) that were measured at all Vermont lakes surveyed in this study. Each graph shows results of each test, for all Vermont lakes. These figures allow the reader to easily compare lakes of interest to the distribution of all the waterbodies sampled across the state.

Trophic Status Indicators

Chlorophyll-a

Chlorophyll-*a* is a green pigment found in plants and algae and is the essential component that plants use to fix carbon dioxide from the air during photosynthesis. Measuring chlorophyll-*a* concentration is a way to estimate the amount of algal (phytoplankton) biomass in a lake. Algae and other plants form the base of the aquatic food web and produce the dissolved oxygen in water needed by other aquatic organisms. Most algae obtain their nutritional needs directly from so-called "primary" or "macro" nutrients (nitrogen, phosphorus, and carbon) in the lake water. Algae serve as the predominant food source for microscopic animals (zooplankton), which in turn provide food for fish and other aquatic life. Because algae are the primary link between nutrient reserves and the aquatic food web, excess nutrient inputs from the surrounding watershed often results in excessive growth of algae (and cyanobacteria) turning lake water green and murky. Excessive algal blooms may impart noxious odors and tastes, and some algae, such as cyanobacteria, can produce toxins (microcystin). When excessive algal growth decays, this can result in depletion of dissolved oxygen in the water column, leading to fish kills. The toxins produced by common cyanobacteria species have been linked to severe illnesses in livestock, pets and wildlife, although in Vermont, this phenomenon has been observed in only two instances on Lake Champlain. Chlorophyll-*a* and Secchi transparency measurements are usually inversely proportional to each other. Dense algal populations, evidenced by a greater chlorophyll-*a* concentration in the water column, commonly bring about a lower than normal Secchi transparency. Several Vermont lakes are naturally "tea-colored", or are affected by sediment loading, and both conditions will also yield low Secchi transparencies, which limit algal production due to light limitation. Chlorophyll-*a* values for the lakes assessed in Vermont ranged from 0.5 to 36.3 µg/l with a mean of 4.1 ± 6.2 µg/l. From these data, 34 lakes were categorized as oligotrophic, 11 as mesotrophic and five as eutrophic (Figure 3).



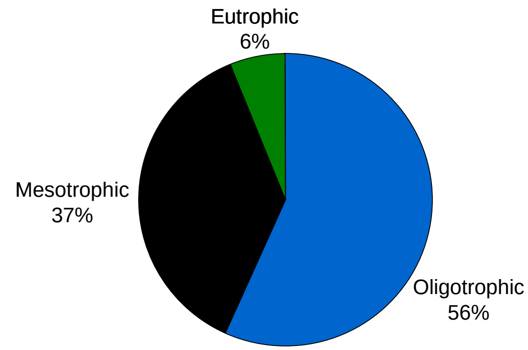
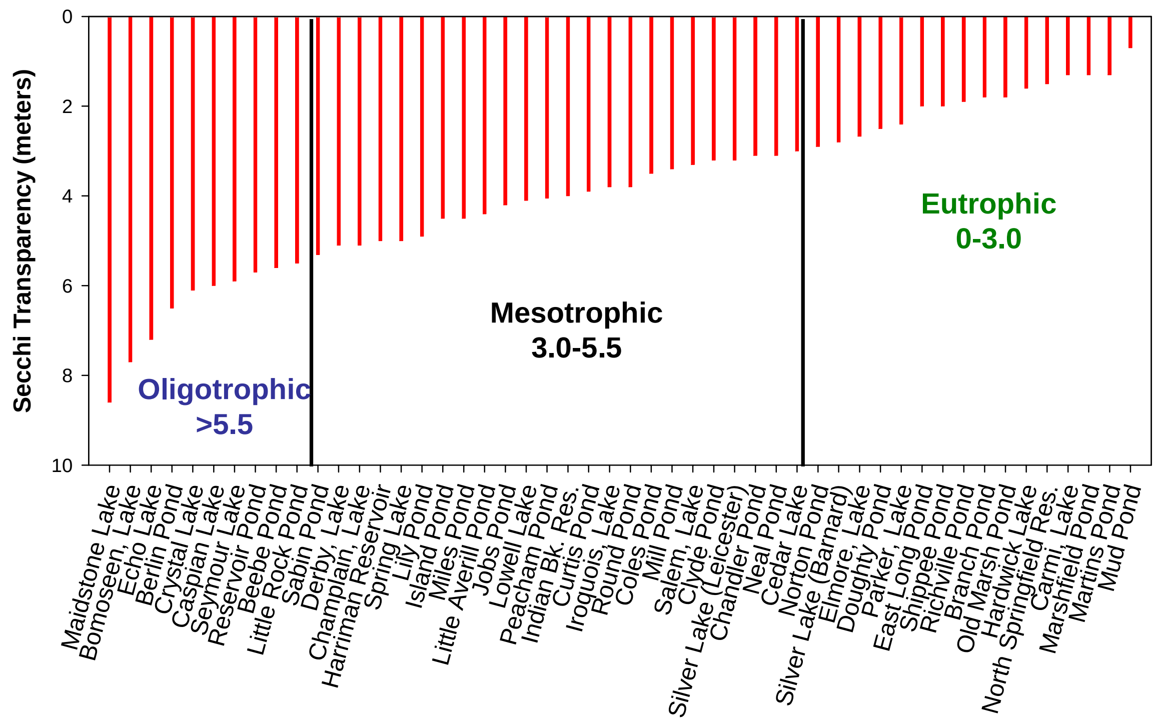


Figure 3. Chlorophyll-*a* values observed in Vermont Survey Lakes during the 2007/2008 summer sampling campaign with corresponding trophic state ranges. Pie chart shows the percent of VT Survey lakes that fall into each range. Margin of error is +/- 5%.

Secchi Disk Transparency

The maximum depth at which algae and macrophytes can grow in a lake is determined by the availability of light. Secchi transparency is a simple measure of the depth to which light penetrates the water column. Secchi disk depth or transparency can be used to estimate the “euphotic zone” in a waterbody, which is the depth to which there is sufficient light penetration to permit algal growth. Lake scientists have determined that light typically penetrates waters to a depth of twice that measured using a Secchi disk. Secchi depths for Vermont Survey lakes ranged from 0.7 to 8.6 meters with a mean depth of 3.9 ± 1.8 meters, categorizing 10 lakes as oligotrophic, 23 lakes as mesotrophic, and 16 lakes as eutrophic.



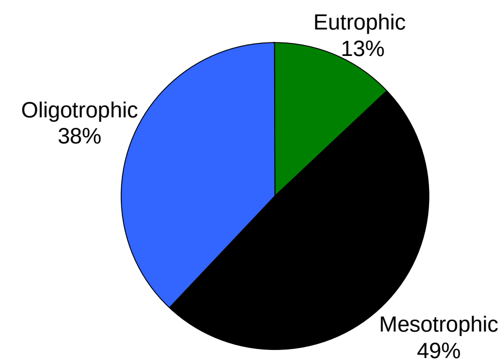


Figure 4. Bar graph of Secchi transparency measurements observed in Vermont Survey Lakes during the 2007/2008 summer sampling campaign with corresponding trophic state index ranges. Pie chart shows the percent of VT Survey lakes that fall into each range. Margin of error is +/- 5%.

Total Phosphorus

In north temperate lakes, phosphorus is the greatest concern in regards to lake eutrophication (nutrient enrichment). Phosphorus is often referred to as the “limiting nutrient” in aquatic ecosystems, meaning it is the constituent that restricts plant growth due to its naturally low levels in the environment. An easy analogy is to consider phosphorus as the “baking soda” necessary to prepare a batch of “cookies,” in that small increases in baking soda cause the cookies to rise uncontrollably. Likewise, small increases in phosphorus loads to a waterbody can cause large algal blooms and excessive plant growth. This rapid increase in biological activity may disrupt the ecological balance of surface waters. Phosphorus can take many forms in the environment, but the single most important and easiest to analyze in a laboratory is total phosphorus, which represents phosphorus attached to particles in the water, and phosphorus which is dissolved, or ready to be used by algae to fuel growth. In Vermont lakes, total phosphorus values ranging from 5.6 to 160 µg/l with a mean of 17.9 ± 25.9 µg/l, categorizing nine lakes as oligotrophic, 23 as mesotrophic, and 19 lakes as eutrophic.

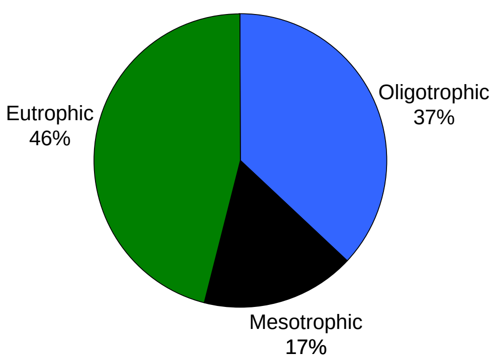
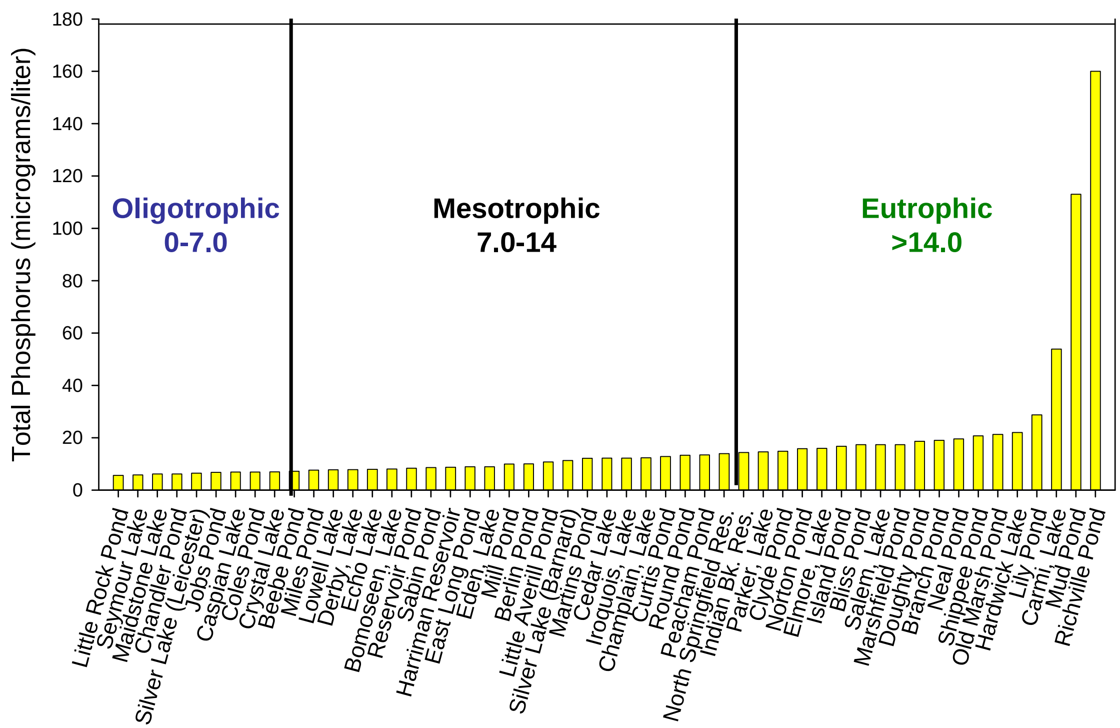


Figure 5. Total phosphorus values observed in Vermont Survey Lakes during the 2007/2008 summer sampling campaign with corresponding trophic state index ranges. Pie chart shows the percent of VT Survey lakes that fall into each range. Margin of error is +/- 5%.



Total Nitrogen

Various forms of nitrogen (nitrate, ammonia, total nitrogen) are measured in lake water. High concentrations of any form of nitrogen in a waterbody may indicate that pollutants from agriculture (e.g. animal manure and fertilizers) or development (sewage and stormwater) are making their way into the water via runoff and/or leaching through soil. The two most important forms of nitrogen in natural waters are nitrate and ammonium as both are readily used by plants and animals. Nitrate (NO_3) is the form of nitrogen that originates in the aforementioned sources as well as through atmospheric deposition (the same deposition that, along with sulfur, drives acidification of lakes). High levels of nitrate may fuel the occurrence of an algal bloom or cause changes in aquatic plant and animal communities. Ammonia (NH_3) is also an important nitrogen component to measure because in elevated levels, it can be toxic to aquatic life. Like total phosphorus, total nitrogen (TN) also measures all forms of nitrogen, is easily tested in the laboratory, and indicates the potential for available nitrogen for plant and animal growth. Total nitrogen values for Vermont survey lakes ranged from 0.15 to 1.0 mg/L with a mean of 0.30 ± 0.15 mg/L (Figure 6). Lakes with total nitrogen in excess of 0.48 may exhibit diminished aesthetic value due to enhanced algal growth.

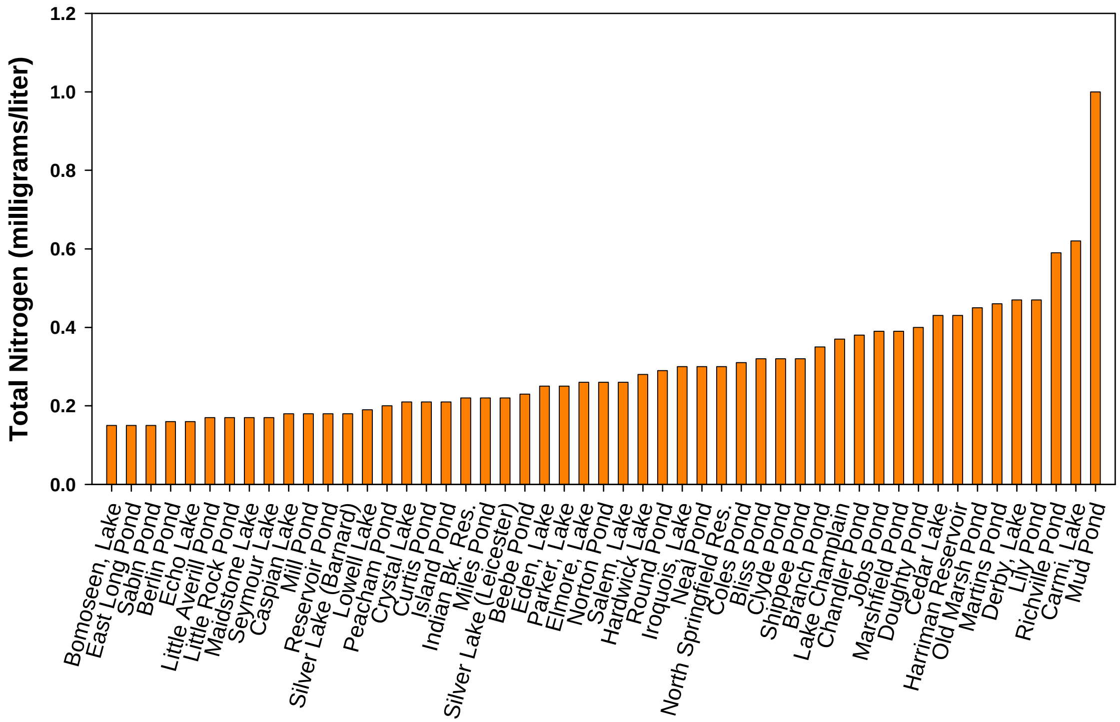


Figure 6. Total nitrogen values observed in Vermont Survey Lakes during the 2007/2008 summer sampling campaign.

Dissolved Oxygen

Dissolved oxygen (DO) is the measurement of oxygen as a dissolved gas in water. Adequate amounts of dissolved oxygen are critical for the survival of fish and aquatic organisms. Dissolved oxygen is considered one of the more important measurements of water quality and an indicator of a lake's ability to support aquatic life. Aquatic organisms have different ranges of DO for optimal functioning. Levels of DO above 5 milligrams per liter (mg/l) are considered optimal and most fish cannot survive below 3 mg/l. Conditions below 1 mg/l are referred to as *hypoxic* and when oxygen is completely absent it is called an *anoxic* environment. Vermont Water Quality Standards set a minimum DO concentration of 5 mg/l to protect warmwater fish habitat, except where low dissolved oxygen is expected due natural lake attributes (naturally eutrophic lakes, or small but deep lakes). Limnologists (lake scientists) commonly plot DO profiles – graphs of the amount of oxygen per unit depth – to understand how lakes stratify with respect to dissolved oxygen and temperature, to understand how well aquatic life is supported throughout the water column. In some lakes, nutrient cycling between sediments and lake water is a function of DO. Figure 7 illustrates a series of DO profiles (blue lines) along with temperature profiles (red lines) along a seasonal timeline for oligotrophic and eutrophic lakes. Levels of DO in a waterbody are affected by the rate of decomposition of organic matter. This is because in lakes, bacteria use oxygen to break down organic matter. In deep, oligotrophic lakes the entire water column may stay completely oxygenated with high DO levels, owing to a larger pool of DO, and because there is less algae and bacteria present to consume the DO. In contrast, eutrophic lakes tend to have decreasing amounts of DO available in the water column because: 1) reduced light availability with depth limits oxygen production by limiting photosynthesis; 2) there is a smaller pool of oxygen available; and 3) organisms continue to consume the available oxygen, eventually depleting the lower portions of the lake of oxygen. Figure 8 shows the percent of the water column at the <5 mg/liter threshold for VT Survey Lakes. Nearly half of the lakes had a completely oxygen-saturated water column, and only three lakes had >50% of the water column below 5 mg/l.

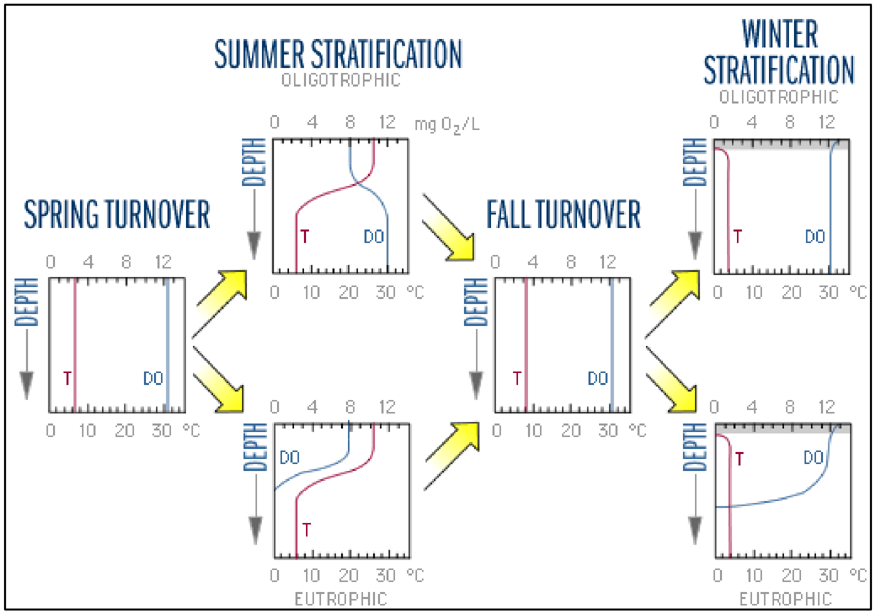


Figure 7. DO and temperature profiles for oligotrophic and eutrophic lakes throughout the seasons. Lake depth is typically on the vertical axis and temperature and DO are on the horizontal axes. Please see this website[3] for the source of this schematic and a detailed description of dissolved oxygen dynamics in lakes throughout the year.

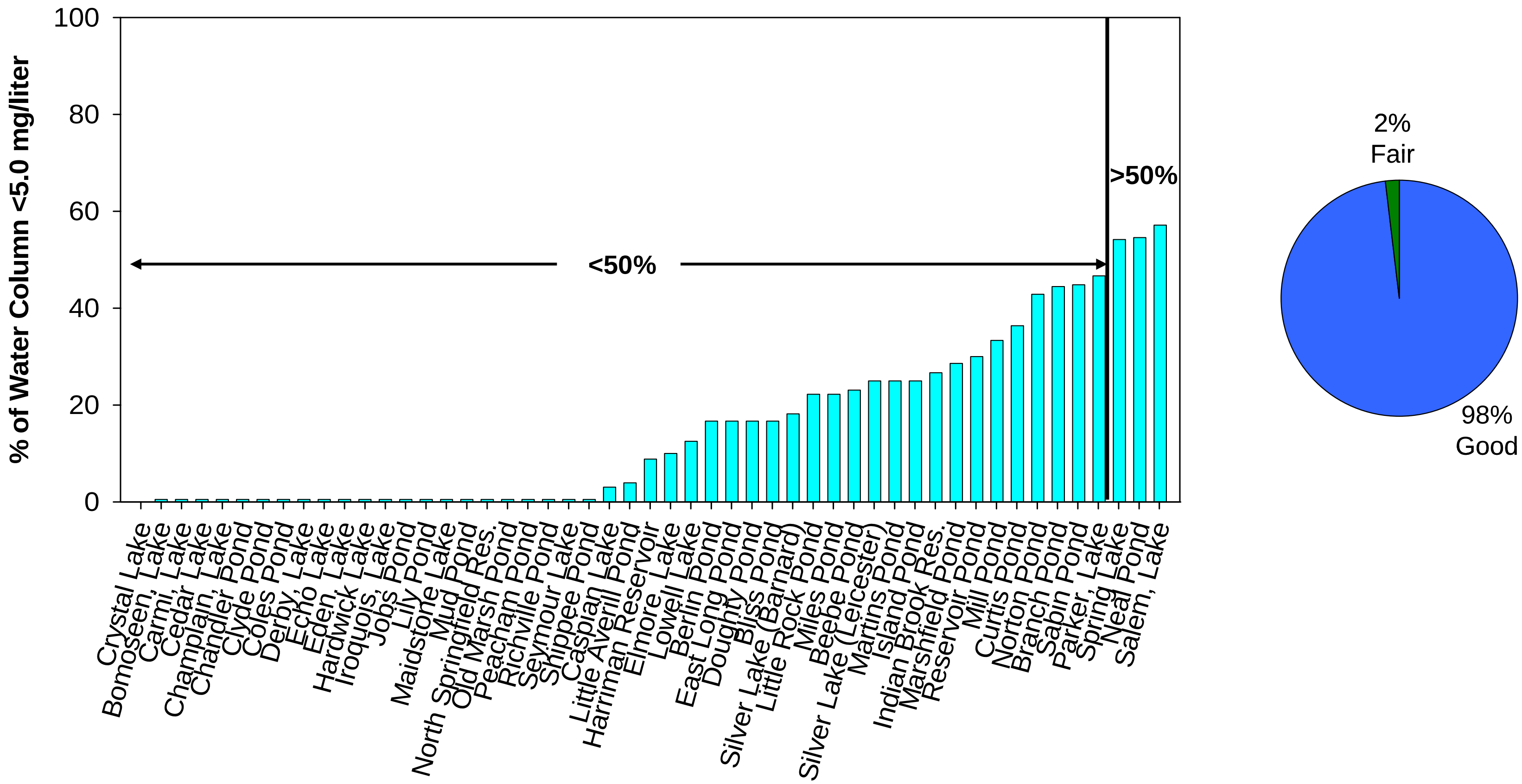


Figure 8. Dissolved oxygen: percent of water column that is less than 5 mg/liter for Vermont Survey Lakes during the 2007/2008 summer sampling campaign. Lakes were identified as fair when >50% of the water column was < 5 mg/l. Accounting for natural attributes, no lakes were considered impaired.

Acidification Potential assessed using Alkalinity

Alkalinity serves as a proxy for sensitivity to acid rain. The alkalinity of natural water is determined by the soil and bedrock through which it passes. Lakes with a significant amount of dissolved bicarbonate ions (e.g. limestone watersheds) are able to neutralize acid and buffer the effects of acid rain precipitation. Conversely lakes that are rich in granites and sandstones, but do not contain acid-neutralizing ions, have low alkalinity and a predisposition to acidification. Alkalinity is important for fish and aquatic life because it protects or buffers against drastic pH changes in the waterbody. Most living organisms, especially aquatic life, function at the optimal pH range of 6.5 to 8.5. Higher alkalinity levels in surface waters will buffer acid rain and prevent pH excursions outside of this range. Alkalinity and pH of lakes decrease with increasing elevation, which is why most of the Vermont lakes affected by acid rain deposition are located in remote and undeveloped regions of the Green Mountains and the Northeast Kingdom, overlying poorly buffered bedrock comprised of schists, granites, and sandstones.

Alkalinity is measured in the laboratory and reported as total alkalinity, or the amount of calcium carbonate per liter of water (mg $CaCO_3$/Liter). Lakes with alkalinities of 2.5 mg/L and lower are considered impaired due to acidification. Lakes with alkalinities below 12.5 mg/L are susceptible to stress due to acidification. Alkalinity measurement for the Vermont survey lakes ranged from 1 to 114 mg/L with a mean of 40 ± 29 mg/L. The survey pinpoints Branch Pond and Shippee Pond as falling in the "impaired" category (Figure 9). For more information on pH, alkalinity and acid rain, please see this website[4].

The Science of Alkalinity

Carbon is the energy currency in aquatic ecosystems. Inorganic carbon is found in the atmosphere, primarily in the form of carbon dioxide (CO_2). When CO_2 is dissolved in water, it can exist in a variety of forms, depending on the pH. These dissolved forms include: carbon dioxide, carbonic acid (H_2CO_3), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) and the chemical conversions among these forms are referred to as the bicarbonate equilibrium. The equilibrium of inorganic carbon dictates the acid neutralizing or buffering capacity referred to as alkalinity – the water's capability to resist changes in pH that would make the water more acidic

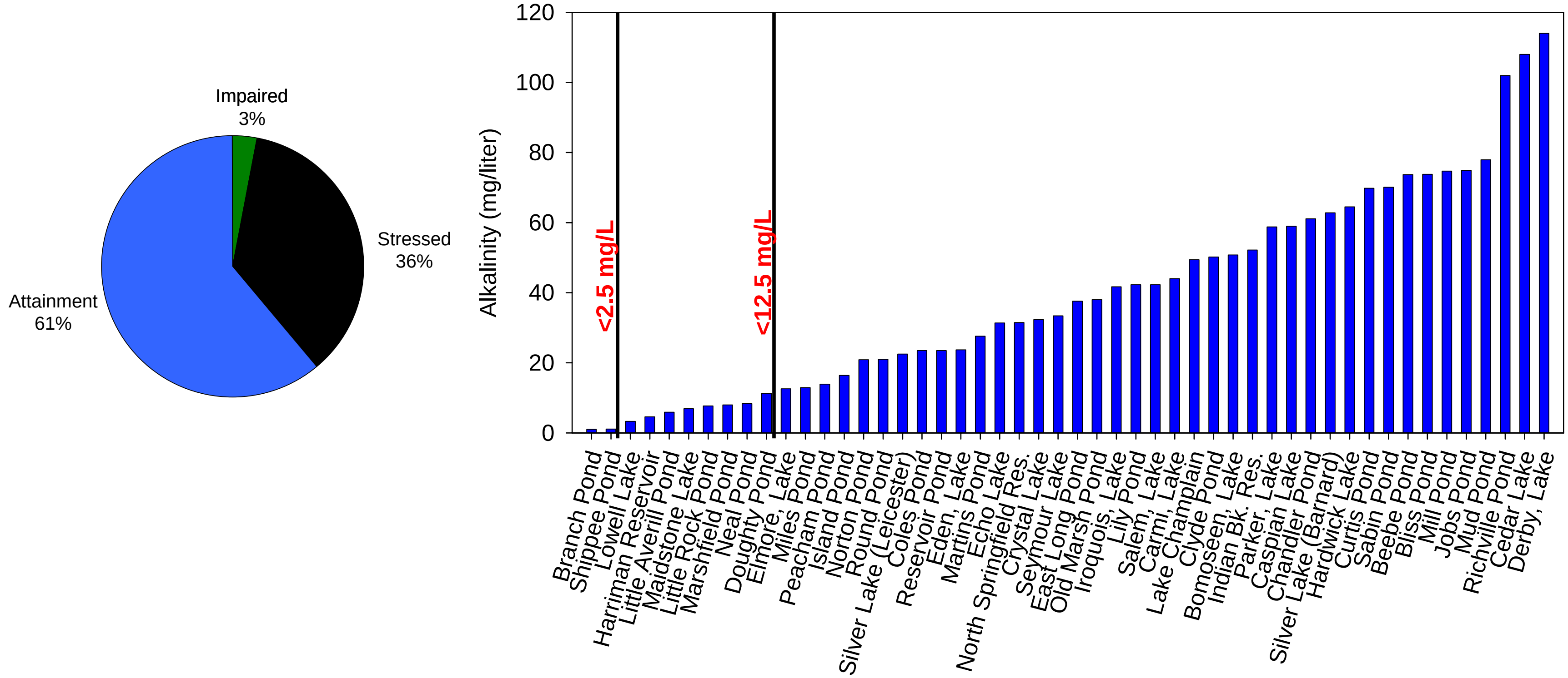


Figure 9. Alkalinity values observed in Vermont Survey Lakes during the 2007/2008 summer sampling campaign. Pie chart shows the percent of VT Survey lakes that fall into each range. Margin of error is +/- 5%. Note the acid-sensitive Little Rock Pond has a high weight, implying a higher percentage of acid stressed lakes than have been documented by Vermont's long-term sampling programs. Omitting this datapoint, the percentages are: impaired, 3%; stressed, 12%; attaining, 85%.

Ecological Indicators

Littoral Habitat

The transformation of lakeshores from natural forested and wetland cover to lawns and sandy beaches, accompanied by development (and redevelopment) of residential homes is a major stressor to lakes. In a survey of 345 lakes in the Northeast during the early 1990s, the US Environmental Protection Agency and US Fish and Wildlife Service determined that the stress from shoreline alteration was a more widespread problem than even eutrophication and acidification[5]. Since 2005, the VTDEC has documented the effects of shoreline development on nearshore and littoral habitat quality in lakes throughout Vermont, with striking results.

As lakeshores are converted from forests to lawn, impervious surfaces, and sand, increased overland runoff results in increased sediment embeddedness, less shading and often more abundant aquatic plant growth in the shallows. Littoral habitat is further altered by the direct removal of woody structure from the shallows, and interruption in the resupply of this critical habitat component by removal of trees along the shoreline. The Wisconsin Department of Natural Resources has estimated that developed sites can contribute up to ***five times*** more runoff, ***seven times*** more phosphorus and ***18 times*** more sediment to a lake than naturally forested sites.

This alteration of the nearshore and littoral habitat affects a variety of both terrestrial and aquatic wildlife. Green frog, dragonfly and damselfly populations decline[6,7,8] . The nesting success and diversity of fish species also declines[9,10,11], with sensitive native species being replaced by more disturbance tolerant species[11,12,13]. Turtles lose basking sites and corridors to inland nest sites[14]. Bird composition shifts from insect-eating to seed-eating species[15]. Even white-tailed deer are affected, with reduction in winter browse along shorelines reducing winter carrying capacity[16]. The removal of conifers along shores also reduces shoreline mink activity[17]. Ultimately, the cumulative effects of lakeshore development have negative implications for many species.

The National Lakes Survey approach to quantifying physical habitat along lakeshores was comprehensive. Over 55 individual measurements were collected at each of the 10 sites visited on each lake, addressing nearshore, shoreline, and littoral habitat conditions. Owing to the obvious impacts associated with cumulative lakeshore development, the results of the National Lakes Survey's littoral habitat assessment are of keen interest. The following graphs contain results from the physical habitat assessments for the Vermont lakes. Figure 10 shows the percentage of the lake shoreline that is developed. "Development" is measured as the presence of buildings, walls and/or maintained lawns at a sampling location. EPA has categorized the level of stress imparted to the ecological integrity of lakes by various levels of development intensity. EPA thresholds classify less than 25% lake shoreline development as low stress to a lake, 25-50% shoreline development as moderate stress, and greater than 50% development as high stress. Approximately half of the lakes surveyed in Vermont have shorelines that are less than 50% developed, and therefore at low-moderate stress, and the other half have shorelines that are more than 50% developed, suggesting high stress to ecological integrity.

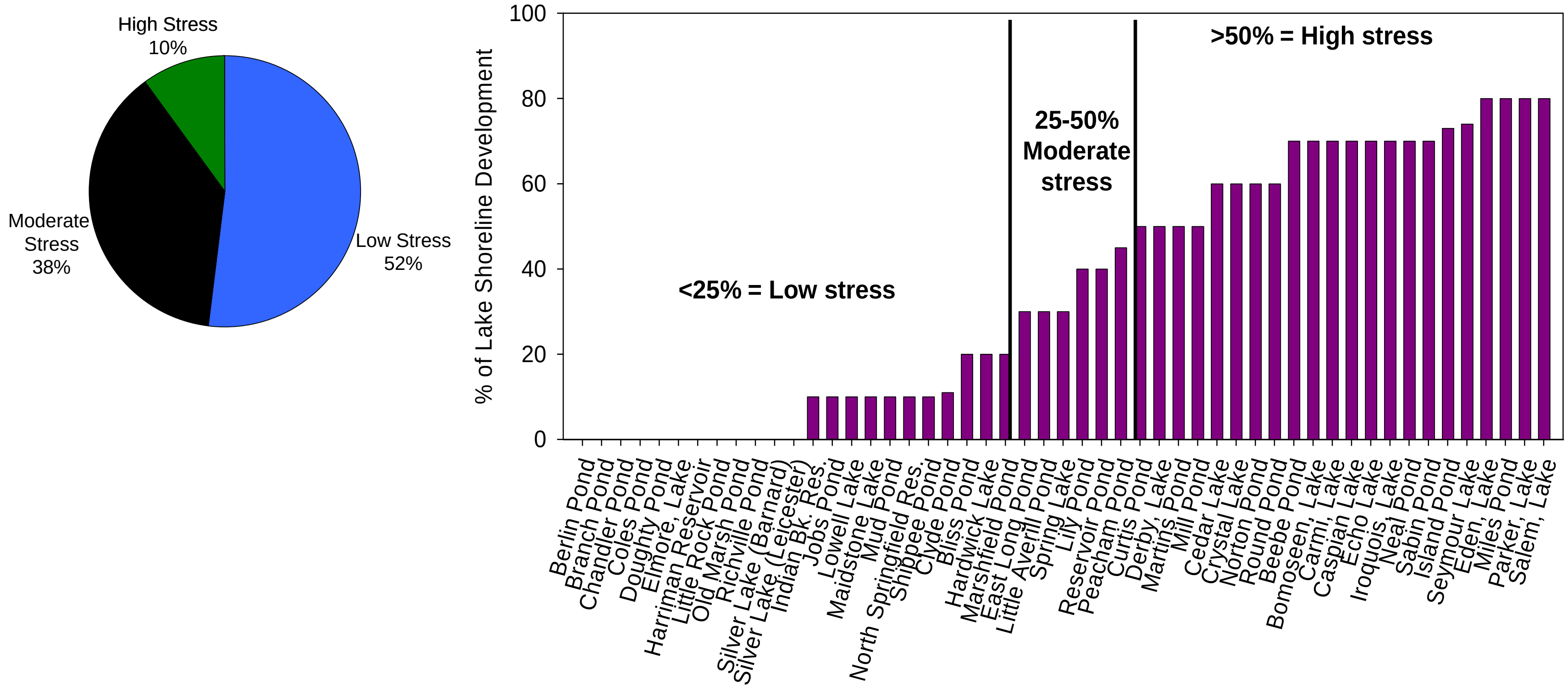
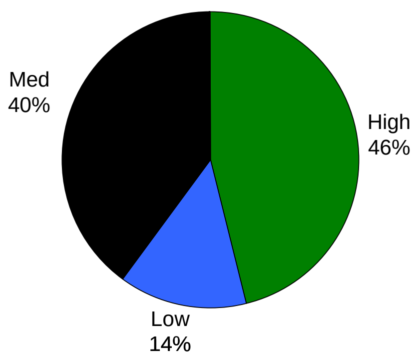


Figure 10. Percentage of shoreline development in Vermont Survey Lakes during the 2007/2008 summer sampling campaign. Pie chart shows the percent of VT Survey lakes that fall into each range. Margin of error is +/- 5%.

Aquatic Macrophytes and Aquatic Invasive Species (AIS)

Results from the Vermont Lake Survey indicate the percentage of total macrophyte coverage for each lake as varying degrees of "structural" habitat for fish and other aquatic organisms (Figure 11). The term "structural" pertains to physical structures within and around which fish and other aquatic organisms can obtain refuge from predation. In general, higher densities of aquatic plants, particularly when there is a diversity of species, yield high structural habitat, which is beneficial for fish. Increased nutrient loading from the surrounding watershed to a lake will fuel the growth of certain aquatic plant species while stifling others, reducing the diversity of plants, which is reduces the quality of fish habitat. The presence of aquatic invasive plant species (AIS), particularly in high densities, can disrupt the function of a lake ecosystem. Accordingly, the detection of such species should be documented, reported and controlled when possible. An important distinction to note is that when plant density is high due to AIS, this does not provide beneficial habitat structure, but rather a monoculture that will not allow any other vegetation to grow in the area. Figure 12 and Table 3 provide information regarding aquatic invasive species for the 2008 Vermont Survey Lakes. For more information on the Vermont Department of Environmental Conservation's Aquatic Invasive Species, please see the AIS website.



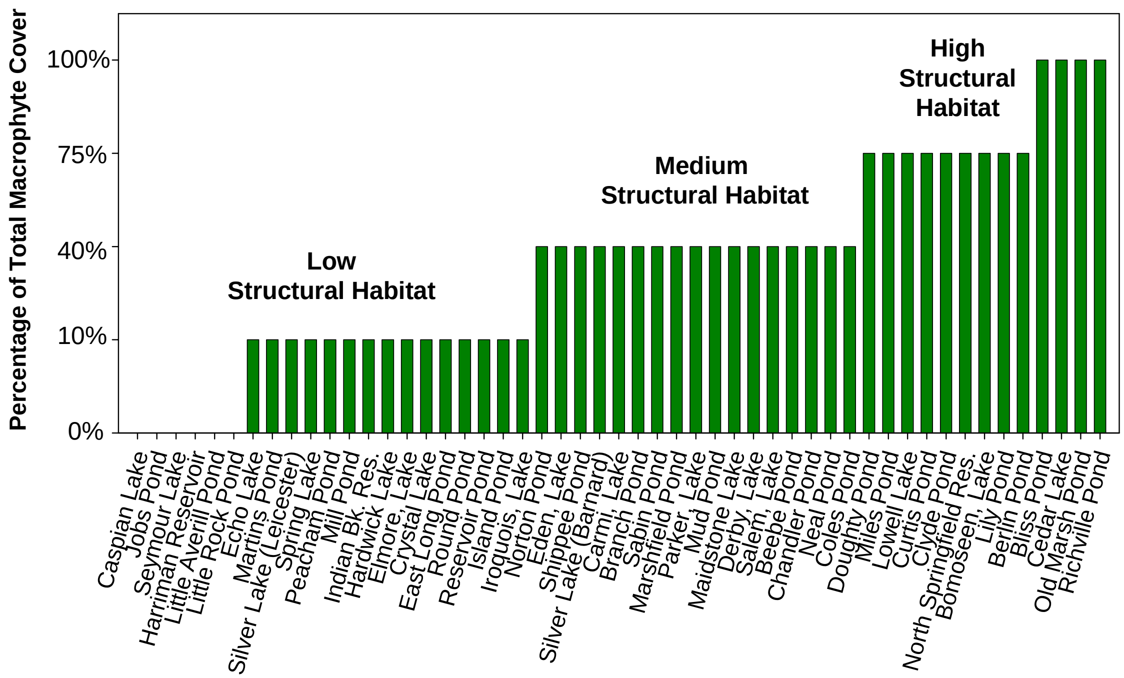


Figure 11. Percentage of total macrophyte cover in Vermont Survey Lakes during the 2007/2008 summer sampling campaign. Pie chart shows the percent of VT Survey lakes that fall into each range (Low, Medium and High Structural Habitat). Margin of error is +/- 5%.

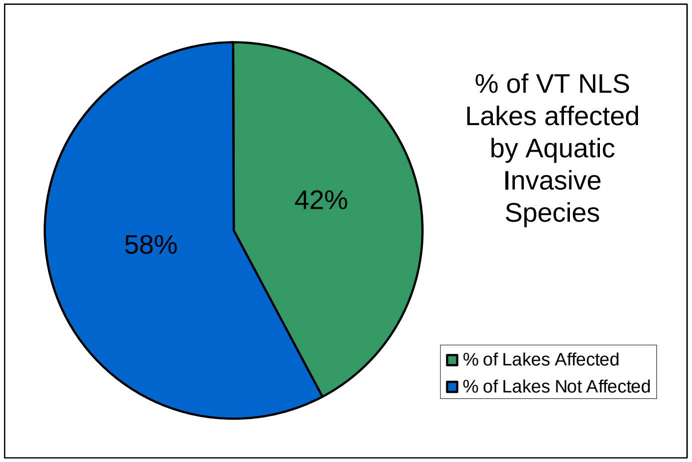


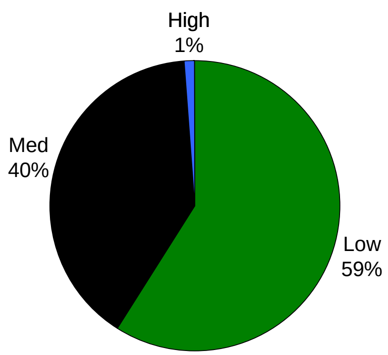
Figure 12. Percentage of 2008 Vermont Survey Lakes that are affected by AIS including Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potamogeton crispus*), water chestnut (*Trapa natans*) and purple loosestrife (*Lythrum salicaria*). Margin of error is +/- 5%. Photo shows dense Eurasian watermilfoil near a swimming beach.

Table 3. List of 2008 Survey Lakes that are affected by four particular aquatic invasive species (Eurasian watermilfoil, water chestnut, purple loosestrife, and curly-leaf pondweed). For Eurasian watermilfoil and water chestnut, letters indicate the density of the plant population (L=light, M=moderate, H=heavy, C=controlled).

Lake Name	Eurasian watermilfoil	Water chestnut	Purple loosestrife	Curly-leaf pondweed
Beebe Pond	present (L)		present	present
Berlin Pond	present (L)			
Bomoseen, Lake	present (M)	present (C)	present	present
Carmi, Lake	present (L)			
Cedar Lake	present (M)			
Clyde Pond	present (L)			
Crystal Lake	present (L)			
Derby, Lake	present (M)			
Elmore, Lake	present (M)			
Indian Bk. Res.	present (L)			
Iroquois, Lake	present (M)			present
Island Pond			present	present
Lake Champlain	present (M)	present	present	present
Lily Pond	present (L)	present (L)		present
Mill Pond	present (M)		present	
North Springfield Reservoir		present (L)		
Old Marsh Pond				present
Richville	present (H)	present (L)	present	present
Round Pond	present (M)			
Seymour Lake	present (L)			
Silver Lake-Barnrd			present	

Woody Habitat

Another key littoral habitat parameter is woody habitat (debris). “Woody debris” refers to the dead or fallen trees and branches that make their way into the littoral zone of a lake from the riparian area. Woody debris inputs to a lake are very important because they regenerate nutrients to the aquatic ecosystem and provide structural habitat for aquatic life such as fish and macroinvertebrates. Notice that the majority of Vermont lakes surveyed exhibit low woody debris coverage; this is likely due to removal for recreational uses, resulting in a loss of structural habitat for aquatic organisms. There were a number of lakes that achieved medium structural habitat designation with 40% cover of woody debris. Of particular concern are when lakes have low habitat structure due to human activities.



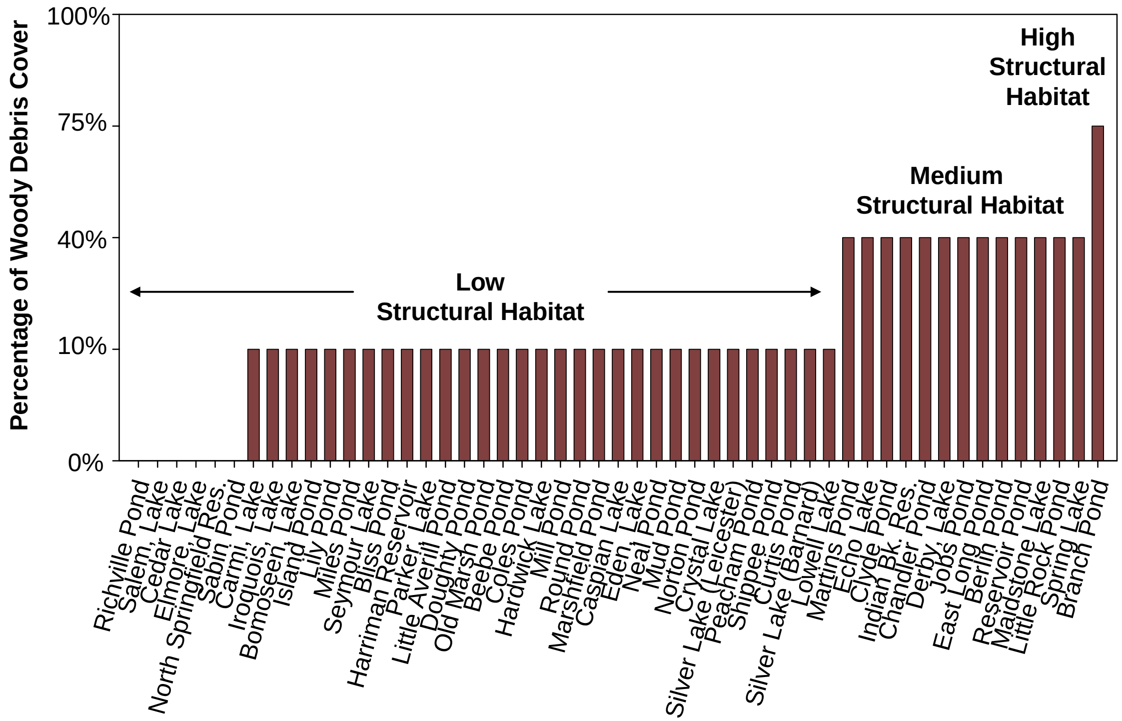


Figure 13. Percentage of woody debris cover observed in Vermont Survey lakes during the 2007/2008 summer sampling campaign. Pie chart shows the percent of VT Survey lakes that fall into each range (Low, Medium and High Woody Debris Structural Habitat). Margin of error is +/- 5%.

Comparison to National Data

In addition to analyzing the data from Vermont lakes, we also conducted a three-way comparison using box and whisker plots between NLS lakes sampled in Vermont (VT), lakes sampled in New England, and all lakes nationwide (National; Figure 14). Box and whisker plots are useful for displaying how measured values compare between sets of data. The median, or the middle line intersecting the boxes in Figure 14, is the value above and below which half of the observations lie. Reported medians are meant to be values representative or typical of the dataset and are not affected by outliers (those extremely high or low values seen as dots outside of the boxes). Box plots also illustrate the overall distribution of the data, allowing the reader to easily compare amongst the three datasets.

Vermont and Northeastern survey lakes are similar in trophic state. VT and NE lakes are comparable in terms of chlorophyll-*a* and total nitrogen, while VT lakes are only minimally higher in total phosphorus concentration and Secchi measurement relative to lakes in other northeastern states. This may be the result of subtle differences in laboratory methods between the phosphorus analyses conducted at the Vermont laboratory and those analyzed at the national laboratory. In comparing VT lakes to lakes nationally, both VT and NE lakes have a higher (deeper) median Secchi measurement, indicating generally clearer water. Conversely, the national median is higher than VT and NE lakes in chlorophyll-*a*, total phosphorus and total nitrogen. This relationship is most likely due to differences in land use between the northeast and the rest of the nation, along with differences in regional expectations. Those states that are more populated or rely heavily on agriculture will greatly impact their waterways with higher nutrient loads, resulting in elevated plant growth and increased chlorophyll-*a* production.

What It All Means

The data collected from the National Lake Survey, in addition to establishing a scientific baseline, has potential to be used in various capacities such as education, research, community organizing, land use decisions, watershed planning, and swimming advisories. The monitoring of lake resources every five years through the National Lake Survey will provide information for regulators, managers and policy makers. The survey will also provide information for landowners and community members that use and value their local lakes for recreational and ecological significance.

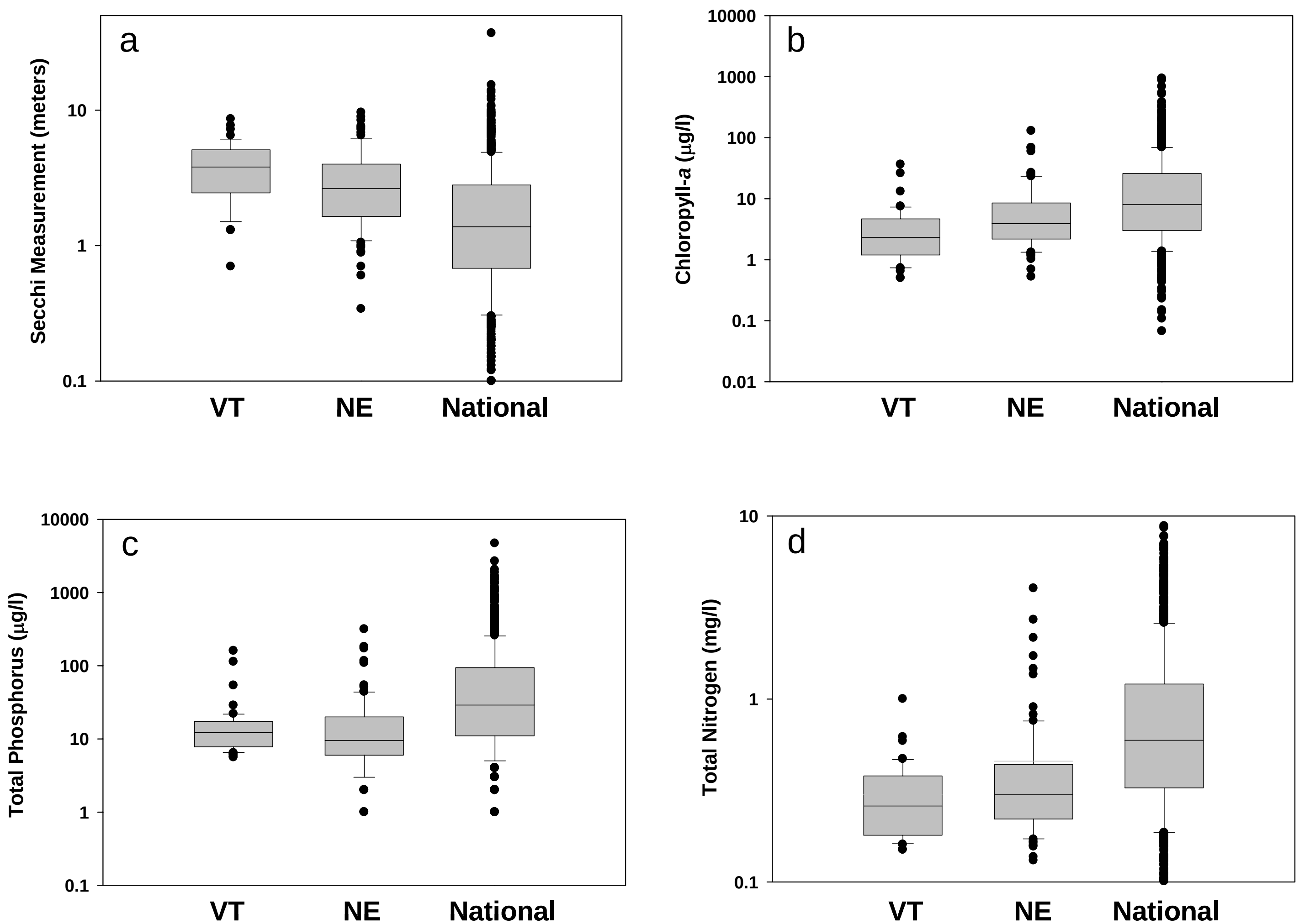


Figure 14. Comparison of key trophic status indicators: a) Secchi, b) Chlorophyll-*a*, c) Total Phosphorus, and d) Total Nitrogen between NLS lakes surveyed in Vermont (VT; n = 51), New England (NE; n = 44), and nationwide (National; n = 1,032). The box and whisker plots show the median (line intersecting box), lower and upper quartiles (top and bottom lines of box), and mild and extreme outliers (values outside of the box). Note the log scale on the y-axis.

Figures 3, 4 and 5 illustrate the placement of Vermont survey lakes into oligotrophic (low nutrients), mesotrophic (intermediate nutrient productivity) and eutrophic (nutrient-rich) categories. The reader should understand that the approach used to survey Vermont's lakes and all the lakes tested under the National Lakes Survey is not intended to comprehensively characterize the trophic condition of any particular lake. The ecological literature describes lake development as a natural progression over thousands of years from deep and oligotrophic to shallow and eutrophic, to a wetland, and then a terrestrial meadow[18]. This idea of typical lake succession is applicable to many small- and medium-sized lakes but there are always exceptions, especially with very deep lakes like lakes Willoughby and Seymour. Natural and human factors interact to influence lake trophic state. Therefore, it is unreasonable to infer trophic condition simply based on a single sampling visit during one day of the summer. Rather, the approach used in this study characterizes the population of VT lakes relative to their trophic condition. In the preceding report and figures, we have provided individual results to provide interested readers the chance to compare lakes in their particular interest to other lakes that are sampled identically.

By contrast, the assessments of littoral development and aquatic plant densities are of sufficient rigor to assess the quality of shoreline and littoral zones. If a lake has only a low quantity of woody debris, for example, it is unlikely that this will change in the near term. If a lake of interest is consistently categorized as eutrophic, or if the quality of the shoreline is assessed as low, the reader is encouraged to view this information as a way to become proactive in considering new management practices and strategies. If you are interested in becoming more involved in protecting Vermont lake(s), please visit the DEC website Lake Protection Series.[19] The Lake Protection Series offers guidance on numerous approaches to maintain the high quality of Vermont lakes and ponds as recreational and ecological resources. Landowners and engaged citizens can make a difference by planting and maintaining a buffer on the lakeshore, being aware of septic system basics, preventing driveway erosion, conducting a watershed survey, participating in lake monitoring, and starting a lake association.

A buffer strip is a 100-foot wide zone of undisturbed vegetation that runs parallel to the lake shoreline. Ideally lake shoreline camps and houses would be built at least 125 feet from the lake to provide enough room for a buffer strip. If an existing structure is closer than 125 feet to the shoreline, there are ways to make improvements to the structure and surrounding property that benefit the lake environment and enhance habitat value as well as property value. Many lakeshore residents have built retaining walls on their property to stop the erosion of the shoreline, which is more than likely occurring because of the absence of the natural stabilizing capability of deep-rooted vegetation. Trading an old wall for a restored natural shoreline will enhance privacy, scenic value, bird watching, shoreline stability, lake ecology, filtration of runoff, and property values. For more information, pleae read and learn about Planting a New Buffer.[20]

Lakeshore residents are responsible for the adequate treatment of their household waste in order to contribute to the maintenance of lake health. If a septic system is not working correctly, it can introduce nutrients and pathogens to a lake ecosystem, resulting in nutrient enrichment (eutrophication) as well as human and wildlife exposure to high levels of bacteria, some of which may be disease-causing organisms. For more information, please read about the Lakeshore Septic System Basics.[21]

Gravel roads and private driveways can be sources of erosion to lakes and streams. Therefore it is critical that residents ensure their driveways and private roads are properly maintained to prevent sediment and nutrient loading into the nearby lake. VT ANR provides helpful tips for evaluating your lakeshore roadways here.[22]

Engaged citizens are encouraged to participate in a Citizen's Lake and Watershed Survey in order to learn about your lake's watershed and potential sources of nutrient and sediment pollution. Observing watershed activities and conditions is the critical first step before taking further action to protect or restore a lake or watershed. A Watershed Survey may take time and effort to finish, but upon completion, various measures of action can be taken to improve many aspects of your lake's condition. Frequently, there are grants that can aid in correcting problem spots detected in the Watershed Survey. Conducting a Survey of a Lake Watershed[23] can help you take protective action for your lake and lake community.

Starting and Running an Effective Lake Association[24] provides a platform for a variety of projects, some of which include water quality monitoring, exotic species spread prevention or control, and shoreland and watershed protection and management. These projects allow lake association members to learn about lake ecology and management so that a clear voice can be presented to the town and state governments to gain attention and provide services that will benefit their lake.

Lakes & Pond Monitoring[25] is critical for establishing a scientific baseline for your lake in the interest of detecting environmental change over time. Carefully structured scientific observation can help lead to understanding a lake's ecosystem – a critical step before any protection or conservation measures can take place. Getting involved in the Vermont Lay Monitoring Program[26] is a great way to promote lake protection and restoration projects that build camaraderie in the community while also educating people about the lake ecosystem. Moreover, the data from the Lay Monitoring Program contribute to a long-term database that is used to assess lake condition trends over time and offers an opportunity to compare a one-time lake sampling event, such as the Vermont Lake Survey, to robust, long-term data.

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