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# Designated Use Assessment and Condition Estimates of New Hampshire's Lakes, Ponds and Reservoirs

# 2017 – 2019

## A statewide probability survey

Ellsworth Pond, Ellsworth, NH

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

February 2022

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# 2017 – 2019

## A statewide probability survey

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## Acronyms

| *Acronym* | *Definition* |
|---|---|
| ALU | Aquatic Life Integrity |
| ANC | Acid Neutralizing Capacity |
| CALM | Consolidated Assessment and Listing Methodology |
| Chl-a | Chlorophyll-*a* |
| DHHS | Department of Health and Human Services |
| PHL-WAL | Public Health Laboratory's Water Analysis Laboratory |
| DO | Dissolved Oxygen |
| EPA | Environmental Protection Agency |
| FS | Full Support |
| II | Insufficient Information |
| JCLC | Jody Connor Limnology Center |
| LDI | Lakeshore Disturbance Index |
| LTSP | Lake Trophic Survey Program |
| NAP | Northern Appalachian eco-region |
| NARS | National Aquatic Resource Survey |
| NHDES | New Hampshire Department of Environmental Services |
| NLA | National Lake Assessment |
| NS | Not Support |
| PAS | Potentially Attaining Support |
| PCR | Primary Contact Recreation |
| PNS | Potentially Not Support |
| SCR | Secondary Contact Recreation |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| VLAP | Volunteer Lake Assessment Program |

## Executive Summary

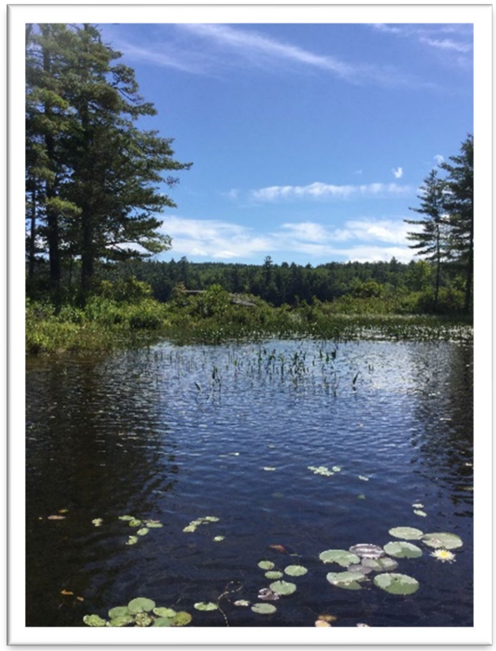
New Hampshire's surface waters are vital natural resources that provide habitat for aquatic life, recreational opportunities, tourism and economic benefits. The New Hampshire Department of Environmental Services (NHDES) is responsible for monitoring and reporting on the condition of the state's surface waters. The Water Monitoring Strategy, published by NHDES in 2016, details the agency's approach for monitoring the condition of the state's inland surface waters. One component of this strategy is to provide regular reports on statewide probabilistic surveys, which use a randomized selection of sample locations intended to be representative of the entire population of surface waters. By collecting data from these randomly selected sites, the overall condition of the waterbody population can be assessed with a known level of confidence. Probability surveys represent a cost-effective means for estimating and reporting on the physical, chemical and biological conditions by waterbody type and the factors that affect these conditions at a particular point in time.

NHDES statewide probability surveys build on the National Aquatic Resource Surveys (NARS) used by the United States Environmental Protection Agency (EPA). In 2017, NHDES participated in the third National Lake Assessment (NLA), in partnership with EPA, to assess the status of and changes in quality of the nation's lakes, ponds and reservoirs. In addition to the NLA, NHDES requested that additional sites in New Hampshire be randomly selected according to EPA's protocols. These additional waterbodies were surveyed by NHDES biology section staff in the summers of 2017, 2018 and 2019. By using EPA's randomized design and methodology, NHDES was able to complete a statewide probabilistic survey of lakes, ponds and reservoirs, the results of which are detailed in this report.

The probabilistic survey assessed New Hampshire's lakes, ponds and reservoirs for designated uses Aquatic Life Integrity (ALU), Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR). Less than 10% of New Hampshire's lakes, ponds and reservoirs met the ALU designated use, primarily due to low pH values. PCR designated use assessment, however, had over 90% of New Hampshire lakes achieving full support, and 100% of New Hampshire lakes were in full support of SCR. This indicates that the majority of New Hampshire lakes and ponds are safe for recreation, despite a lower level of support for aquatic life.

Probabilistic survey data were also compared to national and eco-regional results. A comparison of condition estimates among geographic areas are useful in determining the condition of New Hampshire lakes, ponds and reservoirs relative to other areas of the nation. For most assessed water quality parameters, the highest percentage of New Hampshire lakes were classified as being in fair condition when compared to national or eco-regional benchmarks.

## 1. Introduction



The NLA is a collaboration among the EPA, states, tribes, federal agencies and other organizations to assess the quality of the nation's lakes, ponds and reservoirs (hereafter collectively referred to as lakes). Using probability-based sampling, the survey aims to estimate lake condition on a national and eco-regional scale using consistent protocols. This randomized statistical sampling approach is intended to reflect the full range of variation among lakes in the United States. The NLA is scheduled to occur in five-year increments, with field seasons having occurred in 2007, 2012 and 2017. For a full description of the national project, please visit the 2017 NLA Quality Assurance Project Plan [1].

NHDES has participated in the NLA since its inception in 2007. In 2017, in addition to participating in the NLA, NHDES undertook an intensified state level assessment. To participate in the base NLA, 11 New Hampshire lakes were sampled, with two lakes resampled, per NLA protocol. From an overdraw pool of randomly selected lakes, 39 additional lakes were chosen and sampled over the summers of 2017, 2018 and 2019, for a total of 50 individual lakes, to complete the state level assessment. As the 50 lakes were randomly selected with consideration to their size (i.e. surface area), NHDES can draw conclusions about the conditions of New Hampshire's entire lake population.

## 2. National Aquatic Resource Surveys (NARS)

NARS are collaborative monitoring programs among the EPA, states, tribes, federal agencies and other organizations. These stratified randomized statistical surveys are designed to assess the status of and changes in quality of the nation's coastal waters, lakes and reservoirs, rivers and streams and wetlands. While NARS occurs every year, each waterbody "type" is targeted on a set annual rotation. Lakes are studied via the NLA once every five years, which have occurred in 2007, 2012 and 2017. This study allows for the characterization of lakes at national and regional scales using chemical, physical and biological indicators. It is not intended to represent the condition of individual lakes.

## 3. NHDES Water Monitoring Strategy

In 2016, NHDES released a water monitoring strategy that detailed the Watershed Management Bureau's (WMB) inland surface water monitoring plans from 2014 to 2024. To make informed and accurate water management decisions, communicate to the public the status of the health and safety of the State's waters, and satisfy federal reporting requirements, the Water

Monitoring Strategy [2] outlined three design components to achieve these objectives: probability-based water quality surveys, trend-based monitoring and synoptic (or site-specific) monitoring. Each component targets a different aspect of inland surface water monitoring. Taken together, these three approaches provide the necessary structure to ensure NHDES acts as a steward of public water resources.

Probability-based monitoring refers to the random selection of a subset of sample locations that are representative of the entire population of a particular waterbody type. As sampling every unit of a population is expensive and impractical, random sampling ensures no particular portion of the population is being favored over another. Results of probabilistic sample surveys can be used to make statistically based inferences about the population as a whole. Probability-based monitoring is made possible by collaboration between NHDES and EPA. Through NARS, EPA can characterize a target population (e.g., estuaries, rivers or lakes) at a national and regional scale; however, this program is not fine scaled enough to make inferences at an individual state level. To draw conclusions about New Hampshire specifically, an enhancement or "intensification" must occur. With additional randomly selected waterbody units, the entire population of a particular waterbody type in New Hampshire can be assessed.

NHDES has been assisting EPA in conducting national probabilistic assessments since 2004. Probabilistic assessments have been conducted on estuaries twice, rivers and streams twice and lakes twice in the past 16 years. For lakes, the first statewide probability survey was conducted from 2007 – 2009 [3]. This report summarizes the results of the second probabilistic assessment of lakes. NHDES intends to conduct a statewide lake probabilistic survey every 10 years, with the next survey planned for 2027.

Under Section 305(b) of the Clean Water Act, NHDES is required to submit reports on the quality of New Hampshire's waters to EPA every two years. Data are submitted to the Assessment, Total Maximum Daily Load Tracking and Implementation System (ATTAINS). Probabilistic assessments are useful for this reporting because they can provide a general overall idea of the condition of an entire waterbody type. This probabilistic assessment was used to report on Aquatic Life Use and Primary and Secondary Contact Recreation designated uses, which are required by EPA (see section 'Designated Uses' for more information). Secondarily, this probabilistic assessment compared New Hampshire lakes to national and eco-regional populations. Via NARS, EPA identified thresholds for individual water quality parameters at national and eco-regional scales. These thresholds help classify lakes as being in good (least disturbed), fair (moderately disturbed) or poor (highly disturbed) condition. While not required for reporting under Section 305(b), this comparison allows for a greater understanding of how New Hampshire's lakes compare to other states. The details of EPA's threshold development can be found in the 2012 NLA Technical Report [4].

## 4. Designated Uses

Designated uses are the desirable uses that surface waters should support (e.g. swimming, fishing) and are regulated under New Hampshire's surface water quality standards as described by Env-Wq 1700 and further outlined in the Consolidated Assessment and Listing Methodology

(CALM) [5]. These water quality regulations (e.g., Water Quality Standards) determine the baseline water quality that all surface waters must meet in order to protect their intended (i.e., designated) uses. They are the "yardstick" for identifying where water quality impairments exist and for determining the effectiveness of regulatory pollution control and prevention programs. NHDES is required to report to EPA on the status of the State's designated uses every two years. There are six designated uses for New Hampshire's surface waters, with one designated use split into two sections (Table 2). New Hampshire surface waters are broken up into sections, individually called an "assessment unit," and are evaluated for whether designated uses are attained, impaired or threatened. Different categories exist for whether an assessment unit does or does not meet its designated uses, and these categories are influenced by the number of data points available, the age of the data, how close the data are to thresholds, whether a potential pollutant has been studied and documented, and waterbody class. Waterbody class is broken into Class A and Class B waters, with Class A striving for the highest quality and Class B striving for the second highest quality (RSA 485-A:8). A waterbody's classification is a legislative designation and management goal and not necessarily reflective of current condition.

For the purposes of this report, water quality parameters that inform designated uses are categorized as full support (FS), not support (NS), potentially attaining support (PAS), potentially not support (PNS) and insufficient information (II; Table 1). The probability assessment sought to address Primary Contact Recreation (PCR), Secondary Contact Recreation (SCR) and Aquatic Life Integrity (ALU) designated uses, which is in line with the majority of assessments (Table 2). Other designated uses were either not applicable to lakes, lacked numeric criteria or were cost-prohibitive. Typically, whether a particular waterbody does or does not meet its designated uses is determined from multiple samples collected upon multiple dates over time. A probabilistic assessment, however, provides a statewide overview of how well the entirety of a waterbody group does or does not meet designated uses without classifying individual waterbodies. This parameter-level and designated use-level classification is based upon water quality data collected from a single sample visit (an exception to this sampling methodology is the collection of bacteria samples; see section Field Collection Procedures for more information).

**Table 1. Designated use classification for water quality parameters.**

| Classification | Acronym | EPA Category | Description |
|---|---|---|---|
| Full Support | FS | 2 | All samples for a given parameter meet water quality standards or an exceedance is due to natural causes. |
| Not Support | NS | 4, 5 | Water quality standards are not met, and an impairment is present. Parameter may or may not be a pollutant. |
| Potentially Attaining Support | PAS | 3 | Insufficient data to assess the parameter, however, available data suggest water quality standards are supported. |
| Potentially Not Support | PNS | 3 | Insufficient data to assess the parameter, however, available data suggest water quality standards may not be supported. |
| Insufficient Information | II | 3 | Not enough information to assess water quality standards. |

**Table 2. Designated uses for New Hampshire surface waters.**

<table>
<tr><th>Designated Use</th><th colspan="3">NH Code of Administrative Rules (Env-Wq 1702.17) Description</th><th>Applicable Surface Waters</th></tr>
<tr><td>Aquatic Life Integrity</td><td colspan="3">The surface water can support aquatic life, including a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of the region.</td><td>All surface waters</td></tr>
<tr><td>Fish Consumption</td><td colspan="3">The surface water can support a population of fish free from toxicants and pathogens that could pose a human health risk to consumers.</td><td>All surface waters</td></tr>
<tr><td>Shellfish Consumption</td><td colspan="3">The tidal surface water can support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers.</td><td>All tidal surface waters</td></tr>
<tr><td>Potential Drinking Water Supply</td><td colspan="3">The surface water could be suitable for human intake and meet state and federal drinking water requirements after adequate treatment.</td><td>All surface waters</td></tr>
<tr><td rowspan="3">Swimming and Other Recreation In and On The Water</td><td rowspan="3">The surface water is suitable for swimming, wading, boating of all types, fishing, surfing, and similar activities.</td><td colspan="2">NHDES Clarification</td><td rowspan="3">All surface waters</td></tr>
<tr><td>Primary Contact Recreation<br>(i.e. swimming)</td><td>Waters suitable for recreational uses that require or are likely to result in full body contact and/or incidental ingestion of water</td></tr>
<tr><td>Secondary Contact Recreation<br>(i.e. boating)</td><td>Waters that support recreational uses that involve minor contact with the water.</td></tr>
<tr><td>Wildlife</td><td colspan="3">The surface water can provide habitat capable of supporting any life stage or activity of undomesticated fauna on a regular or periodic basis.</td><td>All surface waters</td></tr>
</table>

## 5. Condition Estimates

The NLA seeks to answer the following questions about lakes across the United States:

1) What is the current biological, chemical, physical and recreational condition of lakes?
2) Is the condition of lakes getting better, worse or staying the same?
3) Which environmental stressors are most associated with degraded biological condition in lakes?

To answer these questions, EPA used two processes for defining benchmarks: 1) fixed benchmarks that spanned the nation; and 2) benchmarks that varied by eco-region (Map 1). Benchmarks serve as the divisions among different classification levels. Fixed benchmarks were used for established limnological definitions (e.g., trophic status; see Lake Productivity section for more information) or water quality thresholds that could be consistently applied (e.g., low dissolved oxygen levels that have been shown to be detrimental to aquatic life). Eco-regional benchmarks, on the other hand, were used when baseline condition is dependent on location (e.g., a lake in a grassland habitat will have different background nutrient levels compared to a lake in a mountainous habitat). For condition estimates trying to quantify disturbance or the magnitude of human alteration of biological processes, the classification levels were broken into three categories: good (least disturbed), fair (moderately disturbed) or poor (highly disturbed) condition.

To establish eco-regional benchmarks, previous NLA surveys targeted reference lakes to establish baseline condition references, or what constituted least disturbed condition for a particular area. After sampling, percentiles for individual water quality parameters for each eco-region were calculated from the reference data. These percentiles were used to establish benchmarks or "cutoffs" among the categories, where the cutoff between least disturbed and moderately disturbed lakes was set at the 75$^{th}$ percentile and the cutoff between moderately and most disturbed lakes was set at the 95$^{th}$ percentile. In other words, any lake with a water quality parameter aligned with the 50$^{th}$ percentile of reference lakes was considered to be in "good" condition; alternatively, if that sampled lake had a water quality parameter that aligned with the 98$^{th}$ percentile of reference lakes, it would be considered to be in "poor" condition for that parameter.

Condition estimates allow EPA to understand and classify water quality on a national and/or eco-regional scale. Under the national survey design, the scale of design is too broad to draw conclusions about New Hampshire individually; however, by participating in a state intensification, enough data are collected to measure the overall condition of New Hampshire lakes as well as compare the state's lakes to the nation and its eco-region for select water quality parameters. New Hampshire's state intensification allowed for the examination of condition of six water quality parameters (Table 3) and trophic class. Assessing condition of macroinvertebrate or plankton communities was beyond the scale of the state intensification. The entirety of New Hampshire falls into the Northern Appalachian eco-region (NAP), which covers all of the New England states, most of New York, the northern half of Pennsylvania, and northeast Ohio (Map 1). There are nine eco-regions in the NLA, which are aggregations of Level III eco-regions delineated by EPA for the continental U.S. (Map 1). NAP eco-region is estimated to encompass 4.6% of the conterminous U.S. and is described as cold to temperate and generally hilly, with some intermixed plains and mountains.

EPA shared the 2017 NLA results and updated benchmark information with NHDES prior to publication for the purpose of this state report. Trophic state and water quality parameters that use national benchmarks were classified using thresholds developed from previous NLAs. Water quality parameters that use eco-regional benchmarks were given updated thresholds using the 2017 data. While the 2017 NLA Technical Report is still in draft, the 2012 NLA Technical Report [4] is available. The results of the 2017 are anticipated to be published in 2022 and will be available on the EPA website, along with results of past NLA surveys.


**Map 1. Eco-regional Map of the Conterminous United States. The entirety of New Hampshire falls into the Northern Appalachian ecoregion (NAP).**

## 6. Lake Productivity

Trophic status is a measurement of a lake's overall biological productivity, or the amount of biological energy cycling within a lake. Higher levels of biological productivity or energy are associated with higher levels of organic matter, such as abundant plant growth, algal blooms or poor water clarity. Oligotrophic, mesotrophic and eutrophic are the most common trophic classifications. Oligotrophic lakes have low nutrient levels, clear water, and few aquatic plants. Eutrophic lakes are highly productive with high levels of organic matter. Water clarity is low, aquatic plants may be abundant, and the eutrophic lake may experience frequent algal blooms. Mesotrophic lakes have productivity levels in between oligotrophic and eutrophic classes. Under typical conditions, a lake slowly becomes more productive over thousands of years (i.e., lake aging). However, in a process called cultural eutrophication, human activities can lead to the premature aging (i.e., increased biological productivity) of a lake through elevated nutrient inputs.

NHDES has been surveying the trophic status of New Hampshire's lakes under the Lake Trophic Survey Program (LTSP) since 1975. NHDES developed a trophic classification for New Hampshire lakes and ponds under the LTSP, which uses a ranking system that incorporates algal concentration (as measured by chlorophyll-*a* concentration), aquatic vegetation density, water transparency and dissolved oxygen levels. This ranking system is original to NHDES, and other methodologies exist to determine trophic status. For example, NLA determines trophic state based on chlorophyll-*a* concentration alone (Table 3). To learn more about NHDES' LTSP, see our Sources of Information and Explanation of Lake Trophic Data document [6].

Trophic classification information is necessary when assessing ALU designated use for chlorophyll-*a* concentration and total phosphorus, as both parameters tend to increase as biological productivity increases (Table 3). Due to the slow process of lake aging, individual lakes are expected to maintain their LTSP trophic classification. If a lake becomes more biologically productive and ensuing LTSP assessments reflect a change in trophic classification, the lake is assumed to be experiencing cultural eutrophication. The lake is still assessed at its historically "best" or least productive trophic class because failure to meet that standard indicates a degraded system. For example, if a lake has a total phosphorus value of 9 μg/L, the ALU designated use would be met if the lake was classified as mesotrophic, but would fail if the lake was classified as oligotrophic (Table 3; see the CALM [5] for more information).

**Table 3. Total phosphorus (TP) and chlorophyll-*a* (Chl-a) values by trophic class.**

| Trophic class | TP (μg/L) | Chl-a (μg/L) | NLA Chl-a Thresholds (μg/L) |
|---|---|---|---|
| Oligotrophic | < 8.0 | < 3.3 | ≤ 2.0 |
| Mesotrophic | ≤ 12.0 | ≤ 5.0 | >2.0 and ≤ 7.0 |
| Eutrophic | ≤ 28.0 | ≤ 11.0 | >7.0 and ≤ 30.0 |
| Hypereutrophic | N/A | N/A | > 30.0 |

## 7. Lake Selection

### 7.1 Eligible Lakes

To be included in the base 2017 NLA, a freshwater lake, pond or reservoir, either natural or human-made, had to have a surface area greater than 2.47 acres (1 hectare), be at least 3.3 feet (1 meter) deep at its deepest point, and have a minimum of a quarter acre (0.1 hectare) of open water during the summer sampling period. Exceptions to this targeted population that may meet the size requirements but are excluded are as follows:

- Ephemeral waterbodies (i.e., highly likely to be dry between May and September).
- Waterbodies along the coast or near an estuary that are tidally influenced.
- Run-of-the-river reservoirs with retention times < 1 week.
- Used exclusively for aquaculture.
- Waterbodies with no recreational or aquatic life uses.
- Sewage lagoons.

- Disposal ponds (e.g., mine tailings).
- Evaporation ponds.
- Storm water retention basins.
- Waterbodies constructed solely for storage of drinking water.
- Active quarries.
- Borrow pits.
- Constructed stock or farm ponds where there was previously no waterbody.

With these criteria, EPA generated a ranked list of lakes for each state. NHDES was responsible for reviewing the list of New Hampshire lakes to ensure the selection criteria were met as well as evaluate lakes based on access (e.g., terrain, remoteness) and permission (e.g., private property). If a lake had been surveyed previously, NHDES historical records were used to determine access and suitability. If the lake has not been previously surveyed, it was examined remotely using aerial photography and road coverage information. If the desktop reconnaissance was insufficient, a field visit was conducted to see if a determination of morphological suitability or access could be made. See the 2017 NLA Site Evaluation Guidelines for additional information [7].

## 7.2 Survey Design

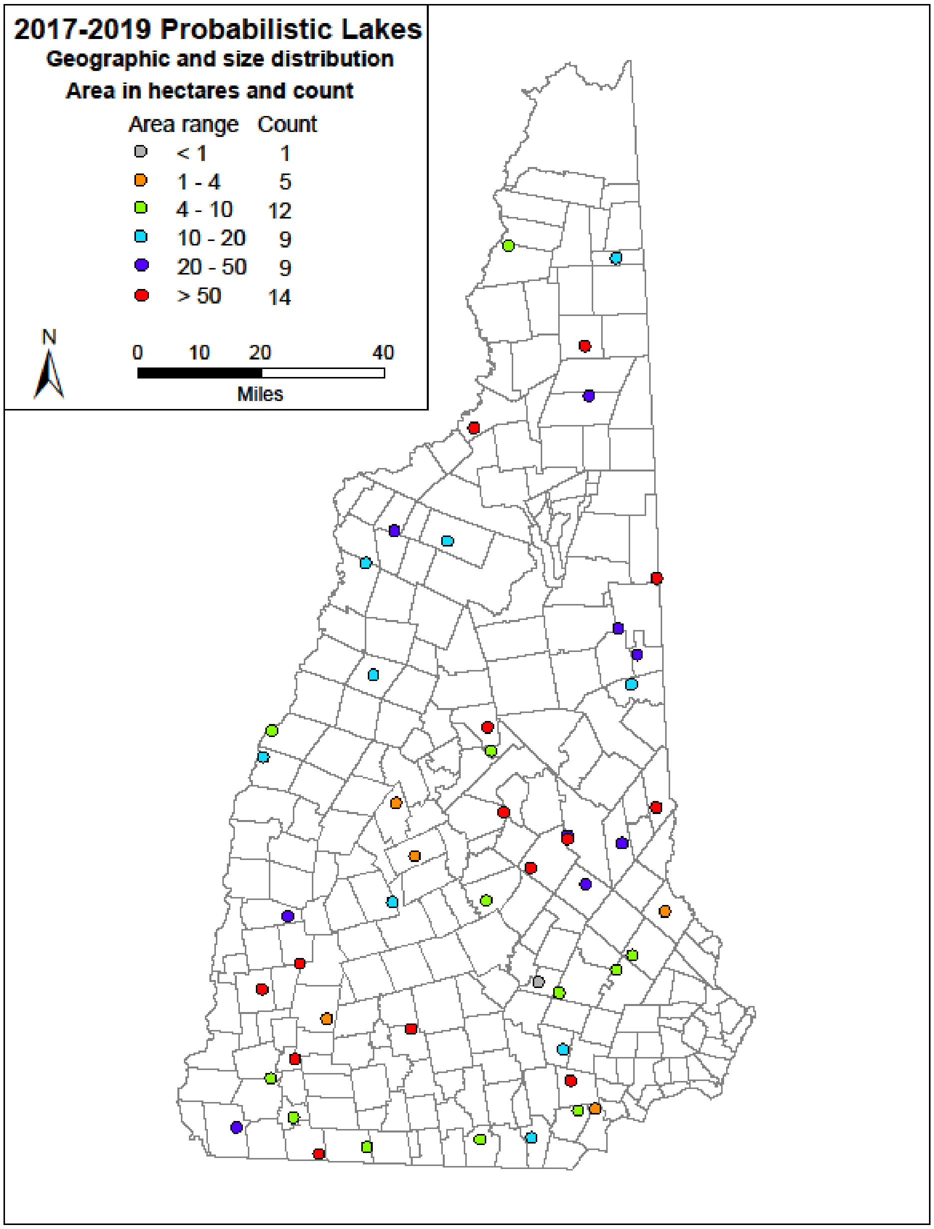
The EPA used a Generalized Random Tessellation Stratified (GRTS) survey design to select lakes for the 2017 NLA to encapsulate the full range of conditions across the entire nation. Using this survey design allows data from the subset of sampled lakes to represent the larger population with known confidence bounds (see the 2012 NLA Technical Report [4] for more information). This selection process categorized lakes based on their surface area (measured in hectares [ha]), previous survey history and location. The surface area categories were 1 to 4 ha, 4 to 10 ha, 10 to 20 ha, 20 to 50 ha and > 50 ha. The previous survey history and location categories considered 2007 and 2012 NLA sample efforts, whether repeat visits were desired, and political boundaries (e.g., state line). The intent of NLA was to sample an equal proportion of lakes from each category to draw conclusions about the entire population. As lakes are not equally distributed throughout the country (e.g., western states have fewer lakes than eastern states) and smaller lakes are more common than large, there were inequalities in the likelihood of lakes being randomly selected. To achieve the goal of assessing the national lake population while accounting for the unequal likelihood of selection, EPA assigned a weighting factor to each size category of lakes for use during data analysis. Weights allow data to have a smaller or larger influence on the final results depending on what size category the lake belonged to, so that no portion of the population was over or underrepresented.

The evaluation process for the NLA differs from many other monitoring and assessment studies in that the accounting of candidate lakes that are not sampled is almost as important as identifying the lakes that will be sampled. Accounting for the status of all candidate lakes, sampled or not, provides the means to improve the survey design and site selection process, refine the sampling frame to reduce the number of non-target waterbodies, and acknowledge any potential caveats for interpreting the results. During any given phase, candidate lakes that are determined to not meet criteria or cannot be sampled are replaced with the next successive lake selected from the ranked "overdraw" list. It is important that these alternate lakes are selected consecutively, without skipping over any on the list, to maintain the random nature of the final list of sampled lakes.

### 7.3 State Intensification (a.k.a. "Overdraw")

NHDES chose to participate in a state probabilistic survey in addition to the 2017 NLA. To conduct a probabilistic assessment, NHDES requested an "overdraw," which was an expanded list of randomly selected lakes from EPA. To help identify lakes for the enhanced survey effort, NHDES provided EPA with a 1: 24,000 National Hydrography Dataset (NHD) linked to the State's waterbody assessment units (AUIDs). Lake selection for the state intensification was subject to the same eligibility requirements and survey design, with the exception of the inclusion of lakes in a smaller size category (0 to 1 hectare), as what was required in the NLA. For NHDES' purposes, lakes are assessed for designated uses regardless of surface area and including all size categories provided the most comprehensive overview of statewide lake condition.

EPA combined the NHD submitted by NHDES with their 2012 NLA data frame, for a total of 3,596 lakes representing 74,208 hectares of lake surface area. This data frame included an estimated 2,140 target and 1,456 non-target lakes. Non-target lakes are waterbodies that did not meet selection criteria. From the overdraw population, 86 lakes were examined remotely and, if necessary, in person, to confirm selection criteria were met (see section Eligible Lakes for more information). Thirty-six lakes were disqualified (23 failed to meet the eligible criteria; eight were inaccessible; and five had access permission denied). The final selection of 50 lakes consisted of 11 lakes that were part of the base NLA and 39 lakes to complete the statewide intensification (Map 2).




**Map 2. Location and size class of New Hampshire waterbodies selected for the probabilistic monitoring survey.**

## 8. Water Quality Parameters

NHDES collected a variety of different water quality parameters (Table 4). These data were informative for determining designated use attainment and/or determining condition estimates as compared to national or eco-regional thresholds.

**Table 4. Designated use and condition estimate water quality parameters collected during the 2017-2019 lake probability survey.**

| Parameter | Unit | Parameter Description | NH Designated Use | Used for NLA Condition Estimates |
|---|---|---|---|---|
| Acid Neutralizing Capacity | mg/L | A measure of a waterbody's ability to resist acidic inputs, a.k.a. buffering capacity. | ALU | Yes |
| Bacteria | CFU/ 100mL or MPN/100mL | A measure of the concentration of E. coli, a common bacterium that is present in the fecal material of warm-blooded animals. | PCR; SCR | |
| Chloride | mg/L | The chloride ion ($Cl^-$) is found naturally in some surface and ground waters and in high concentrations in seawater. New Hampshire tends to have naturally low chloride content, making elevated concentrations an indication of anthropogenic disturbance. Elevated chloride levels can be toxic to freshwater aquatic life. | ALU | |
| Chlorophyll-a | µg/L | A photosynthetic pigment found in plants that serves as a measure of the abundance of suspended algae. | PCR; ALU | Yes |
| Cyanobacteria | cells/mL | Photosynthetic bacteria that are capable of producing toxic blooms. Occurs naturally in waterbodies but can increase in abundance with excessive nutrients. Formerly known as blue-green algae. | PCR | |
| Dissolved Oxygen | mg/L and % | The concentration of oxygen in water. Low or highly variable dissolved oxygen concentrations can result from excessive biological activity such as decomposition of organic material. | ALU | Yes |
| Invasive Aquatic Plants | Species | Non-native species that are a threat to ecological, aesthetic, recreational and economic values of freshwater resources. | ALU | |
| Lakeshore Disturbance | Qualitative Ranking | A measure of the presence of human activity on the lakeshore and in the nearshore area. | | Yes |
| pH | None | A measure of the water's acidity. In addition to natural processes, the pH of surface water is affected by the precipitation of acidic compounds, such as sulfuric or nitric acid, released into the atmosphere as a result of industrial processes. | ALU | |
| Total Nitrogen | mg/L | The sum of Total Kjeldahl Nitrogen (ammonia, organic and reduced nitrogen) and Nitrate-Nitrite Nitrogen. Nitrogen is naturally abundant in the environment but elevated values in lakes can be caused by sewage or fertilizer run-off. | | Yes |
| Total Phosphorus | µg/L | Typically, the limiting nutrient for aquatic plants and algae in NH lakes. Sources of total phosphorus may be natural, such as background weathering and leaf litter, or anthropogenic, such as stormwater run-off, septic system inputs, or fertilizers. | ALU | Yes |
| Water Temperature* | Degree Celsius | Aquatic communities are adapted to specific water temperature conditions. Water temperatures can be affected by air temperature, shading, tributary streams, water clarity and global climate patterns. | ALU* | |

ALU = Aquatic Life Integrity; PCR = Primary Contact Recreation; SCR = Secondary Contact Recreation  * Necessary for determining DO assessment

## 9. Field Collection Procedures

Lakes were sampled once during summer months (June 1 – September 15) according to NLA and NHDES protocols. Base NLA lakes were sampled during the summer of 2017, while overdraw lakes, for the purpose of completing the statewide probabilistic assessment, were sampled during the summers of 2017, 2018 or 2019.

The NLA requires the collection of a multitude of physical, chemical and biological indicators. Base NLA sampling was performed by four NHDES staff, split into two teams. One team circumnavigated the shoreline to stop at ten randomly generated, equally spaced locations for macroinvertebrate collection and physical habitat assessment. Physical habitat assessment characterized both the riparian and littoral zone, using quantitative scoring to assess qualitative factors, such as human disturbance, habitat complexity and water level fluctuations. Invasive aquatic plants were documented at the habitat sites or noted as a general waterbody feature. The other team determined the location of the deepest point of the lake. Once the deepest point was located, water temperature, dissolved oxygen, specific conductance and pH readings were collected at predefined depth levels using a multi-parameter water quality sonde. These profiles were collected every meter (or every half meter for waterbodies < 3 m deep) from the water surface to approximately a half meter above the lake bottom. Water transparency was measured with a Secchi disk, and plankton were collected via vertical tow using a Wisconsin plankton net. Water samples were collected using a composite tube that collected water from the surface to two-meters depth (hereafter referred to as a "two-meter composite"). Lastly, a sediment core was collected at the deep spot location. These samples and data were submitted to EPA or their contracted laboratories. For a detailed description of field protocols, visit the NLA 2017 Field Operations Manual [8]. Additional water from the two-meter composite was reserved for processing at NHDES' Jody Connor Limnology Center (JCLC) or the Department of Health and Human Services Public Health Laboratory's Water Analysis Laboratory (DHHS PHL-WAL; see Table 4 for parameter information). An *E. coli* sample was collected near the shoreline at a recreational swimming area or in an area deemed most likely to receive human contact. This same near-shore area was revisited two more times to collect two additional *E. coli* samples, for a total of three samples, within a 60-day time period. Collecting three *E. coli* samples in a 60-day time period was specifically for assessing this parameter for the contact recreation designated use and not a part of the 2017 NLA sampling protocol (Table 4; CALM [5]). If a cyanobacteria bloom was suspected, a water sample was taken at the area of the suspected bloom. The reserve water from the two-meter composite, *E. coli*, and cyanobacteria samples were analyzed at NHDES' JCLC or DHHS PHL-WAL, depending on the parameter.

Overdraw sites were subject to sampling for a subset of NLA sample procedures. No macroinvertebrate samples, plankton samples, or sediment cores were collected. Physical habitat assessments were only conducted if the sample event was paired with NHDES' LTSP (see section Lake Productivity for more information). A single team deployed directly to the deep spot location to collect a water temperature, dissolved oxygen, specific conductance and pH profile using a multi-parameter water quality sonde. Once the profile was completed, a two-meter composite water sample was collected. During the three years of sample collection, equipment failure occasionally sidelined the multi-parameter water quality sonde. In such cases, only a water temperature and dissolved oxygen profile was collected. An *E. coli* sample was collected near the shoreline at a recreational swimming area or in an area deemed most likely to receive human contact. This same near-shore area was revisited two more times to collect two separate *E. coli* samples, for a total of three samples, within a 60-day time period. If a cyanobacteria bloom was suspected, a water sample was taken at the area of the suspected bloom. Invasive aquatic plant presence was determined from historical records if not noted during the visit. Overdraw water samples were analyzed exclusively at JCLC and DHHS PHL-WAL. Table 4 outlines the water quality parameters that were analyzed. The results of the water samples processed at JCLC and PHL-WAL, for both base and overdraw sites, are presented in this report.

## 10. Climate Conditions

Summer temperature and precipitation records, in this case defined as the months of June, July and August, were obtained for Concord, NH from the National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) for the years of 2017, 2018 and 2019. Each summer's records were compared to the 30-year average (1981-2010).

In the summer of 2017, average summer temperature was equal to the 30-year average, and total precipitation was 1.16 inches below the historic average. In the summer of 2018, average summer temperature was 2.4° F above the 30-year average, and total precipitation was 7.99 inches above the historic average. In the summer of 2019, average summer temperature was 0.83° F above the 30-year average, and total precipitation was 2.01 inches above the historic average.

## 11. Data Analysis

Fifty lakes that were randomly selected with consideration to their location and size class are presented in this report (see section Lake Selection for more information). The data were collected for the purpose of assessing New Hampshire's entire lake population, not of the individual lakes themselves.

Water quality parameters were analyzed using an R Shiny app developed by EPA called NARS Population Estimate Calculation Tool [9], which was designed to assist states with analyzing their state intensification data. This app serves as a wrapper for the spsurvey R package and allows for population estimates of both categorical and continuous variables using the size-base weights and location of each randomly selected lake (see section Survey Design for more information). This tool takes into consideration the location and area of lakes by size category during calculations, so that no portion of the population was over or underrepresented.

Both designated use and condition estimates were calculated using this tool. Each water quality parameter for each of the 50 lakes was compared to the thresholds established for either designed use assessment or condition estimate, categorized (e.g., FS or NS; good, fair, or poor), and uploaded into the tool. Using information such as lake location and size category, the NARS Population Estimate Calculation Tool extrapolated percentages for each water quality parameter to the entire target population (approximately 2,140 New Hampshire lakes; see section State Intensification (a.k.a. "Overdraw") for more information). Note that all percentages as well as the total target lake population are estimated based on the combination of EPA's and NHDES' lake coverage dataframes and may have discrepancies or rounding errors.

# 12. Results

## 12.1 Designated Use

Results are representative of the statewide distribution of New Hampshire lakes. This is the second lake probability survey conducted by NHDES. Each water quality parameter was assessed in regard to its designated use, consisting of Primary Contact Recreation (PCR), Secondary Contact Recreation (SCR), or Aquatic Life Integrity (ALU; Table 4). The designated use listing convention is full support (FS), not support (NS), potentially not support (PNS), potentially attaining support (PAS), and insufficient information (II; Table 1). For water quality parameters whose designated use attainment is dependent upon lake trophic class, lakes that have never been given a trophic classification were classified as II. Results for each parameters condition are expressed as percentages and total count, along with the corresponding standard error and upper and lower 95% confidence intervals.

### 12.1.1 Acid Neutralizing Capacity (ANC)

ANC is considered a screening level indicator of ALU, which means it cannot be used to make a definitive assessment of whether a lake obtains this designated use. Lakes < 20 mg/L are considered PNS, and lakes ≥ 20 mg/L are considered PAS.

Based on this threshold, 80.4% of New Hampshire lakes were PNS and 19.6% were considered PAS for ANC (Table 5).

**Table 5. Aquatic Life Integrity (ALU) support for acid neutralizing capacity (ANC).**

| Designated Use Classification | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|
| | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | Lower | Upper | | | Lower | Upper |
| Potentially Not Support (PNS) | 80.4 | 7.3 | 66.0 | 94.8 | 1719.3 | 316.2 | 1099.6 | 2139* |
| Potentially Attaining Support (PAS) | 19.6 | 7.3 | 5.2 | 34.0 | 419.7 | 169.2 | 88.1 | 751.3 |
| | | | | | | | | |
| Total | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

### 12.1.2 Bacteria

Fecal bacteria, as measured by *E. coli* levels, present a public health risk to people who have contact with those waters and are therefore assessed under PCR and SCR. According to the CALM [5], May 24 to

September 15 is considered the critical time period for bacteria exposure since that is when most swimming in New Hampshire waters occurs and therefore was targeted for sample efforts. Bacteria levels can be assessed as a single sample or as a geometric mean when more than one sample is available. As outlined in the CALM [5] and RSA 485-A:8, to calculate a geometric mean, three independent samples must be collected on three separate days within a 60-day window. The state intensification met the goal of collecting three independent bacteria samples within a 60-day window for all lakes with one exception, in which case two samples were collected.

The CALM [5] outlines different bacteria criteria/thresholds based on lake classification. To achieve FS of PCR, the *E. coli* geometric mean criteria for Class A freshwater must be ≤ 47 cts/ 100 mL and ≤ 126 cts/ 100 mL for Class B freshwater. To achieve FS of SCR, the *E. coli* geometric mean threshold for Class A freshwater must be ≤ 235 cts/ 100 mL and ≤ 630 cts/ 100 mL for Class B freshwater. Using these measures, 98% of New Hampshire lakes supported PCR and 100% supported SCR (Table 6).

**Table 6. Primary and Secondary Contact Recreation (PCR; SCR) support for bacteria.**

| Designated Use Classification | | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | | Lower | Upper | | | Lower | Upper |
| PCR | Full Support (FS) | 98 | 1.7 | 94.6 | 100 | 2095.5 | 337.7 | 1433.7 | 2139* |
| | Not Support (NS) | 2 | 1.7 | 0 | 5.4 | 43.5 | 36 | 0 | 114.1 |
| | | | | | | | | | |
| SCR | Full Support (FS) | 100 | 0 | 100 | 100 | 2139 | 337.4 | 1477.8 | 2139* |
| | | | | | | | | | |
| Total | | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

### 12.1.3 Chloride

Chloride is not a core parameter for ALU in the CALM [5]; however, it can be toxic to aquatic life in high concentrations. Natural background levels of chloride in New Hampshire lakes tend to be low (< 10 mg/L), but it can be introduced via road salting for winter ice management, septic systems and water softeners. Increases in groundwater chloride levels have been documented in New Hampshire (USGS 2012 [10]), and ongoing data collection by NHDES suggests chloride levels in surface water are also increasing; however, the ALU thresholds are great enough that they are rarely exceeded. The ALU chloride thresholds stipulate that a lake may not meet ALU if chloride levels are chronically > 230 mg/L or acutely > 860 mg/L. With these criteria, 100% of New Hampshire lakes had chloride levels below the chronic threshold and were in FS of ALU for chloride (Table 7).

**Table 7. Aquatic Life Integrity (ALU) support for chloride.**

| Designated Use Classification | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|
| | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | Lower | Upper | | | Lower | Upper |
| Full Support (FS) | 100.0 | 0.0 | 100.0 | 100.0 | 2139.0 | 337.4 | 1477.8 | 2139* |
| Not Support (NS) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | |
| Total | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

### 12.1.4 Chlorophyll-*a* (Chl-a)

Algal growth, as measured by Chl-a, can impair the public safety and aesthetic enjoyment of lakes, as well as interfere with natural processes; therefore, Chl-a is assessed for both PCR and ALU. For PCR, Chl-a > 15 µg/L is the designated use threshold, as that is the level determined to interfere with recreational activities. ALU, on the other hand, seeks to account for cultural eutrophication by applying the best historic trophic class when determining whether this designated use is supported. The ALU Chl-a thresholds are < 3.3 µg/L for oligotrophic lakes, ≥ 3.3 and ≤ 5.0 µg/L for mesotrophic lakes, and > 5 and ≤ 11 µg/L for eutrophic lakes. As ALU depends on a historic trophic classification to determine if the designated use is met, lakes that have not been assessed under NHDES' LTSP were categorized as II.

Using these criteria, 94.3% of lakes were in FS of PCR, with 5.7% in NS (Table 8). For ALU, 28.9% of lakes were FS, 36% were NS, and 35.1% were II (Table 8).

**Table 8. Primary Contact Recreation (PCR) and Aquatic Life Integrity (ALU) support for chlorophyll-*a* (Chl-a).**

| Designated Use Classification | | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | | Lower | Upper | | | Lower | Upper |
| PCR | Full Support (FS) | 94.3 | 2.7 | 89.0 | 99.6 | 2016.4 | 352.7 | 1325.0 | 2139* |
| | Not Support (NS) | 5.7 | 2.7 | 0.4 | 11.0 | 122.6 | 50.1 | 24.5 | 220.7 |
| | | | | | | | | | |
| ALU | Full Support (FS) | 28.9 | 7.1 | 15.0 | 42.7 | 617.1 | 103.5 | 414.3 | 819.9 |
| | Not Support (NS) | 36.0 | 10.0 | 16.4 | 55.7 | 770.8 | 246.9 | 286.9 | 1254.6 |
| | Insufficient Information (II) | 35.1 | 10.9 | 13.7 | 56.6 | 751.1 | 308.2 | 147.0 | 1355.3 |
| | | | | | | | | | |
| Total | | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

#### 12.1.5 Cyanobacteria

Cyanobacteria, while naturally occurring, can occasionally become a threat to human health in high concentrations, and therefore are assessed under PCR. Criteria for NS is met when either > 50% of the algal cell count are cyanobacteria or if the cyanobacteria cell count is > 70,000 total cells/mL of water. Cyanobacteria can be difficult to monitor, as blooms may last for only a few hours and can change location and depth in the water column. For this probabilistic assessment, a water sample was only collected from a suspected bloom area on the day of the sample event. Using this methodology and criteria, 100% of lakes were in FS of PCR (Table 9).

**Table 9. Primary Contact Recreation (PCR) support for cyanobacteria.**

| Designated Use Classification | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|
| | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | Lower | Upper | | | Lower | Upper |
| Full Support (FS) | 100 | 0 | 100 | 100 | 2139 | 337.4 | 1477.8 | 2139* |
| Not Support (NS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | |
| Total | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

#### 12.1.6 Dissolved Oxygen (DO)

DO is critical to supporting aquatic life and is assessed as both concentration (mg/L) and saturation (%) under ALU. The CALM [5] outlines DO thresholds based on lake classification (Table 10). These thresholds account for the fact that samples are often not collected during the time of day one would expect the minimum concentrations to occur. For Class A, DO measurements throughout the entire water column, minus the reading closest to the lake bottom due to proximity to the sediment (within one meter of lake bottom), are considered when determining if ALU is supported. For Class B freshwater, only DO measurements in the epilimnion of stratified lakes or top 25% of the water column of unstratified lakes are considered. Fourteen percent of examined lakes were Class A, and 86% were Class B. Stratification is present if the top and bottom water temperatures of the measured water column differ by five or more degrees Celsius. When such a temperature differential is present, the epilimnion is the part of the water column that is within one degree Celsius of the water temperature at 1-meter depth.

**Table 10. Dissolved oxygen (DO) Aquatic Life Integrity (ALU) thresholds based on lake class.**

| Designated Use Classification | | Class A | Class B |
|---|---|---|---|
| DO Concentration (mg/L) | Full Support (FS) | ≥ 7 mg/L | ≥ 6 mg/L |
| | Insufficient Information (II) | ≥ 6 mg/L but < 7 mg/L | ≥ 5 mg/L but < 6 mg/L |
| | Not Support (NS) | < 6 mg/L | < 5 mg/L |
| DO Saturation (%) | Full Support (FS) | ≥ 85% saturation | ≥ 85% saturation |
| | Insufficient Information (II) | ≥ 75% but < 85% saturation | ≥ 75% but < 85% saturation |
| | Not Support (NS) | < 75% saturation | < 75% saturation |

Using these thresholds, 71.5% of New Hampshire's lakes were in FS of ALU for DO concentration, followed by 15.9% of NS and 12.6% of II (Table 11). For DO saturation, 40.2% of New Hampshire's lakes were NS, followed closely by FS (39.6%), and lastly II (20.2%; Table 11).

**Table 11. Aquatic Life Integrity (ALU) support for dissolved oxygen (DO).**

| Designated Use Classification | | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | | Lower | Upper | | | Lower | Upper |
| DO Concentration (mg/L) | Full Support (FS) | 71.5 | 9.9 | 52.1 | 91.0 | 1530.3 | 296.0 | 950.1 | 2110.5 |
| | Not Support (NS) | 15.9 | 8.0 | 0.2 | 31.5 | 339.0 | 182.2 | 0.0 | 696.2 |
| | Insufficient Information (II) | 12.6 | 7.5 | 0.0 | 27.3 | 269.7 | 172.1 | 0.0 | 607.0 |
| | | | | | | | | | |
| DO Saturation (%) | Full Support (FS) | 39.6 | 8.5 | 23.0 | 56.2 | 846.8 | 188.2 | 477.9 | 1215.7 |
| | Not Support (NS) | 40.2 | 10.1 | 20.4 | 60.0 | 860.5 | 288.5 | 295.0 | 1425.9 |
| | Insufficient Information (II) | 20.2 | 7.7 | 5.0 | 35.3 | 431.8 | 175.3 | 88.2 | 775.3 |
| | | | | | | | | | |
| Total | | 100 | | | | 2139 | | | |

### 12.1.7 Invasive Aquatic Plants

Invasive aquatic plants are fast-growing, non-native species that can outcompete native aquatic plant growth. The most commonly found invasive aquatic plant species in New Hampshire is Variable milfoil (*Myriophyllum heterophyllum*). To be in FS of ALU, a lake must not have invasive aquatic plants present in its surface water. This probabilistic assessment found that 84.7% of New Hampshire's lakes were in FS of ALU, with 15.3% NS (Table 12).

**Table 12. Aquatic Life Integrity (ALU) support for invasive aquatic plants.**

| Designated Use Classification | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|
| | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | Lower | Upper | | | Lower | Upper |
| Full Support (FS) | 84.7 | 7.1 | 70.7 | 98.7 | 1812.1 | 310.4 | 1203.6 | 2139* |
| Not Support (NS) | 15.3 | 7.1 | 1.3 | 29.3 | 326.9 | 166.1 | 1.5 | 652.4 |
| | | | | | | | | |
| Total | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

### 12.1.8 pH

The pH of surface waters, as a measure of acidity, has important implications for chemical and biological processes, and therefore is assessed under ALU. Changes in pH can be due to natural influences, like geology, algal photosynthesis, decomposition, or anthropogenic influences, like sulfur dioxide or nitrogen oxide pollution (i.e. "acid rain"). New Hampshire surface waters have a naturally low buffering capacity due to geology, which makes waterbodies vulnerable to acid inputs. ALU is not met when waterbody pH is either < 6.5 or > 8.0. Values above or below those thresholds have been found to stress aquatic organisms and can affect the solubility and toxicity of chemicals and heavy metals in the water.

pH was measured from the water sample collected from the 2-meter composite as well as from a multi-parameter water quality sonde that collected water temperature, dissolved oxygen, specific conductance and pH profile data from the deepest point in a lake at predefined depth levels, spanning the entire water column. During the three years of data collection, equipment failure occasionally occurred. When the multi-parameter water quality sonde was unavailable, a water temperature and dissolved oxygen profile were collected at the deep spot location. A multi-parameter profile was collected at 37 of the 50 surveyed lakes, with a DO/water temperature profile collected at the remaining 13. For lakes with a multi-parameter profile, the entire pH profile was assessed for ALU support, minus the bottom reading (due to potential interference from the sediment-water interface). For lakes without a multi-parameter profile reading, the pH result from the 2-meter composite was substituted for the assessment. As pH values tend to decline deeper in the water column, having to use only the 2-meter composite data for approximately a quarter of the lakes likely led to an overestimate of pH support for ALU.  With this consideration, the assessment found that 16.6% of New Hampshire lakes supported ALU, while 83.4% were NS (Table 13).

**Table 13. Aquatic Life Integrity (ALU) support for pH.**

| Designated Use Classification | Percent (%) | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|
| | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | Lower | Upper | | | Lower | Upper |
| Full Support (FS) | 16.6 | 4.6 | 7.6 | 25.7 | 355.8 | 72.1 | 214.6 | 497.1 |
| Not Support (NS) | 83.4 | 4.6 | 74.3 | 92.4 | 1783.2 | 357.7 | 1082.1 | 2139* |
| | | | | | | | | |
| Total | 100 | | | | 2139 | | | |

* Value truncated to total number of lakes in the estimated target population

### 12.1.9 Total phosphorus (TP)

As a limiting nutrient in freshwater, TP can influence algal and aquatic plant abundance. Class A waters are expected to only contain naturally occurring TP, and Class B waters are expected to contain TP in such levels that no designated uses are impaired, unless naturally occurring (Env-Wq 1703.14). In order to assess compliance, lake productivity (i.e., trophic class) must also be considered, as some lakes will naturally have higher levels of TP than others. The ALU TP thresholds are < 8.0 µg/L for oligotrophic lakes, ≤ 12.0 µg/L for mesotrophic lakes, and ≤ 28.0 µg/L for eutrophic lakes. As a trophic classification is used to determine if ALU is supported, lakes that have not been assessed under NHDES' LTSP were categorized as II. Because ALU support is threatened by the algal growth driven by TP levels, not TP levels themselves, lakes are first examined in regard to ALU Chl-a thresholds (Section 12.1.4). If Chl-a supports ALU, TP can either be FS if the TP trophic threshold is also upheld, or it can be PNS if it is above the threshold. If Chl-a does not support ALU, TP can either be NS if it is also above the threshold, or it can be PNS if the TP threshold is met.

Using these guidelines, the probabilistic assessment found that 12.9% of lakes are in FS of ALU, with 31.2% NS and 20.7% PNS (Table 14). Just over a third (35.1%) were II as no trophic classification was available (Table 14).

**Table 14. Aquatic Life Integrity (ALU) support for total phosphorus (TP).**

| Designated Use Classification | Percent | | | | Count (n) | | | |
|---|---|---|---|---|---|---|---|---|
| | All Lakes | Standard Error | 95% Confidence | | All Lakes | Standard Error | 95% Confidence | |
| | | | Lower | Upper | | | Lower | Upper |
| Full Support (FS) | 12.9 | 4.0 | 5.1 | 20.8 | 277.0 | 70.0 | 139.7 | 414.3 |
| Not Support (NS) | 31.2 | 9.8 | 12.0 | 50.4 | 667.8 | 242.4 | 192.7 | 1142.9 |
| Potentially Not Supporting (PNS) | 20.7 | 5.7 | 9.6 | 31.8 | 443.1 | 92.3 | 262.3 | 624.0 |
| Insufficient Information (II) | 35.1 | 10.9 | 13.7 | 56.6 | 751.1 | 308.2 | 147.0 | 1355.3 |
| | | | | | | | | |
| Total | 100 | | | | 2139 | | | |

## 12.2 Condition

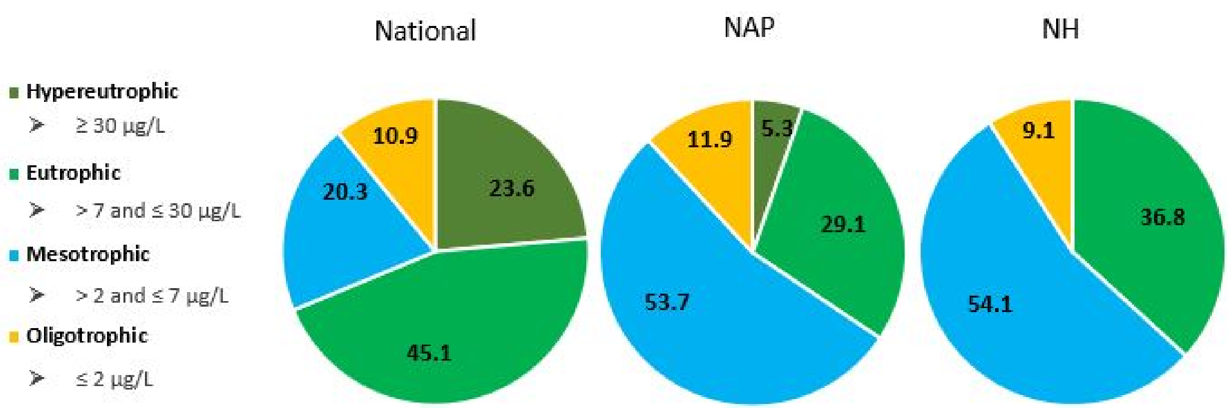
Forty-nine of the 50 randomly selected lakes were analyzed using EPA's thresholds developed for condition estimates. One lake was removed because its surface area did not meet NLA selection criteria and therefore was outside the scope of comparison. Lake productivity was examined via trophic classification, and six water quality parameters were compared to national and eco-regional thresholds as defined by EPA (see section Condition Estimates for more information). The condition categories are good (least disturbed), fair (moderately disturbed), or poor (highly disturbed). For each individual parameter, New Hampshire's statewide lake condition estimates are expressed as percentages of lakes in each classification category and are displayed in the figures below. These percentages, as well as standard errors and upper and lower 95% confidence intervals, are available in Appendices D and E. EPA provided the national and eco-regional condition estimate results prior to official publication as a courtesy to NHDES. While the national and eco-regional condition estimates presented within this report are assumed to be final, EPA may reanalyze and/or modify their results as they deem necessary.

### 12.2.1 Trophic Classification

NLA trophic state was based on the Chl-a measurement taken during the onetime NLA visit. Trophic class is an estimate of biological productivity, which is described as oligotrophic, mesotrophic or eutrophic. The NLA methodology for determining trophic class differs from the methodology used by NHDES, which in addition to using different Chl-a thresholds, also considers DO, aquatic plant growth and water transparency in its trophic assessments (see section Lake Productivity for more information). The trophic classifications presented here are to compare New Hampshire lakes to a national benchmark; they are not comparable to the trophic classifications generated by NHDES' LTSP or used in designated use assessments. The NLA trophic classifications define oligotrophic lakes as having Chl-a ≤ 2 µg/L, mesotrophic lakes as having Chl-a > 2 µg/L and ≤ 7 µg/L, eutrophic lakes as having Chl-a > 7 and ≤ 30 µg/L, and hypereutrophic lakes as having Chl-a > 30 µg/L.

Oligotrophic lakes, which naturally have the lowest Chl-a, were found to make up 9.1% of New Hampshire's lake population, slightly lower than 11.9% for NAP and 10.9% for the Nation (Figure 1). New Hampshire had a similar population of mesotrophic lakes (54.1%) compared to NAP (53.7%), but more than the Nation (20.3%; Figure 1). Eutrophic lakes (36.8%), which are typically the most productive trophic class found in New Hampshire, were higher than NAP (29.1%), but less than the Nation (45.1%; Figure 1). Additionally, both National and NAP results contained an additional trophic class called hypereutrophic, which is reflective of extremely high Chl-a levels, that did not occur in New Hampshire. With percentages combined for both eutrophic and hypereutrophic lakes, New Hampshire had a similar percentage of productive lakes compared to NAP (34.4%) but a much lower percentage compared to the Nation (68.7%; Figure 1).

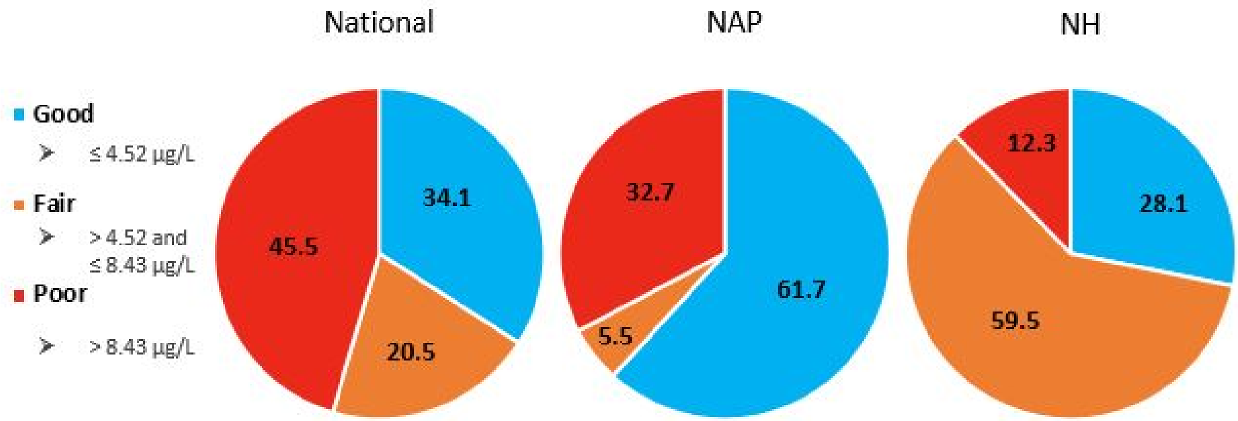
**Figure 1. Percentage of lakes in each trophic class as determined by chlorophyll-*a* (Chl-a) concentration for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on 2017 National Lake Assessment (NLA) results.**




### 12.2.2 Chlorophyll-*a* (Chl-a)

EPA's Chl-a thresholds for determining condition categories are not identical to their Chl-a trophic thresholds and are based on percentiles calculated from eco-regional reference lakes (see section Condition Estimates for more information). New Hampshire data were examined using NAP thresholds developed from the 2017 NLA. NAP Chl-a thresholds considered ≤ 4.52 µg/L to be good condition, > 4.52 and ≤ 8.43 µg/L to be fair condition, and > 8.43 µg/L to be poor condition. Using these thresholds, the majority of New Hampshire lakes were considered to be in fair condition (59.5%), followed by good (28.1%) and lastly poor (12.3%; Figure 2). New Hampshire had a lower percentage of lakes in good condition compared with NAP (61.7%) and the Nation (34.1%; Figure 2), as well as poor condition (32.7% and 45.5% respectively; Figure 2).

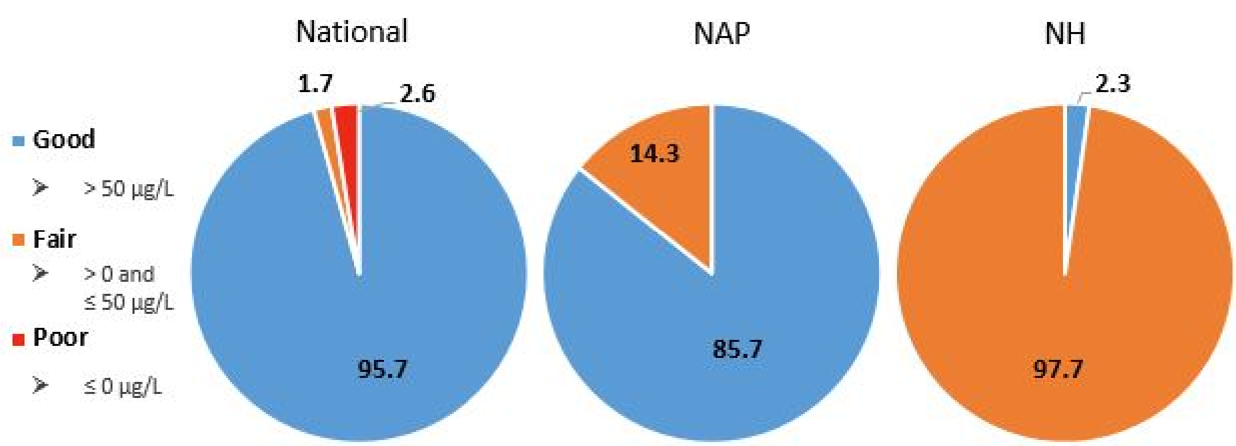
**Figure 2. Chlorophyll-*a* (Chl-a) condition for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on 2017 National Lake Assessment (NLA) results.**




### 12.2.3 Acid Neutralizing Capacity (ANC)

EPA guidelines for determining thresholds for a lake's ability to buffer against acid inputs was a national guideline that considered both ANC and dissolved organic carbon (DOC) concentrations. Good condition was set at ANC > 50 µg/L. Fair condition could be achieved with either natural (ANC ≤ 50 µg/L & DOC ≥ 6 mg/L) or anthropogenic (ANC 0-50 µg/L & DOC < 6 mg/L) causes. ANC ≤ 0 µg/L and DOC < 6 mg/L were considered poor condition. DOC was not collected at any of the overdraw sites; therefore, only ANC was used to determine thresholds. New Hampshire's lakes were largely in fair condition (97.7%), with a small percentage in good condition (2.3%), compared to the majority of NAP and National lakes in good condition (Figure 3). This is largely attributed to New Hampshire's natural geology and the effects of anthropogenic stressors such as acid rain (see section pH for more information).

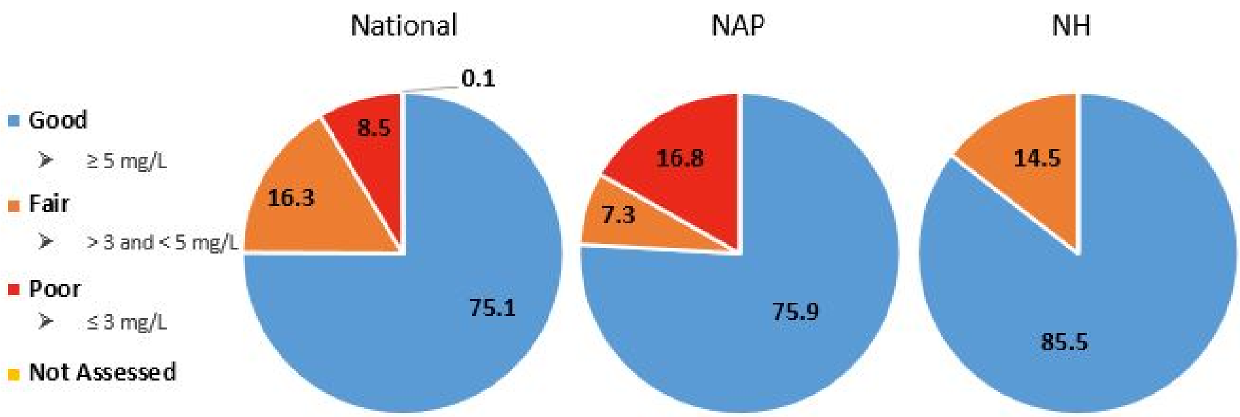
**Figure 3. Acid Neutralizing Capacity (ANC) condition for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on the 2017 National Lake Assessment (NLA) results.**




### 12.2.4 Dissolved Oxygen (DO)

EPA guidelines for DO concentration thresholds were based on national benchmarks, with ≥ 5 mg/L considered good, 3-5 mg/L considered fair, and ≤ 3 mg/L considered poor. Surface water DO concentration was calculated by taking the mean of all DO values between the surface and two meters depth, inclusive. Using these national guidelines, the majority of New Hampshire's lakes were in good condition (85.5%), followed by fair condition (14.5%; Figure 4). No lakes were considered to be in poor condition (Figure 4). The percentage of New Hampshire lakes in good condition was greater than National and NAP percentages (75.1% and 75.9% respectively; Figure 4).

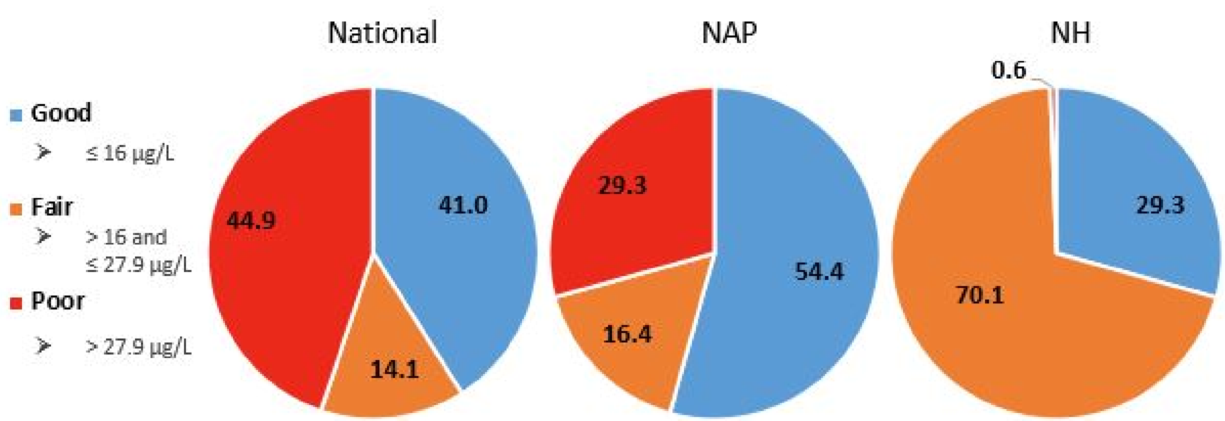
**Figure 4. Dissolved Oxygen (DO) condition for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on 2017 National Lake Assessment (NLA) results.**




### 12.2.5 Total Phosphorus (TP)

The thresholds for TP were developed regionally from the 2017 NLA data, and the NAP TP benchmarks were applied to New Hampshire lakes. NAP TP thresholds considered ≤ 16.0 µg/L to be good condition, >16.0 and ≤ 27.9 µg/L to be fair condition, and > 27.9 µg/L to be poor condition. The majority of New Hampshire's lakes were in fair condition (70.1%), followed by good condition (29.3%) and, lastly, poor condition (0.6%; Figure 5). New Hampshire had lower percentages of lakes in good condition and poor condition compared to the Nation (41.0% and 44.9% respectively) and NAP (54.4% and 29.6% respectively; Figure 5).

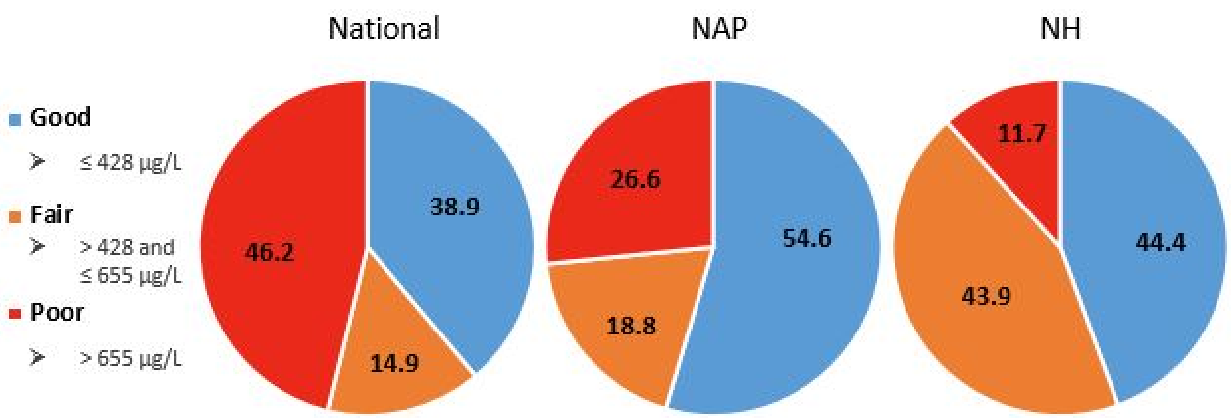
**Figure 5.Total phosphorus (TP) condition for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on 2017 National Lake Assessment (NLA) results.**



### 12.2.6 Total Nitrogen (TN)

The thresholds for TN were developed regionally from the 2017 NLA data, and the NAP TN benchmarks were applied to New Hampshire lakes. NAP TN thresholds had ≤ 428 µg/L considered good condition, > 428 and ≤ 655 µg/L considered fair condition, and > 655 µg/L considered poor condition. TN was calculated by adding total Kjeldahl nitrogen results with inorganic nitrogen (nitrite and nitrate) results. If a value was less than the detection limit, the detection limit value was divided in half and the half value was applied. For example, the detection limit of inorganic nitrogen is 50 µg/L. If a waterbody was listed as having a value below 50 µg/L, the value 25 µg/L was used in calculating TN. The majority of New Hampshire's lakes were in good condition (44.4%), followed closely by fair condition (43.9%) and lastly poor condition (11.7%; Figure 6). New Hampshire had a lower percentage of lakes in good condition compared to NAP (54.6%), but a greater percentage than the Nation (38.9%; Figure 6).

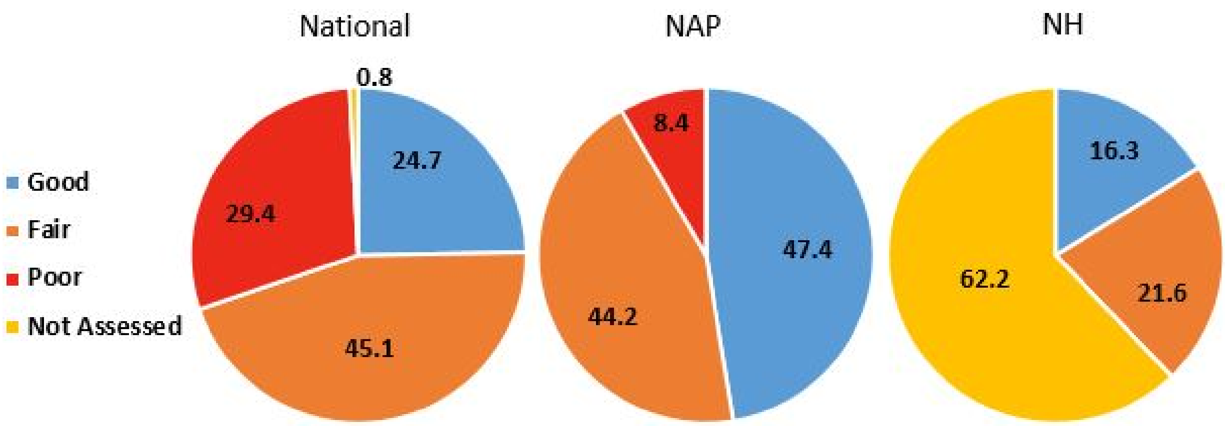
**Figure 6. Total nitrogen (TN) condition for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on 2017 National Lake Assessment (NLA) results.**




### 12.2.7 Lakeshore Disturbance Index (LDI)

Lakeshore habitat assessments are done at 10 randomly generated lakeshore sites, equally spaced from each other, and characterized both the riparian and littoral zone with quantitative scoring to assess qualitative factors, such as human disturbance, habitat complexity and water level fluctuations. EPA focused on a subset of the habitat assessment data, specifically the estimates of human activity in the lakeshore and nearshore area, to develop a formula to calculate LDI (see EPA's 2012 NLA Technical Report [4] for LDI development). The LDI considers the type of disturbance, the proximity of the disturbance to the lake, and the number of times a disturbance is recorded. It indicates how intensively lakeshores are modified for human use, with types of disturbance ranging from lawns and houses to power lines and orchards. Due to the intensive and time-consuming nature of these assessments, lakeshore habitat assessments were only done at base NLA and lakes paired with NHDES' LTSP. Most of New Hampshire lakes are considered unassessed (62.2%; Figure 7). The remaining assessed lakes were determined to be in fair condition (21.6%) and good condition (16.3%) for LDI (Figure 7). While it is difficult to draw comparisons to national and eco-regional results with a high 'not assessed' population, LDI is a promising method for quantifying human activities immediately adjacent to and within a lake.

**Figure 7. Lakeshore Disturbance Index (LDI) condition for New Hampshire (NH), Northern Appalachian Region (NAP), and the Nation based on 2017 National Lake Assessment (NLA) results.**




## 13. Discussion

### 13.1 Designated Use

Less than 10% of New Hampshire's lakes fully meets the ALU designated use (Table 15). This low percentage is driven by low pH (83.4% not attaining), followed by DO saturation (40.2% not attaining) and Chl-a (36% not attaining; Table 15). ANC, while considered a screening indicator and not used for final assessments, was similar to pH (80.4% potentially not attaining; Table 15). While some water quality parameters like pH had low attainment, other parameters had high attainment for ALU. Chloride, while not a core ALU parameter, had 100% attainment, and 84.7% of NH lakes were estimated to not be affected by invasive aquatic plant species (Table 15). Approximately one third of New Hampshire lakes could not be assessed for ALU parameters Chl-a and TP, due the absence of a historical trophic assessment (Table 15). Recall that ALU support is threatened by the algal growth driven by TP levels, not TP levels themselves, so lakes are first examined in regard to ALU Chl-a thresholds. If Chl-a supports ALU, TP can either be FS if the TP trophic threshold is also upheld, or it can be PNS if it is above the threshold. If Chl-a does not support ALU, TP can either be NS if it is also above the threshold, or it can be PNS if the TP threshold is met. This resulted in greater ALU support for Chl-a than TP (28.9% and 12.9% respectively), with a portion of lakes designated as PNS for TP ALU (20.7%; Table 15). DO concentration had greater ALU support than DO saturation (71.5% and 39.6% respectively; Table 15). Water can contain more DO at lower temperatures, higher pressures, and lower salinities, so as measurements occur deeper in the water column, DO saturation can decline even if DO concentration remains constant.

Support for PCR and SCR designated uses were high. Nearly all of New Hampshire's lakes supported PCR and all lakes support SCR for bacteria (98% and 100% respectively; Table 15). For Chl-a, support of PCR is held to a fixed value (> 15 µg/L) at a level indicating likely interference with recreational activities and is not dependent on trophic class. With this threshold, Chl-a PCR support was 94.3% (Table 15). Lastly, 100% of lakes were in full support PCR for cyanobacteria (Table 15).

**Table 15. The percent (%) of lakes for each water quality parameter in designated uses Aquatic Life Integrity (ALU), Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR). The final column is the percent of designated use attainment for lakes considering all water quality parameters. The totals in each column may not equal 100% due to rounding.**

| Designated Use | | Water Quality Parameter | | | | | | | | COMBINED ALU |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ANC | Chloride | Chl-a | DO (mg/L) | DO (%) | Invasive | pH | TP | |
| ALU | FS | | 100 | 28.9 | 71.5 | 39.6 | 84.7 | 16.6 | 12.9 | **9.1** |
| | NS | | 0 | 36 | 15.9 | 40.2 | 15.3 | 83.4 | 31.2 | **90.9** |
| | PAS | 19.6 | | | | | | | | |
| | PNS | 80.4 | | | | | | | 20.7 | |
| | II | | | 35.1 | 12.6 | 20.2 | | | 35.1 | |
| | *TOTAL* | *100* | *100* | *100* | *100* | *100* | *100* | *100* | *99.9* | ***100*** |
| **Designated Use** | | **Bacteria** | **Bacteria (Secondary)** | **Chl-a** | **Cyano** | | | | | **COMBINED PCR** |
| PCR; SCR | FS | 98 | 100 | 94.3 | 100 | | | | | **92.2** |
| | NS | 2 | 0 | 5.7 | 0 | | | | | **7.8** |
| | PAS | | | | | | | | | |
| | PNS | | | | | | | | | |
| | II | | | | | | | | | |
| | *TOTAL* | *100* | *100* | *100* | *100* | | | | | ***100*** |

ANC = Acid Neutralizing Capacity; Chl-a = Chlorophyll-*a*; DO = Dissolved Oxygen; TP = Total Phosphorus; Cyano = Cyanobacteria

FS = Full Support; NS = Not Support; PAS = Potentially Attaining Support; PNS = Potentially Not Support; II = Insufficient Information

### 13.1.1 Comparison to Previous Lake Probabilistic Survey

The first statewide probability survey that NHDES conducted for lakes was from was 2007 – 2009 [3], and this report summarizes the results of the second probabilistic lake assessment. Comparing the results of the current assessment to the results of the previous assessment is not a perfect comparison due to the NLA's inclusion of lakes with a surface area < 4 hectares in the 2017 – 2019 intensification. The current assessment captured a broader range of lake sizes than the previous assessment so changes in the percentages of attainment may be due to the inclusion of a new size category that was previously unassessed or may reflect actual changes in water quality. Additionally, the smaller size category resulted in the inclusion of several lakes that had never been sampled under NHDES' LTSP. With no historic trophic classification on record, approximately one third of New Hampshire lakes could not be assessed for ALU parameters Chl-a and TP and were classified as II.

For ALU, ANC indicated an increase in PAS from the previous to the current assessment (4.7% vs 19.6% PAS); however, pH was unchanged (16% vs 16.6%; Table 16). This increase may be due to ongoing recovery from acid rain or may reflect salt pollution (see section Influencing Factors for more information); however, chloride was excluded from the previous assessment so the latter cannot be confirmed (Table 16). Chl-a and TP indicated a decrease in ALU attainment from the previous to the current assessment (Chl-a: 44% vs 28.9% FS; TP 38.4% vs 12.9% FS); however, approximately one third of lakes were II in the current survey due to never having received a trophic survey (35.1%; Table 16). In contrast, all lakes had a trophic survey available in the previous survey (Table 16). This difference in assessed versus unassessed lakes for the current and previous probabilistic surveys increases the range of uncertainty around the estimated percentages, meaning it is less certain if an actual difference is being documented or if a small number of assessed lakes are having an outsized impact on the results (Table 16; Appendix C). DO concentration indicated a decline in ALU support (88% vs 71.5% FS) as did DO saturation (47.9% vs 39.6% FS; Table 16). Declines in DO can be caused by many different factors, such as increases in temperature, decomposition, or respiration, or decreases in Chl-a concentration or water clarity (see section Influencing Factors for more information). Invasive aquatic plant species indicated similar attainment levels in the previous and current assessments (83.9% vs 84.7% FS; Table 16).

PCR and SCR water quality parameters achieved similar attainment levels across assessments. PCR bacteria attainment levels were comparable (100% vs 98% FS), as were Chl-a (96.3% vs 94.3% FS) and cyanobacteria (99.1% vs 100% FS; Table 16). SCR bacteria achieved 100% designated use support in both assessments (Table 16).

**Table 16. The percent (%) of lakes for each water quality parameter in the targeted designated uses for the current and previous state assessments.**

| Water Quality Parameter | Current Assessment (2017 - 2019) | | | | | Previous Assessment (2007 - 2009) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Designated Use: Aquatic Life Integrity | | | | | | | | | |
| | FS | NS | PAS | PNS | II | FS | NS | PAS | PNS | II |
| Acid Neutralizing Capacity (ANC) | | | 19.6 | 80.4 | | | | 4.7 | 95.3 | |
| Chloride | 100 | 0 | | | | *Not Assessed* | | | | |
| Chlorophyll-*a* (Chl-a) | 28.9 | 36 | | | 35.1 | 44 | 56 | | | |
| Dissolved Oxygen (DO) (mg/L) | 71.5 | 15.9 | | | 12.6 | 88 | 9.5 | | | 2.5 |
| Dissolved Oxygen (DO) (%) | 39.6 | 40.2 | | | 20.2 | 47.9 | 15.7 | | | 36.3 |
| Invasive Species | 84.7 | 15.3 | | | | 83.9 | 16.1 | | | |
| pH | 16.6 | 83.4 | | | | 16 | 84 | | | |
| Total Phosphorus (TP) | 12.9 | 31.2 | | 20.7 | 35.1 | 38.4 | 56 | | 5.6 | |
| **Water Quality Parameter** | **Designated Use: Primary and Secondary Contact Recreation** | | | | | | | | | |
| | **FS** | **NS** | **PAS** | **PNS** | **II** | **FS** | **NS** | **PAS** | **PNS** | **II** |
| Bacteria | 98 | 2 | | | | 100 | 0 | | | |
| Bacteria (Secondary) | 100 | 0 | | | | 100 | 0 | | | |
| Chlorophyll-*a* (Chl-a) | 94.3 | 5.7 | | | | 96.3 | 3.7 | | | |
| Cyanobacteria | 100 | 0 | | | | 99.1 | 0.9 | | | |

FS = Full Support; NS = Not Support; PAS = Potentially Attaining Support; PNS = Potentially Not Support; II = Insufficient Information

### 13.1.2 Comparison to Lake Trend Report

NHDES' Water Monitoring Strategy [2] provided a blueprint for components of a conceptual model designed to achieve specific water quality-based objectives. One of those components is probability-based water quality surveys, and another component is trend-based monitoring (see section NHDES Water Monitoring Strategy for more information). The results of the 2017 – 2019 probability monitoring of lakes are presented in this report, while the report of trend-based monitoring of lakes was released in 2020, entitled New Hampshire Lake Trend Report: Status and trends of water quality indicators [11].

Trend-based monitoring tracks water quality parameters annually at the same lakes over decades. The lakes are not randomly selected; for instance, the majority of long-term water quality data presented in the 2020 Lake Trend Report [11] were collected as part of the Volunteer Lake Assessment Program (VLAP). Lakes in VLAP tend to have larger surface area, be located at a lower latitude, and be less productive (i.e., mesotrophic or oligotrophic) than the state's lake population as a whole. This long-term monitoring allows for NHDES to examine water quality trends on those select lakes over time. Probability-based monitoring, on the other hand, is a truly objective snapshot of statewide lake condition. It includes a portion of the lake population that would otherwise rarely be sampled (e.g., waterbodies < 4-hectare surface area), and therefore provides the most comprehensive view of New Hampshire's lakes. It does not, however, provide a level of detail that can track changes in individual lakes, identify water quality shifts that are below a designated threshold, or document water quality impacts that require targeted monitoring. For example, 100% of lakes were documented as FS for cyanobacteria for designated use PCR (Table 16); however, that was determined from whether a cyanobacteria bloom was observed and collected during the single site visit. As cyanobacteria blooms can change location in a lake or dissipate after a few days or even hours, the sample design of the probability survey was not well suited for understanding the frequency of cyanobacteria blooms in New Hampshire, and an increase in cyanobacteria advisories has been recorded when more targeted sampling methodology was used (Table 17). Similarly, 98% of lakes were FS for PCR bacteria and 100% of lakes were FS for SCR bacteria in the current probability survey (Table 16), but targeted monitoring of beaches has indicated a greater percentage of beaches experiencing advisories (Table 17). Lastly, the percentage of lakes with invasive species present was similar for both probabilistic surveys, but targeted site visits have confirmed that the number of infested lakes has increased over time (Table 17).

Although results from the two reports are not directly comparable, the results of each can complement or contrast each other when the same water quality parameter is considered (Table 17). This comparison can help highlight water quality parameters of interest and if documented changes are occurring broadly or within a subset of lakes (Table 17). For instance, by comparing the results of the probability surveys and the Lake Trend Report, ANC emerges as a parameter that appears to be increasing broadly in New Hampshire's lake population; however, increases in ANC appear to be decoupled from pH (Table 17). To better understand what is driving this response, monitoring parameters associated with both acid rain recovery and freshwater salinization would be useful (see section Influencing Factors for more information). Similarly, increases in TP were documented in both monitoring efforts; however, ALU Chl-a, which is assumed to increase as TP increases, only indicated an increase in the probability survey comparison (Table 17). This may indicate that lakes experiencing Chl-a increases are not represented in the Lake Trend Report or that Chl-a concentration is being regulated by other factors despite any increases in TP (e.g., 'lake browning'; see section Influencing Factors for more information). Dissolved oxygen decreases were noted in both the probabilistic surveys, as well as in the Lake Trend Report, highlighting that there appears to be a shift occurring (Table 17). Dissolved oxygen is influenced by many factors, and potential drivers of this apparent change are as increases in temperature, decomposition, respiration, or ammonia levels or decreases in chl-a concentration or water clarity (see section Influencing Factors for more information).

**Table 17. Comparison of water quality parameters that were examined in the 2007-2009 lake probabilistic survey, the 2017 – 2019 lake probabilistic survey, and the 2020 Lake Trend Report for designated uses Aquatic Life Integrity (ALU), Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR).**

| Water Quality Parameter | Designated Use | Change from previous to current probability assessment | New Hampshire Lake Trend Report conclusions | Report Comparison |
|---|---|---|---|---|
| Acid Neutralizing Capacity (ANC) | ALU | Potentially Attaining Support: increased from 4.7% to 19.6% | Significantly increasing in eutrophic and mesotrophic lakes | Complement |
| Bacteria | PCR; SCR | Similar attainment in both assessments | Significantly increasing percent of beach advisories and days that an advisory was in place | Contrast |
| Chlorophyll-*a* (Chl-a) | ALU | Full Support: decreased from 44% to 28.9% | No trends by trophic class | Contrast |
| Chlorophyll-*a* (Chl-a) | PCR | Similar attainment in both assessments | No trends by trophic class | Complement |
| Cyanobacteria | PCR | Similar attainment in both assessments | Significantly increasing issuances of advisories | Contrast |
| Dissolved Oxygen (DO) (mg/L) | ALU | Full Support: decreased from 88% to 71.5% | Significantly decreasing in mesotrophic lakes | Complement |
| Invasive Species | ALU | Similar attainment in both assessments | Significantly increasing number of infested lakes | Contrast |
| pH | ALU | Similar attainment in both assessments | No trends by trophic class | Complement |
| Total Phosphorus (TP) | ALU | Full Support: decreased from 38.4% to 12.9% | Significantly increasing in eutrophic lakes | Complement |

## 13.2 Condition

Trophic class and six water quality parameters were compared to National and Northern Appalachian eco-region results of the 2017 NLA. This is the first time that condition estimates were calculated specifically for New Hampshire lakes and compared to national and eco-regional results. New Hampshire's most common trophic classification was mesotrophic (Figure 1). A majority of lakes were classified as fair for Chl-a, ANC and TP, and a majority were classified as good for DO concentration and TN (Table 18). LDI had a majority of lakes classified as unassessed (Table 18).

**Table 18. Percentage (%) of New Hampshire lakes in their estimated condition by individual water quality parameter. Thresholds were developed by EPA at a national or eco-regional scale, depending on the parameter. Totals in each column may not equal 100% due to rounding.**

| Condition | Chlorophyll-*a* (Chl-a) | Acid Neutralizing Capacity (ANC) | Dissolved Oxygen (DO) (mg/L) | Total Phosphorus (TP) | Total Nitrogen (TN) | Lakeshore Disturbance Index (LDI) |
|---|---|---|---|---|---|---|
| Good | 28.1 | 2.3 | 85.5 | 29.3 | 44.4 | 16.3 |
| Fair | 59.5 | 97.7 | 14.5 | 70.1 | 43.9 | 21.6 |
| Poor | 12.3 | 0 | 0 | 0.6 | 11.7 | 0 |
| Not Assessed | 0 | 0 | 0 | 0 | 0 | 62.2 |
| *TOTAL* | *99.9* | *100* | *100* | *100* | *100* | *100.1* |

See Appendix E for standard errors and upper and lower 95% confidence intervals.

Results of comparisons among New Hampshire, the Nation and NAP lakes were parameter dependent. For trophic class, New Hampshire lakes had a similar percentage of oligotrophic lakes when compared to NAP or the Nation (9.1%, 11.9%, and 10.9% respectively; Figure 1). New Hampshire and NAP had a similar percentage of mesotrophic lakes, with both greater than the Nation (54.1%, 53.7%, and 20.3% respectively; Figure 1). The most productive trophic class found in New Hampshire was eutrophic, with a percentage higher than NAP but lower than the Nation (36.8%, 29.1%, and 45.1% respectively; Figure 1). The most productive trophic class, hypereutrophic, was not found in New Hampshire but was present in NAP and the Nation (0%, 5.3%, and 23.6% respectively, Figure 1).

For Chl-a, New Hampshire had the greatest percentage of lakes classified as fair, followed by good, and lastly poor (59.5%, 28.1%, and 12.3% respectively; Figure 2; Table 18). Both NAP and the Nation had higher percentages of lakes classified as good (61.7% and 34.1% respectively) and poor (32.7% and 45.5% respectively; Figure 2) when compared to New Hampshire. For ANC, the large majority of New Hampshire lakes were classified as fair, followed by good (97.7% and 2.3% respectively; Figure 3; Table 18). NAP and the Nation had much greater percentages of lakes classified as good (85.7% and 95.7% respectively; Figure 3). Most New Hampshire's lakes were in good condition for DO, and New Hampshire had a greater percentage of lakes in good condition than NAP or the Nation (85.5%, 75.9%, and 75.1% respectively; Figure 4). For TP, the majority of New Hampshire lakes were classified as fair, followed by good, and lastly poor (70.1%, 29.3%, and 0.6% respectively; Figure 5; Table 18). Both NAP and the Nation had higher percentages of lakes classified as good (54.4% and 41% respectively) and poor (29.3%

and 44.9% respectively; Figure 5) when compared to New Hampshire. For TN, the majority of New Hampshire lakes were classified as good, followed closely by fair (44.4% and 43.9% respectively; Figure 6: Table 18). NAP had a greater percentage, and the Nation had a lower percentage of lakes classified as good for TN (54.6% and 38.9% respectively; Figure 6) when compared to New Hampshire. LDI is an innovative method for quantifying human shoreline impacts; however, most New Hampshire lakes were unassessed (62.2%; Figure 7; Table 18) which prevented definitive comparisons to NAP or the Nation.

The lake condition results indicate that, for several parameters, most New Hampshire lakes are moderately impacted by human influences and are showing some signs of degradation; however, it should be noted that the smallest size class (< 4 hectare) had a large influence on the final results. Less than a third of New Hampshire lakes were in good condition for Chl-a and TP, less than the percentage for both NAP and the Nation (Appendix E). While the exact cause of degradation is unknown, potential influences are stormwater run-off, fertilizer use and land use changes (see section Influencing Factors for more information). Although a higher percentage of lakes were in good condition for TN, nearly an equal percentage of lakes were in fair condition. TN can be influenced by the same factors as Chl-a and TP, as well as aerial deposition. ANC, with nearly all lakes in fair condition, is thought to be largely influenced by historical acid rain inputs; however, this may be starting to shift (Table 18; also see section Comparison to Previous Lake Probability Survey). New Hampshire's dissolved oxygen compared favorably to NAP and the Nation; however, overall decreases may be occurring (see section Comparison to Previous Lake Trend Report). No conclusive comparisons can be made for LDI (Table 18).

## 13.3 Influencing Factors

Multiple anthropogenic influences are occurring simultaneously on our land and waterscapes which can make determining the causes of changing water quality indicators difficult. For instance, the low attaining or potentially not attaining percentages of pH and ANC are likely a result of the legacy of acid rain effects. In particular, New Hampshire ecosystems are especially vulnerable to the effects of acid rain (Kahl et al., 2004). Our natural geology, dominated by granite, means that our lakes have naturally low buffering capacity (i.e., ANC), so small amount of acid inputs (in the form of sulfur dioxide or nitrogen oxides) can quickly overwhelm the ability of a lake to protect itself. Most of the acid rain that falls in New Hampshire originates from outside of the state (Driscol et al., 2001). Due to federal legislation such as the Clean Air Act, acid rain severity has decreased in the last several decades; however, recovery from its effects is slow and ongoing (Kahl et al., 2004; Nelson et al., 2021; Strock et al., 2014). At the same time, salt pollution (e.g., road salting, water softeners) and human-accelerated weathering have been attributed to increasing pH and ANC in freshwater systems (Kaushal et al., 2018), making it difficult to interpret changes to these water quality parameters.

New Hampshire's climate is projected to get warmer and wetter, with winters warming faster than summer seasons and the southern part of the state warming faster than the north (Hambug et al., 2013; Wake et al., 2014). Precipitation, in addition to increasing in overall volume, has also increased in intensity, downpouring a greater amount of water per hour which leads to surges in run-off (Hoerling et al., 2016). Increased heavy precipitation events, coupled with changing land use, influence run-off volume and nutrient input into surface waters (Blair and Sanger, 2016; Spierre and Wake, 2010). A warmer, wetter climate has been linked to increased cyanobacteria blooms (Gobler, 2020), increased transfer of nutrients and pathogens (Coffey et al., 2019), and earlier ice-out (Hodgkins et al., 2002), all of which can influence the water quality parameters examined in this report (see also the 2020 Lake Trend Report [11]).

Both acid rain recovery and increased heavy precipitation events are hypothesized to be driving a recently documented phenomenon in the Northeast called "lake browning" (Meyer-Jacob et al., 2019; SanClements et al., 2012; Williamson et al., 2016). Increases in dissolved organic matter, which causes more tea-colored water, has been shown to reduce the ability of light to reach deeper into the water column, resulting in decreases in water clarity, Chl-a concentration, and dissolved oxygen as well as increases in water temperature and bacteria (Creed et al., 2018; Williamson et al., 2016).

Human population is also increasing, causing changes is land use, stormwater run-off, erosion, impervious surfaces, and nutrient loading. In particular, NLA data has highlighted increases in TP, TN, and the loss of oligotrophic lakes nationwide, which is attributed in part to agricultural and urban run-off (Stoddard et al., 2016). The New Hampshire Department of Energy projected that New Hampshire's total population is projected to increase by approximately 83,000 people from 2020 to 2040, with the highest growth anticipated across southern New Hampshire [12]. Impacts to water quality from human development can be mitigated to some extent by protecting vegetative buffers and corridors, managing stormwater, and using best management practices.

## 13.4 Conclusion

By partnering with EPA, NHDES not only was able to contribute data to national and eco-regional lake assessments but also was afforded the opportunity to conduct a randomized assessment of all of New Hampshire's lakes, ponds and reservoirs. This assessment included lakes smaller than what are typically targeted under NHDES' lake monitoring programs (i.e., lakes < 4-hectare surface area). The inclusion of this size class provided a broader picture of the health of New Hampshire's lakes, but also had a strong influence on the final results due to the weighting factor. This assessment found high support for PCR and SCR designated uses, indicating that most lakes are safe for recreational activities, but overall low support for ALU, which was driven by pH (83.4% NS; Table 15). Additionally, by comparing the results of the 2017 – 2019 lake probabilistic survey to the survey conducted in 2007-2009, potential shifts in water quality parameters were identified. ANC demonstrated an increase in potential designated use attainment (4.7% vs 19.6% PAS; Table 16), whereas attainment of other parameters (e.g., Chl-a, DO, TP) may have declined (Table 16). Some parameters (e.g., pH, Invasive species) showed little change over the decade. Results of this probability survey were also compared to other monitoring efforts (e.g., Lake Trend Report [11]), which offered some support to the probabilistic findings that ANC and TP may be increasing and DO decreasing.

This report documents the first attempt to compare New Hampshire to national and eco-regional thresholds. Despite having a similar distribution of trophic classes, New Hampshire had a lower percentage of good condition lakes for Chl-a, ANC, and TP when compared with NAP and the Nation and only had a greater percentage of lakes in good condition for DO (Appendix E). Three out of six examined water quality parameters had the greatest percentage of lakes in fair condition, followed by good and lastly unassessed. While low ANC values have been a known feature of New Hampshire lakes for decades due to acid rain impacts and ongoing recovery, the underperforming Chl-a and TP parameters suggest that nutrient loading may be a concern in many New Hampshire lakes. Although some nutrient load to lakes occurs naturally via weathering or leaf litter, excessive nutrients can enter lakes via septic systems, agricultural fertilizers, stormwater run-off, or clearcutting. However, the seemingly underperforming parameters may be due to the weighting factor of the smallest lake size class. As small lakes are abundant but more difficult to sample, they are given more influence (e.g., a higher weight) over the results during the data analysis.

The probabilistic survey highlights the importance of population-wide assessments in identifying broad shifts in water quality. Results of the survey indicate that, for several parameters, most New Hampshire lakes are moderately impacted by human influences and are showing some signs of degradation. The most likely causes of New Hampshire water quality degradation are acid rain impacts and land use changes leading to excess nutrient and salt loads. Continued monitoring of the same water quality parameters summarized in this report in future probability surveys, as well as other methods of tracking changes (e.g., trend monitoring) will help clarify shifts in New Hampshire's water quality. Additionally, using consistent lake size classes in future probabilistic surveys will remove uncertainty around designated use support estimates. Repeating the condition estimates with EPA-derived thresholds will help orient our understanding of how New Hampshire lakes compare to our eco-region and the nation. Lastly, NLA methodology provided a novel way to quantify riparian and littoral habitat to better understand alternations to lake shorelines. Expanding these habitat assessments could provide an additional metric for understanding lake health. The next statewide lake probabilistic survey is planned to accompany the 2027 NLA.

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**Appendix A. New Hampshire lakes assessed for the 2017 National Lake Assessment or 2017 – 2019 state intensification. Note that the survey was meant for national and statewide probabilistic assessment and was not intended to draw conclusions about individual lakes. Lakes were randomly selected.**

| Lake Name | NH waterbody ID | Town | NLA ID | Latitude | Longitude | Historic NHDES Trophic Class | Surface Category (ha) | Lake area (ha) |
|---|---|---|---|---|---|---|---|---|
| Bancroft Reservoir | NHIMP802020103-05 | Rindge | NLA17_NH-10038 | 42.7495 | -71.9482 | NA | 4 to 10 | 5.97 |
| Bear Pond | NHLAK700020108-01 | Center Harbor | NLA17_NH-10279 | 43.6824 | -71.5504 | MESOTROPHIC | 4 to 10 | 5.38 |
| Beaver Lake | NHLAK700061203-02-01 | Derry | NLA17_NH-10024 | 42.9061 | -71.2969 | MESOTROPHIC | >50 | 51.83 |
| Beaver Pond | NHLAK700030304-09 | Sutton | NLA17_NH-10059 | 43.3259 | -71.8690 | NA | 10 to 20 | 12.65 |
| Boston Lot Lake | NHLAK801040402-01 | Lebanon | NLA17_NH-10291 | 43.6659 | -72.2897 | OLIGOTROPHIC | 10 to 20 | 17.55 |
| Brindle Pond | NHLAK700060402-01 | Barnstead | NLA17_NH-10052 | 43.3677 | -71.2447 | MESOTROPHIC | 20 to 50 | 34.11 |
| Brownwell Rec Dam | NHIMP700010702-01 | Danbury | NLA17_NH-10047 | 43.5585 | -71.8572 | NA | 1 to 4 | 1.57 |
| Calef Pond | NHLAK700060703-01 | Auburn | NLA17_NH-10280 | 42.9784 | -71.3212 | MESOTROPHIC | 10 to 20 | 12.90 |
| Cold Spring Imp. | NHIMP700060503-10 | Allenstown | NLA17_NH-10268 | 43.1374 | -71.4000 | NA | 0 to 1 | 0.63 |
| Crystal Lake | NHLAK600020304-02-01 | Eaton | NLA17_NH-10045 | 43.9069 | -71.0737 | OLIGOTROPHIC | 20 to 50 | 33.96 |
| Dunklee Pond | NHLAK700061001-01 | Hollis | NLA17_NH-10050 | 42.7671 | -71.5875 | EUTROPHIC | 4 to 10 | 8.73 |
| Echo Lake | NHLAK801030302-01-01 | Franconia | NLA17_NH-10044 | 44.1753 | -71.6925 | OLIGOTROPHIC | 10 to 20 | 13.52 |
| Ellsworth Pond | NHLAK700010206-01 | Ellsworth | NLA17_NH-10063 | 43.8776 | -71.7520 | MESOTROPHIC | 20 to 50 | 20.11 |
| Forest Lake | NHLAK802010401-01-01 | Winchester | NLA17_NH-10042 | 42.7934 | -72.3664 | MESOTROPHIC | 20 to 50 | 37.58 |
| Gilman Pond | NHLAK801060403-01 | Unity | NLA17_NH-10285 | 43.2908 | -72.2070 | OLIGOTROPHIC | 20 to 50 | 28.27 |
| Head Pond | NHLAK801010703-02 | Berlin | NLA17_NH-10292 | 44.5177 | -71.2269 | MESOTROPHIC | 20 to 50 | 33.86 |
| Hills Pond | NHLAK700060401-04 | Alton | NLA17_NH-10066 | 43.4823 | -71.3033 | MESOTROPHIC | 20 to 50 | 32.75 |
| Horseshoe Pond | NHLAK700030403-05 | Andover | NLA17_NH-10031 | 43.4345 | -71.7973 | MESOTROPHIC | 1 to 4 | 3.83 |
| Kenison Pond | NHLAK600030705-01 | Nottingham | NLA17_NH-10289 | 43.1654 | -71.1488 | EUTROPHIC | 4 to 10 | 6.13 |
| Kimball Pond | NHLAK700060302-06 | Canterbury | NLA17_NH-10023 | 43.3291 | -71.5658 | EUTROPHIC | 4 to 10 | 4.51 |
| Lake Winnisquam | NHLAK700020201-05-01 | Laconia | NLA17_NH-10003 | 43.5370 | -71.5110 | OLIGOTROPHIC | >50 | 1669.50 |
| Lime Pond | NHLAK801010403-03 | Columbia | NLA17_NH-10048 | 44.8718 | -71.4897 | MESOTROPHIC | 4 to 10 | 6.52 |
| Little Greenough Pond | NHLAK400010502-04 | Wentworth's Location | NLA17_NH-10002 | 44.8403 | -71.1344 | OLIGOTROPHIC | 10 to 20 | 13.11 |
| Lovell Lake | NHLAK600030401-01-01 | Wakefield | NLA17_NH-10017 | 43.5469 | -71.0156 | OLIGOTROPHIC | >50 | 209.16 |

| Lake Name | NH waterbody ID | Town | NLA ID | Latitude | Longitude | Historic NHDES Trophic Class | Surface Category (ha) | Lake area (ha) |
|---|---|---|---|---|---|---|---|---|
| Lower Mountain Lake | NHLAK801030505-03 | Haverhill | NLA17_NH-10027 | 44.1236 | -71.9591 | OLIGOTROPHIC | 10 to 20 | 16.13 |
| Marchs Pond | NHLAK600030601-04 | New Durham | NLA17_NH-10275 | 43.4637 | -71.1274 | OLIGOTROPHIC | 20 to 50 | 29.06 |
| Martin Meadow Pond | NHLAK801030102-02 | Lancaster | NLA17_NH-10288 | 44.4422 | -71.6062 | MESOTROPHIC | >50 | 52.70 |
| Mitchell Pond | NHLAK700061102-07 | Windham | NLA17_NH-10267 | 42.8338 | -71.2737 | MESOTROPHIC | 4 to 10 | 5.56 |
| Ottarnic Pond | NHLAK700061206-02 | Hudson | NLA17_NH-10058 | 42.7716 | -71.4237 | EUTROPHIC | 10 to 20 | 16.37 |
| Pearl Lake | NHLAK801030503-03 | Lisbon | NLA17_NH-10028 | 44.1995 | -71.8664 | MESOTROPHIC | 20 to 50 | 22.48 |
| Pequawket Pond | NHLAK600020303-07-01 | Conway | NLA17_NH-10006 | 43.9694 | -71.1357 | OLIGOTROPHIC | 20 to 50 | 47.52 |
| Pleasant Pond | NHLAK700060604-01 | Francestown | NLA17_NH-10272 | 43.0276 | -71.8094 | OLIGOTROPHIC | >50 | 73.59 |
| Pontook Reservoir | NHLAK400010602-11 | Dummer | NLA17_NH-10274 | 44.6337 | -71.2382 | MESOTROPHIC | >50 | 160.52 |
| Reeds Pond | NHIMP700030202-01 | Stoddard | NLA17_NH-10276 | 43.0503 | -72.0790 | NA | 1 to 4 | 2.21 |
| Sand Pond | NHLAK802010101-08 | Marlow | NLA17_NH-10030 | 43.1803 | -72.1666 | OLIGOTROPHIC | >50 | 63.02 |
| Sand Pond | NHLAK802010303-07 | Troy | NLA17_NH-10282 | 42.8183 | -72.1848 | MESOTROPHIC | 4 to 10 | 5.44 |
| Shellcamp Pond | NHLAK700060201-05 | Gilmanton | NLA17_NH-10039 | 43.4072 | -71.4236 | MESOTROPHIC | >50 | 50.58 |
| Sip Pond | NHLAK802020103-10 | Fitzwilliam | NLA17_NH-10004 | 42.7330 | -72.1033 | MESOTROPHIC | >50 | 53.37 |
| Spruce Pond | NHLAK600030702-02-01 | Deerfield | NLA17_NH-10029 | 43.1118 | -71.3329 | MESOTROPHIC | 4 to 10 | 8.41 |
| Squam Lake | NHLAK700010501-04-01 | Holderness | NLA17_NH-10287 | 43.7373 | -71.5612 | OLIGOTROPHIC | >50 | 2713.58 |
| Stonehouse Pond | NHLAK600030605-02 | Barrington | NLA17_NH-10013 | 43.1998 | -71.0960 | MESOTROPHIC | 4 to 10 | 4.42 |
| Storrs Pond | NHLAK801040402-02-01 | Hanover | NLA17_NH-10015 | 43.7291 | -72.2616 | OLIGOTROPHIC | 4 to 10 | 6.82 |
| Sunset Lake | NHLAK700060401-12 | Alton | NLA17_NH-10266 | 43.4732 | -71.3036 | OLIGOTROPHIC | >50 | 83.61 |
| Taylors Reservoir | NHLAK700061101-02 | Salem | NLA17_NH-10036 | 42.8388 | -71.2189 | MESOTROPHIC | 1 to 4 | 3.74 |
| Tural Reservoir | NHIMP700010303-03 | Wentworth | NLA17_NH-10283 | 43.8610 | -71.9318 | NA | 10 to 20 | 10.22 |
| Upper Danforth Pond | NHLAK600020803-03 | Freedom | NLA17_NH-10001 | 43.8367 | -71.0932 | MESOTROPHIC | 10 to 20 | 12.02 |
| Upper Kimball Pond | NHLAK600020401-01 | Chatham | NLA17_NH-10067 | 44.0867 | -71.0093 | MESOTROPHIC | >50 | 67.35 |
| Upper Wilson Pond | NHLAK802010303-09 | Swanzey | NLA17_NH-10026 | 42.9095 | -72.2577 | MESOTROPHIC | 4 to 10 | 4.03 |
| Warren Lake | NHLAK801070203-01 | Alstead | NLA17_NH-10046 | 43.1186 | -72.2886 | OLIGOTROPHIC | >50 | 78.97 |
| Woodward Pond | NHIMP802010202-05 | Roxbury | NLA17_NH-10286 | 42.9556 | -72.1809 | NA | >50 | 59.76 |

**Appendix B. Mean, standard error, upper and lower 95% confidence intervals, maximum value, and minimum value of individual parameters of New Hampshire lakes. Lakes were assessed during the 2017 National Lake Assessment or 2017 – 2019 state intensification and were randomly selected.**

| Parameter | Unit | Mean | Standard Error | 95% Confidence Intervals | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | |
| Acid Neutralizing Capacity | mg/L | 10.51 | 1.97 | 6.66 | 14.36 | 0.4 | 81.1 |
| Chloride [1] | mg/L | 15.96 | 2.92 | 10.24 | 21.69 | < 3 | 88.1 |
| Chlorophyll-*a* | µg/L | 6.29 | 0.49 | 5.33 | 7.25 | 0.67 | 23.39 |
| E. coli (Geometric Mean) | CFU/ 100 mL or MPN/ 100 mL | 19.42 | 4.46 | 10.68 | 28.16 | 3.56 | 128.3 |
| pH [2] | none | 6.50 | 0.11 | 6.27 | 6.72 | 5.55 | 7.82 |
| Total Nitrogen | µg/L | 485.74 | 22.66 | 441.33 | 530.15 | 150 | 1005 |
| Total Phosphorus | µg/L | 19.10 | 0.99 | 17.16 | 21.05 | 6.0 | 33.9 |
| Secchi Depth [3] | meter | 2.46 | 0.21 | 2.04 | 2.88 | 1.0 | 9.3 |
| Specific Conductance [3] | µS/cm | 86.03 | 14.74 | 57.14 | 114.92 | 10.71 | 366 |

[1] Data missing for one lake. Values are estimated from 49 out of the 50 assessed lakes.

[2] pH data presented are from the 2-meter composite and do not include pH data from water column profiles. As pH tends to decrease deeper into the water column, values are higher than what is typically found throughout a full water column.

[3] These data were not used in assessments and are presented for informational purposes only.

**Appendix C. Parameter Level Comprehensive Assessment of New Hampshire Lakes.**

| Parameter | Designated Use | Category | Percent of Lakes | 95% Confidence Limit | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| All parameters | ALU | FS | 9.1 | 2.3 | 15.8 |
| All parameters | ALU | NS | 90.9 | 84.2 | 97.7 |
| Acid Neutralizing Capacity | ALU | FS | 19.6 | 7.3 | 5.2 |
| Acid Neutralizing Capacity | ALU | NS | 80.4 | 7.3 | 66.0 |
| Chloride | ALU | FS | 100.0 | 100.0 | 100.0 |
| Chloride | ALU | NS | 0.0 | 0.0 | 0.0 |
| Chlorophyll-*a* | ALU | FS | 28.9 | 15.0 | 42.7 |
| Chlorophyll-*a* | ALU | II | 35.1 | 13.7 | 56.6 |
| Chlorophyll-*a* | ALU | NS | 36.0 | 16.4 | 55.7 |
| Dissolved Oxygen | ALU | FS | 71.5 | 9.9 | 52.1 |
| Dissolved Oxygen | ALU | II | 12.6 | 7.5 | 0.0 |
| Dissolved Oxygen | ALU | NS | 15.9 | 8.0 | 0.2 |
| Dissolved Oxygen Saturation | ALU | FS | 39.6 | 8.5 | 23.0 |
| Dissolved Oxygen Saturation | ALU | II | 20.2 | 7.7 | 5.0 |
| Dissolved Oxygen Saturation | ALU | NS | 40.2 | 10.1 | 20.4 |
| Invasive Species | ALU | FS | 84.7 | 70.7 | 98.7 |
| Invasive Species | ALU | NS | 15.3 | 1.3 | 29.3 |
| pH | ALU | FS | 16.6 | 7.6 | 25.7 |
| pH | ALU | NS | 83.4 | 74.3 | 92.4 |
| Total Phosphorus | ALU | FS | 12.9 | 5.1 | 20.8 |
| Total Phosphorus | ALU | II | 35.1 | 13.7 | 56.6 |
| Total Phosphorus | ALU | NS | 31.2 | 12.0 | 50.4 |
| Total Phosphorus | ALU | PNS | 20.7 | 9.6 | 31.8 |
| All parameters | PCR | FS | 92.2 | 85.8 | 98.7 |
| All parameters | PCR | NS | 7.8 | 1.3 | 14.2 |
| Bacteria | PCR | FS | 98.0 | 94.6 | 100.0 |
| Bacteria | PCR | NS | 2.0 | 0.0 | 5.4 |
| Chlorophyll-*a* | PCR | FS | 94.3 | 89.0 | 99.6 |
| Chlorophyll-*a* | PCR | NS | 5.7 | 0.4 | 11.0 |
| Cyanobacteria | PCR | FS | 100.0 | 100.0 | 100.0 |
| Cyanobacteria | PCR | NS | 0.0 | 0.0 | 0.0 |
| Bacteria | SCR | FS | 100.0 | 100.0 | 100.0 |
| Bacteria | SCR | NS | 0.0 | 0.0 | 0.0 |

ALU = Aquatic Life Integrity; PCR = Primary Contact Recreation; SCR = Secondary Contact Recreation

FS = Full Support; NS = Not Support; II = Insufficient Information; PAS = Potentially Attaining Support; PNS = Potentially Not Support

**Appendix D. Percentages, standard error, and upper and lower 95% confidence intervals of trophic classifications of lakes for the Nation, the Northern Appalachian Region, and New Hampshire. Lakes were assessed during the 2017 National Lake Assessment or 2017 – 2019 state intensification and were randomly selected.**

| Group | Trophic Class | Percent (%) | Standard Error | 95% Confidence | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| National | Hypereutrophic | 23.6 | 2.9 | 18.0 | 29.3 |
| | Eutrophic | 45.1 | 3.9 | 37.5 | 52.7 |
| | Mesotrophic | 20.3 | 2.2 | 16.0 | 24.7 |
| | Oligotrophic | 10.9 | 2.3 | 6.4 | 15.4 |
| North Appalachian Region (NAP) | Hypereutrophic | 5.3 | 2.1 | 1.1 | 9.5 |
| | Eutrophic | 29.1 | 9.9 | 9.7 | 48.5 |
| | Mesotrophic | 53.7 | 9.6 | 34.8 | 72.6 |
| | Oligotrophic | 11.9 | 4.3 | 3.5 | 20.2 |
| New Hampshire (NH) | Hypereutrophic | 0.0 | 0.0 | 0.0 | 0.0 |
| | Eutrophic | 36.8 | 10.2 | 12.9 | 52.9 |
| | Mesotrophic | 54.1 | 10.1 | 39.1 | 78.9 |
| | Oligotrophic | 9.1 | 2.8 | 2.7 | 13.5 |

**Appendix E. Percentages, standard error, and upper and lower 95% confidence intervals of condition estimates for the Nation, the Northern Appalachian Region, and New Hampshire. Lakes were assessed during the 2017 National Lake Assessment or 2017 – 2019 state intensification and were randomly selected.**

| Region | Chlorophyll-a | | | | | Acid Neutralizing Capacity | | | | | Dissolved Oxygen | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Condition | % | Std Error | 95% Confidence Lower | 95% Confidence Upper | Condition | % | Std Error | 95% Confidence Lower | 95% Confidence Upper | Condition | % | Std Error | 95% Confidence Lower | 95% Confidence Upper |
| National | Good | 34.1 | 3.4 | 27.3 | 40.8 | Good | 95.7 | 2.0 | 91.7 | 99.7 | Good | 75.1 | 3.5 | 68.2 | 81.9 |
| | Fair | 20.5 | 3.9 | 12.8 | 28.1 | Fair | 1.7 | 0.4 | 0.9 | 2.6 | Fair | 16.3 | 2.9 | 10.7 | 21.9 |
| | Poor | 45.5 | 3.7 | 38.2 | 52.7 | Poor | 2.6 | 2.0 | 0.0 | 6.5 | Poor | 8.5 | 2.5 | 3.7 | 13.4 |
| | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.1 | 0.1 | 0.0 | 0.2 |
| North Appalachian Region (NAP) | Good | 61.7 | 9.5 | 43.1 | 80.4 | Good | 85.7 | 4.3 | 77.3 | 94.2 | Good | 75.9 | 10.2 | 55.9 | 96.0 |
| | Fair | 5.5 | 1.8 | 1.9 | 9.1 | Fair | 14.3 | 4.3 | 5.8 | 22.7 | Fair | 7.3 | 2.9 | 1.6 | 13.0 |
| | Poor | 32.7 | 9.7 | 13.7 | 51.8 | Poor | 0.0 | 0.0 | 0.0 | 0.0 | Poor | 16.8 | 10.6 | 0.0 | 37.6 |
| | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 |
| New Hampshire (NH) | Good | 28.1 | 6.9 | 14.6 | 41.7 | Good | 2.3 | 1.8 | 0.0 | 5.9 | Good | 85.5 | 8.5 | 68.7 | 100.0 |
| | Fair | 59.5 | 8.5 | 43.0 | 76.1 | Fair | 97.7 | 1.8 | 94.1 | 100.0 | Fair | 14.5 | 8.5 | 0.0 | 31.3 |
| | Poor | 12.3 | 4.1 | 4.2 | 20.4 | Poor | 0.0 | 0.0 | 0.0 | 0.0 | Poor | 0.0 | 0.0 | 0.0 | 0.0 |
| | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 |

| Region | Total Phosphorus | | | | | Total Nitrogen | | | | | Lakeshore Disturbance Index | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Condition | % | Std Error | 95% Confidence Lower | 95% Confidence Upper | Condition | % | Std Error | 95% Confidence Lower | 95% Confidence Upper | Condition | % | Std Error | 95% Confidence Lower | 95% Confidence Upper |
| National | Good | 41.0 | 4.0 | 33.2 | 48.8 | Good | 38.9 | 4.0 | 31.1 | 46.8 | Good | 24.7 | 4.1 | 16.8 | 32.7 |
| | Fair | 14.1 | 1.9 | 10.2 | 17.9 | Fair | 14.9 | 2.0 | 11.0 | 18.8 | Fair | 45.1 | 3.6 | 38.0 | 52.1 |
| | Poor | 44.9 | 3.7 | 37.7 | 52.2 | Poor | 46.2 | 3.8 | 38.8 | 53.5 | Poor | 29.4 | 3.1 | 23.4 | 35.5 |
| | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.8 | 0.5 | 0.0 | 1.7 |
| North Appalachian Region (NAP) | Good | 54.4 | 9.3 | 36.2 | 72.5 | Good | 54.6 | 9.5 | 36.0 | 73.2 | Good | 47.4 | 9.3 | 29.1 | 65.7 |
| | Fair | 16.4 | 4.5 | 7.6 | 25.1 | Fair | 18.8 | 7.3 | 4.5 | 33.2 | Fair | 44.2 | 9.5 | 25.5 | 62.8 |
| | Poor | 29.3 | 9.8 | 10.0 | 48.6 | Poor | 26.6 | 10.0 | 7.0 | 46.2 | Poor | 8.4 | 3.0 | 2.5 | 14.2 |
| | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 |
| New Hampshire (NH) | Good | 29.3 | 6.4 | 16.7 | 41.9 | Good | 44.4 | 9.4 | 26.0 | 62.8 | Good | 16.3 | 4.8 | 6.9 | 25.7 |
| | Fair | 70.1 | 6.5 | 57.3 | 82.8 | Fair | 43.9 | 10.1 | 24.1 | 63.7 | Fair | 21.6 | 8.0 | 5.9 | 37.2 |
| | Poor | 0.6 | 0.5 | 0.0 | 1.7 | Poor | 11.7 | 4.1 | 3.7 | 19.6 | Poor | 0.0 | 0.0 | 0.0 | 0.0 |
| | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 0.0 | 0.0 | 0.0 | 0.0 | Not Assessed | 62.2 | 9.2 | 44.2 | 80.2 |