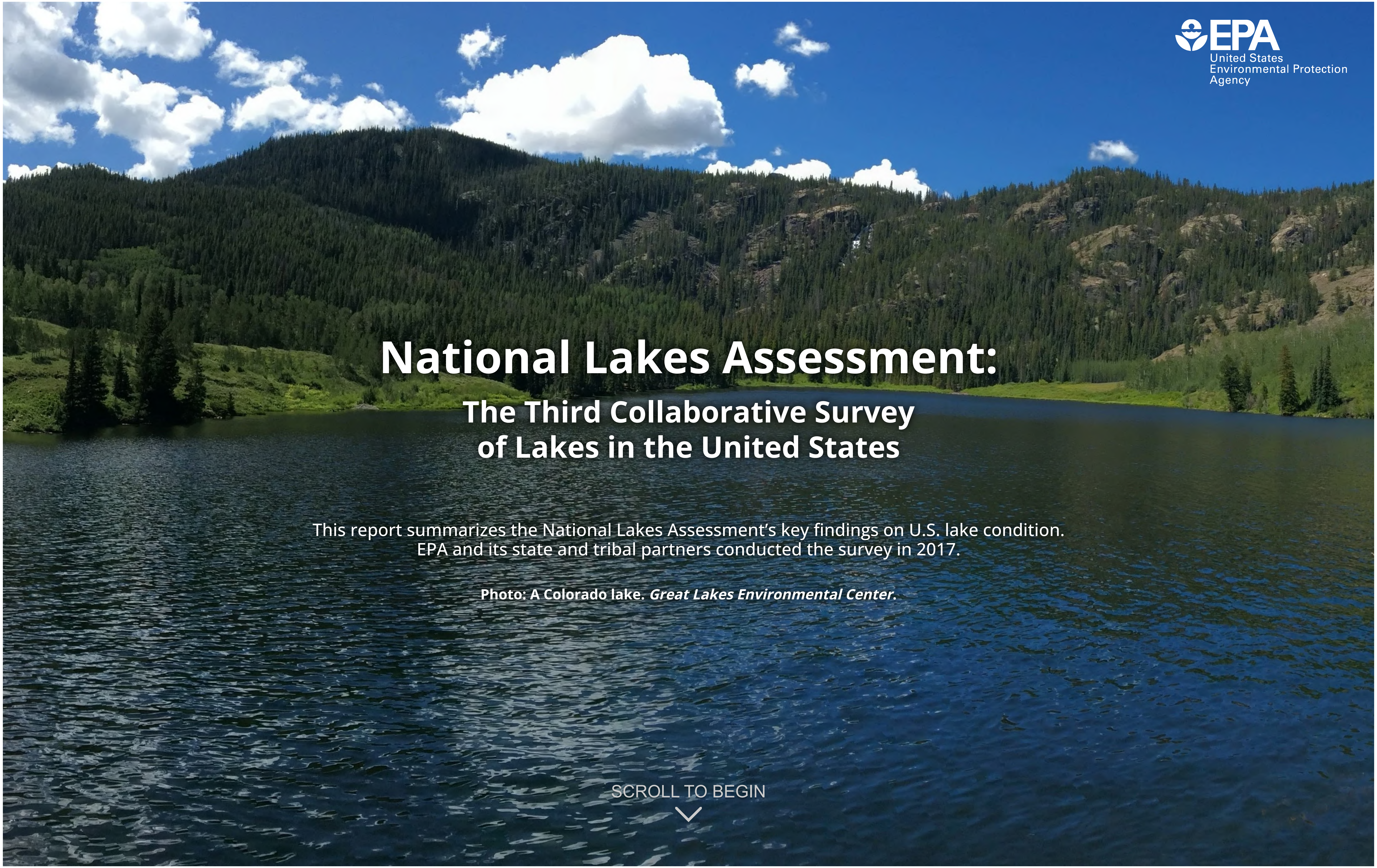

EPA
United States
Environmental Protection
Agency

National Lakes Assessment:

The Third Collaborative Survey of Lakes in the United States

This report summarizes the National Lakes Assessment's key findings on U.S. lake condition.
EPA and its state and tribal partners conducted the survey in 2017.

Photo: A Colorado lake. *Great Lakes Environmental Center*.

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Introduction

Healthy lakes enhance our quality of life. They sustain food webs and provide habitat for fish and wildlife. Lakes contribute to a healthy economy, supporting tourism and recreation, as well as supplying drinking water. For the National Lakes Assessment (NLA), the Environmental Protection Agency (EPA), states, tribes, and other partners surveyed a wide array of lakes, from small ponds and prairie potholes to large lakes and human-made reservoirs, on federal, tribal, state, and private land (see Acknowledgments for a list of partners).

The *National Lakes Assessment: The Third Collaborative Survey of Lakes in the United States* presents the results of the 2017 survey of lake condition in the conterminous

> Sharing a common boundary. The conterminous U.S includes the continental United States except Alaska.

United States. The first two surveys took place in 2007 and 2012. During spring and summer of 2017, 89 field crews sampled 1,005 lakes, using standardized sampling procedures to collect data on biological, chemical, physical, and recreational indicators. The measured values were compared to NLA benchmarks to assess lake condition.

The NLA is designed to answer the following questions about lakes across the United States.

1. What percent of waters support healthy ecosystems and recreation?
2. What are the most common water quality problems?
3. Is water quality improving or getting worse?
4. Are investments in improving water quality focused appropriately?

The NLA is one of four statistical surveys that make up the National Aquatic Resource Surveys (NARS) program, which is designed to assess the condition of all waters nationally over time. For more information, see the NARS history page. The NLA can help stakeholders plan for the protection and restoration of lakes across the United States.

In addition to examining the health of lakes on a national scale, the NLA is designed to provide statistically valid results on the condition of a number of subpopulations. Subpopulation results can provide additional information on the conditions of the nation's lakes on a regional scale or for a particular lake type (natural lakes vs. reservoirs).

This report focuses on NLA 2017 results at national scale, comparing the condition of lakes to that from NLA 2012. Regional highlights are provided as well.

Results from the NLA can help us better understand the condition of lakes in the United States, some of the stressors affecting them, and how stressors relate to local conditions. While this report explores associations between these indicators, it does not explain or identify the causes of degraded conditions or sources of stressors. Additional research is needed to address these questions. Further, data from future assessments will help determine whether changes observed between 2012 and 2017 represent a trend or are the result of natural variability.

KEY FINDINGS ON 2017 CONDITION

Key results for 2017 are summarized below. Following standard practices (described in the Background section), EPA analysts classified results for most indicators as good, fair, or poor. For a few indicators, results indicate whether chemicals were detected or whether levels exceeded a single benchmark.

> Many of the indicators included in the NLA are natural components of lakes but can also serve as measures of water quality degradation. For example, some level of a nutrient like phosphorus is necessary to support lake aquatic communities, but excessive quantities can be detrimental. The NLA explores how these measures compared to expectations or benchmarks.

Nutrient pollution was the most widespread stressor measured.

- Across the country, 45% of lakes were in poor condition with elevated phosphorus, and 46% were in poor condition with elevated nitrogen.
- Hypereutrophic conditions, typically characterized by excess nutrients, high levels of algae growth, and low transparency, were observed in 24% of lakes.
- Excess nutrients can contribute to algal blooms and low oxygen levels, affecting ecological health, public health, and recreation in lakes.

Poor biological condition was more likely when lakes were in poor condition with respect to nutrients.

- Nationally, in lakes where phosphorus was elevated, benthic macroinvertebrate communities (e.g., insect larvae, snails, and clams living on the lake bottom) were 2.3 times more likely to be in poor condition. In natural lakes (i.e., excluding reservoirs), this risk increased to 6.9.
- Based on benthic macroinvertebrates, EPA found that 24% of lakes were in poor condition and 29% of lakes were in fair condition.

- Based on zooplankton (microscopic animals in the water column), 22% of lakes were in poor condition, and 23% of lakes were in fair condition.
- Chlorophyll *a*, which indicates the amount of microscopic algae and cyanobacteria present, was in excess and rated poor in 45% of lakes.

A field crew member collecting a zooplankton sample. *EPA*.

Lakeshore disturbance was widespread, yet other physical habitat conditions were rated good in more than half of all lakes.

- Only 25% of lakes were in good condition based on lakeshore disturbance measures, indicating moderate to high levels of human activity and shoreline alterations in 75% of lakes.
- Only 3% of lakes had poor (large) drawdown. The drawdown indicator measures water levels and their fluctuation.

- Most lakes were rated good for shallow water habitat (65%), riparian (lakeshore) vegetation cover (51%), and habitat complexity (55%) conditions.

The algal toxins known as microcystins were detected in 21% of lakes.

- Microcystins measured in the open waters exceeded the EPA recreational criterion in 2% of lakes, representing 4,400 lakes across the nation.
- For information on algal toxins in specific lakes, people should check with state, tribal, or local governments before swimming, boating, or fishing.

The herbicide atrazine was detected at low levels in 30% of lakes and was sometimes associated with poor biological condition.

- Atrazine levels exceeded the EPA benchmark, the "concentration equivalent level of concern" for aquatic plant communities, in 0.5% of lakes, representing 1,200 lakes.
- In reservoirs (but not in natural lakes), poor biological condition was almost three times more likely for benthic macroinvertebrates when atrazine was detected.

Elephant's head (*Pedicularis groenlandica*), a common alpine riparian plant, growing near a Colorado lake. *Great Lakes Environment Center*.

KEY FINDINGS ON CHANGE FROM 2012 TO 2017

For both nutrients and biological indicators, there was little change between surveys at the national level, except for chlorophyll *a*.

- The percentage of lakes in good chlorophyll *a* condition decreased significantly, from 46% to 34%.

There were significant changes in some chemical and physical habitat measures.

- Lakes with good habitat complexity increased 13 percentage points in 2017.
- Lakes with good ratings for dissolved oxygen decreased by 12 percentage points.
- Detection of microcystins decreased among lakes in 2017 by 16 percentage points.

NLA DASHBOARD

EPA developed an interactive dashboard to accompany this report. It contains regional results and allows comparisons between natural lakes and reservoirs. For a subset of lakes, those at least 4 hectares in area, results are available back to 2007 (NLA 2007 included only these larger lakes).

Users can also get to the dashboard by following the link at the bottom of each graph in this report. Those links will bring users to a customized page with regional data for each indicator. Users can then navigate to other dashboard views using the "Condition Estimate" dropdown and other dashboard controls.

HOW CAN I FIND OUT MORE?

Read the other sections of this report for more detail on the results nationally for each indicator. See the NLA 2017 Technical Support Document (U.S. EPA 2022) for technical details on the survey design, benchmarks, and data analyses that underpin the findings in this report. Additional information on the NLA and previous NLAs is available at EPA's NLA home page. The NARS team prepares additional products using the science and data from the assessments. Readers may want to visit the NLA homepage periodically to find more resources; the page is updated as new items come out. Other NLA information, such as published scientific research, is available at the NARS website, along with NARS results for other surveys.

Background

This section provides a brief background on the survey methodology. For details on survey design, field methods, and quality assurance plans, see EPA's NARS manuals page. For details on the NLA 2017 survey design, see EPA's design documents page.

CHOOSING INDICATORS

EPA used several indicators to assess the chemical, physical, recreational, and biological condition of lakes. Although there are others that could be used to describe lake condition, EPA has determined that these indicators align with the goals of the survey described earlier and are the most representative at a national scale (U.S. EPA 2009). EPA grouped indicators into four categories.

Baxter State Park, Maine. *Natalie Auer*.

The **trophic state** indicator category has just one indicator: Trophic state

There are three **biological** indicators: Chlorophyll *a* | Benthic macroinvertebrates | Zooplankton

There are six **chemical** indicators: Acidification | Atrazine | Microcystins | Dissolved oxygen | Nutrients (nitrogen and phosphorus)

There are five **physical** indicators: Lake drawdown exposure | Lakeshore disturbance | Riparian vegetation cover | Shallow water habitat | Lake habitat complexity

SELECTING LAKES

EPA used a statistical sampling approach to select lakes for this assessment, to ensure that survey results were unbiased. For more information on statistical surveys, see What Are Probability Surveys? and Selecting a Sampling Design. The target population

> A population of interest to the researchers. Members of the population share characteristics.

for the NLA was the set of lakes in the conterminous U.S. meeting the definition below.

How Were Lakes Defined?

To be included in the survey, a water body had to be a pond, natural lake, or reservoir

> An artificial lake that is created when water backs up behind a dam or other impoundment structure.

at least 2.47 acres (1 hectare) in area, at least 3.3 feet (1 meter) deep, and with at least a quarter acre (0.1 hectare) of open water. In addition, lakes were required to have a lake water minimum residence time

The amount of time it takes a unit of water to pass through a water body. For NLA 2017, this determination was based on available state data or best professional judgment.

of one week. The Great Lakes and the Great Salt Lake were not included in the survey, nor were commercial treatment and/or disposal ponds, tidally influenced lakes, or ephemeral lakes.

Of the total 224,916 lakes in the target population in 2017, approximately 36% were natural (81,996 lakes), and 64% were reservoirs (142,920 lakes).

The 1,005 lakes sampled were identified using a statistical method called stratified random sampling. This approach is also used in social science and health fields to determine the status of populations. In such a design, lakes are categorized into groups (for instance, by size or location), and every lake in the target population has a known probability of being selected for sampling. The NLA 2017 design was stratified by state to ensure there were sites in every conterminous state.

The statistical design of the survey allows EPA to extrapolate the results from the 1,005 lakes sampled to the 224,916 U.S. lakes meeting the definition in the box above. Throughout this report, percentages reported for a given indicator apply to the 224,916 lakes in the target population. For example, if the condition is described as poor for 10% of lakes nationally, this means that the number of lakes estimated to be degraded for that indicator is 22,492.

To produce the results for each indicator, EPA assigned each randomly selected site a weight based upon the total number of lakes that the site represented. This enabled EPA to estimate the proportion of all lakes in each condition category (e.g., good, fair, poor). See the appendix and NLA 2017 Technical Support Document (U.S. EPA 2022) for details.

When designing the survey, EPA considered the number of lakes that should be sampled. The greater the number of sites sampled, the more confidence in the results. The 1,005 sites sampled in the NLA 2017 allow EPA to determine the condition of lakes within a margin of error of approximately ±5%, with 95% confidence at the national scale. See Exhibit 1 for a map of the 2017 sampling sites and their distribution across ecoregions

Ecoregions are areas that contain similar environmental characteristics such as climate, vegetation, soil type, and geology.

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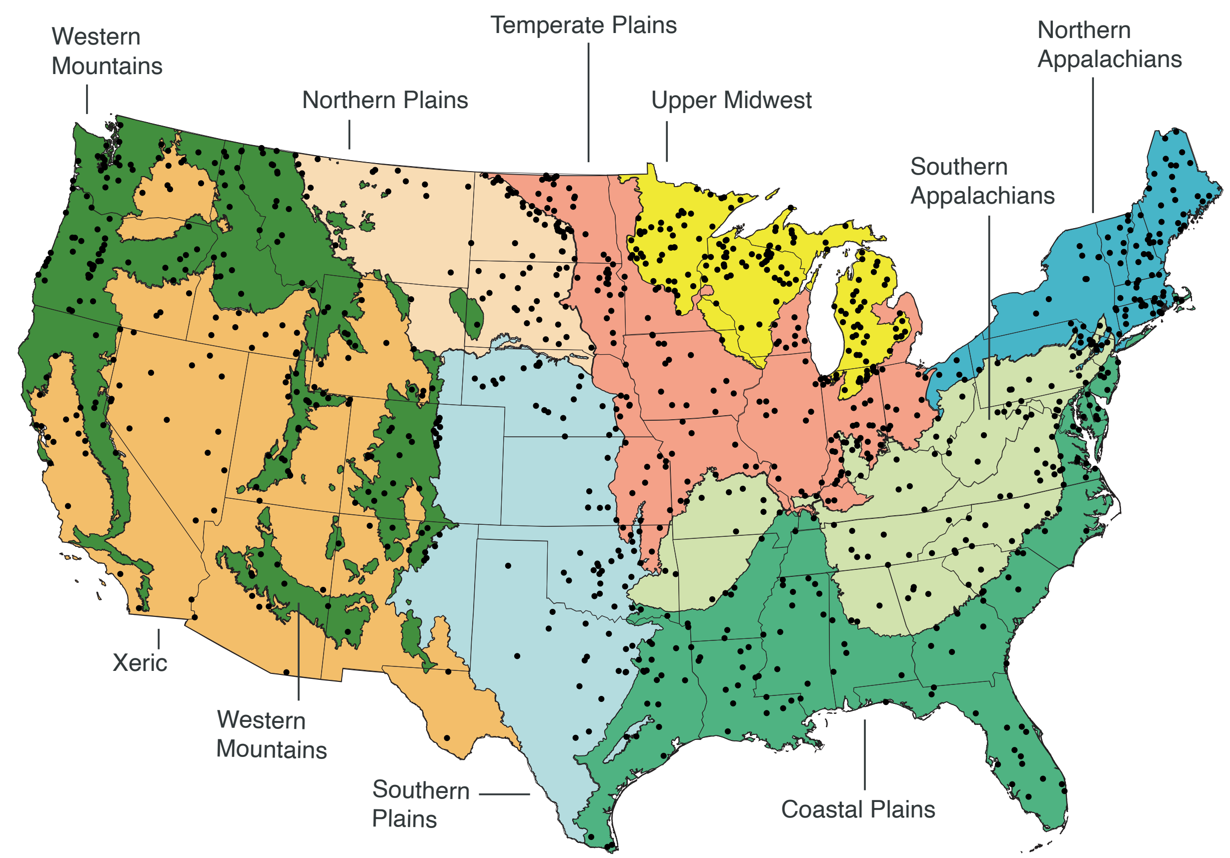
Exhibit 1: Map of NLA 2017 Sampling Sites in Each Ecoregion



FIELD SAMPLING

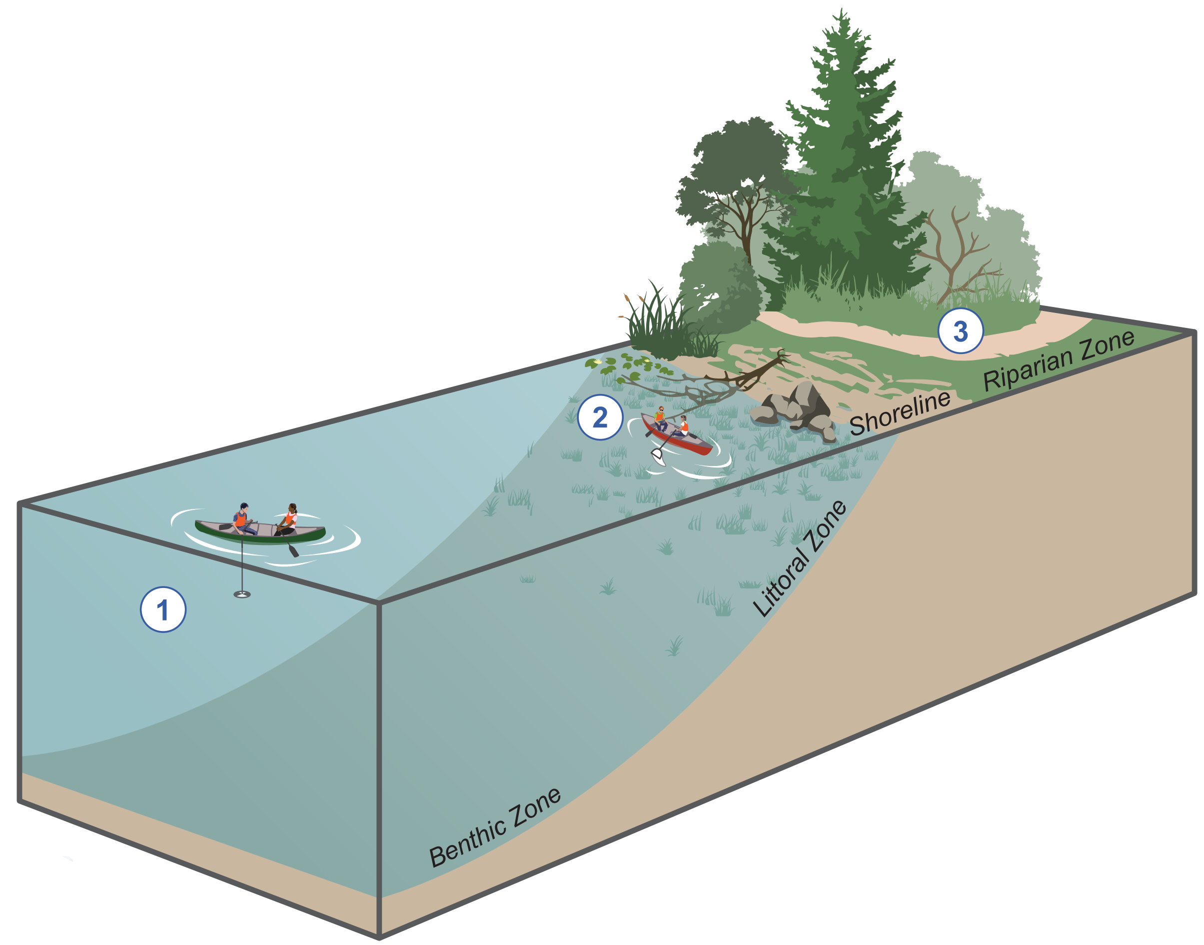
Sampling each lake took a full day. To ensure consistency in collection procedures and to assure the quality of resulting data, field crews participated in training, used standardized field methods, and followed strict quality control protocols (U.S. EPA 2017).

At each lake, crews collected samples at multiple depths, at a mid-lake site reflecting the lake's deepest point (or a site with a depth of 50 meters in deep lakes). From their boats, crews also collected samples in the littoral zone

> The shallow nearshore area in which sunlight penetrates the water all the way to the lake floor and allows rooted vegetation to grow. For assessment purposes, littoral sampling and observations were conducted 10 meters or less from shore.

and recorded littoral and riparian (lakeshore) habitat observations at ten locations evenly distributed around the lake perimeter (see Exhibit 2 for details).

Exhibit 2: Field Crew Sampling for NLA 2017



(1) Mid-lake, crews recorded temperature, pH, and dissolved oxygen at multiple depths using an electronic sensor. They determined water clarity and light penetration by lowering a black and white disk called a Secchi disk. Near the surface (at depths up to 2 meters), they collected samples for atrazine, nutrients, chlorophyll *a*, and microcystins, using a long plastic tube. Also near the surface, they collected zooplankton with a fine mesh net. Lastly, they collected research indicator samples including bacteria, phytoplankton, lake sediment chemistry, dissolved gas, and environmental DNA. (2) In the littoral zone, crews sampled benthic macroinvertebrates from the lake bottom with a D-frame dip net. (3) From the boat, they recorded vegetation characteristics and signs of human disturbance in the littoral, shoreline, and riparian zones.

ASSESSMENT BENCHMARKS

NLA analysts reviewed the raw data for each indicator independently and assigned the values in each dataset to categories (for example, "above benchmark" or "at or below benchmark," or good, fair, or poor). To assign the appropriate condition category, the NLA 2017 used two types of assessment benchmarks.

The first type consisted of fixed benchmarks based on values identified in the peer-reviewed scientific literature. For example, an EPA recommended swimming advisory was used nationally to classify lakes for microcystins.

The second type consisted of NLA-specific ecoregional benchmarks based on the distribution of indicator values from a set of reference lakes

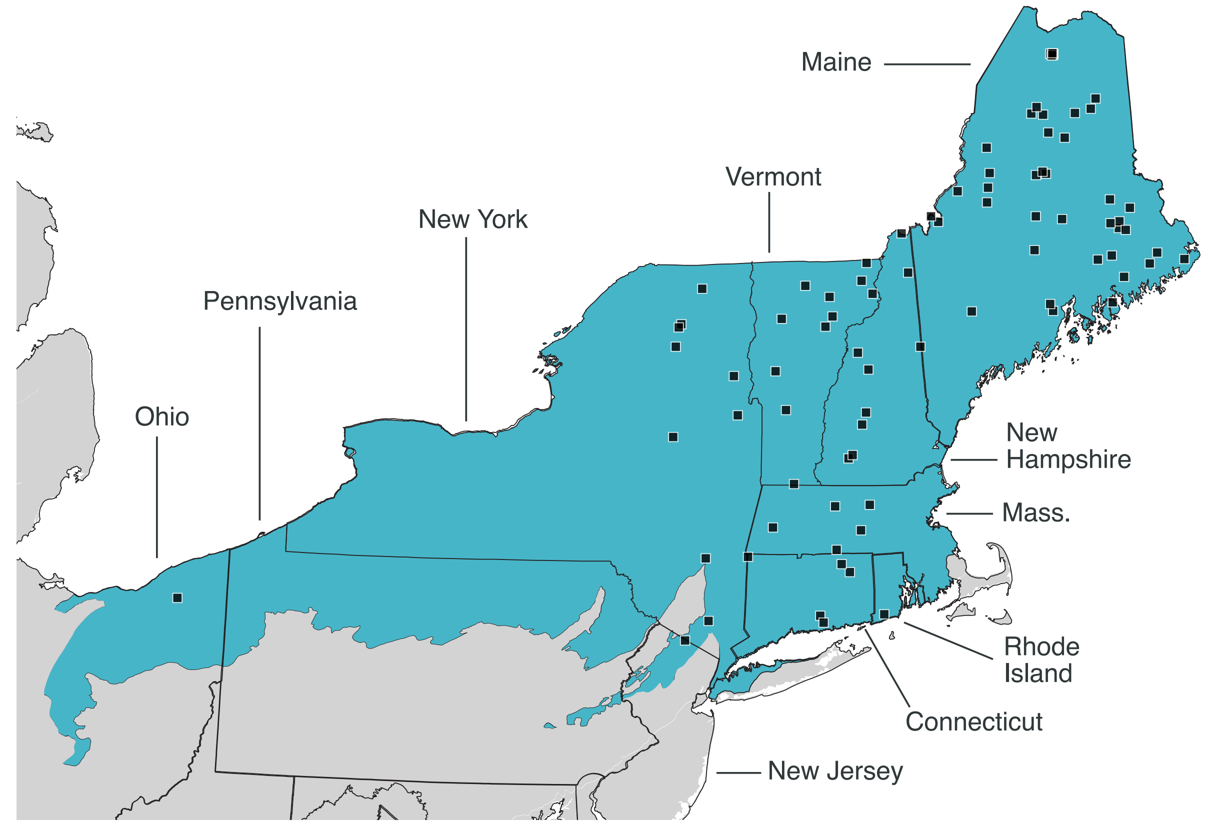
> A reference lake is a lake, either natural or reservoir, with attributes (such as water quality) that come as close as practical to those expected in a natural state, i.e., a least-disturbed lake.

. EPA chose this regional benchmark approach because lake characteristics in different ecoregions vary due to climate, geology, and ecology, as well as human disturbance. Numerous scientific studies described in the NLA 2017 Technical Support Document, as well as peer reviews of this report and other NARS surveys, support the use of regional benchmarks to evaluate the condition of lakes and other types of waters (U.S. EPA 2022).

The steps below describe EPA's process for setting regional benchmarks and then determining lake condition. Exhibits 3-6 provide an example of how the phosphorus benchmark was derived for the Northern Appalachian ecoregion. The process for other indicators and ecoregions was similar, resulting in regionally relevant benchmarks for each of the nine ecoregions. The Technical Support Document describes this process in more detail and provides indicator-specific details about both types of benchmarks (including screening for reference lakes).

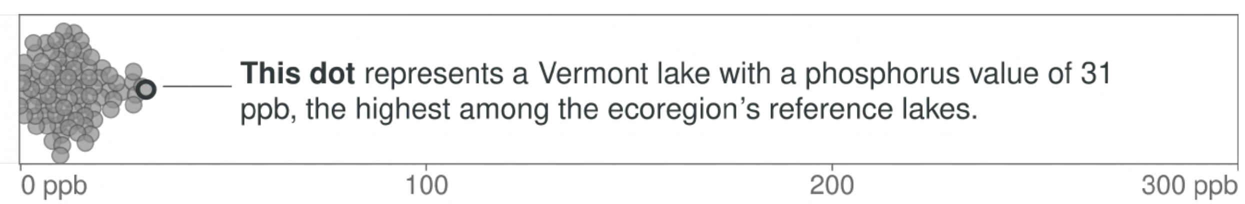
1. Screen Lakes to Identify Reference Sites. First, NLA teams compiled lake information from all NLA surveys for both the randomly selected lakes and a smaller set of hand-picked lakes thought to have low levels of human disturbance. EPA scientists evaluated these lakes by considering reference screening factors, such as chloride and sulfate concentrations and land use. Lakes that passed screening were considered less disturbed than others and qualified as reference lakes. Exhibit 3 shows a map of reference lakes in the Northern Appalachians ecoregion.

Exhibit 3: Reference Lakes in the Northern Appalachians Ecoregion



In the exhibit below, each dot indicates the observed phosphorus level (in parts per billion, or ppb) at one of the reference lakes. Many of the dots overlap because they have similar low phosphorus values.

Exhibit 4: Phosphorus Values of Northern Appalachian Reference Sites

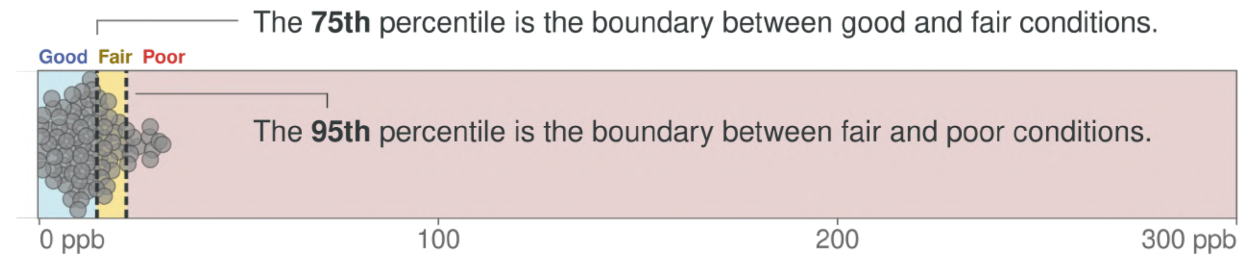


2. Calculate Condition Benchmarks Using Reference Lake Data. EPA then used the 75th and 95th percentiles

The 75th percentile is the point below which 75% of reference values fall. The 95th percentile is the point below which 95% of reference values fall. For phosphorus, the higher the value, the worse water quality is. (For indicators like benthic macroinvertebrate condition, the lower the value, the worse water quality is. In such cases, values below the 5th percentile are considered poor condition, and those above the 25th indicate good condition.)

of the reference lake phosphorus distribution to set the benchmarks for the condition categories (see the exhibit below).

Exhibit 5: Phosphorus Condition Benchmarks in the Northern Appalachians Ecoregion



3. Assign Condition Categories to NLA Lakes. Using those regional benchmarks, EPA assigned the phosphorus condition (good/fair/poor) to each of the lakes that were randomly sampled as part of the NLA. As an example, the exhibit below shows the phosphorus value for each lake sampled in the Northern Appalachian ecoregion and the condition category in which it falls.

Exhibit 6: Phosphorus Values of Northern Appalachian Sites Randomly Sampled in 2017

For NLA 2017, EPA recalculated all regional benchmarks to include data from reference lakes sampled in 2017, strengthening confidence in the benchmark values. Robust benchmarks facilitate analyses of trends and changes in condition. In some cases, the benchmarks changed from those calculated in 2012; some stayed the same. See the appendix and the Technical Support Document for more information. Where benchmarks were revised, data from previous surveys were assessed against the new benchmarks in order to analyze change from 2012 to 2017. To see the ecoregional condition for phosphorus (and other indicators) for 2017, visit the NLA 2017 dashboard.

The NLA assessment benchmarks have no legal effect and are not equivalent to individual state water quality standards, nor do the condition categories correspond to the assessment by states and tribes of the quality of lakes relative to their specific water quality standards under the Clean Water Act. For additional information on state-specific and local water quality data and assessments, visit EPA's How's My Waterway application.

National Results

This chapter presents information on each of the NLA indicators. Each indicator section contains three parts: a brief explanation of why the indicator matters, results from the 2017 survey, and change in condition from 2012 to 2017. For more details on the benchmarks for each indicator, see the NLA 2017 Technical Support Document. To download raw data from the survey, visit EPA's NARS data page. Note that the 2012 condition estimates reported here differ from the results reported in the NLA 2012 report due to changes in benchmarks and statistical adjustments to population estimates (see the appendix). All comparisons between earlier NLAs and NLA 2017 should be made using the new information presented in the 2017 report and dashboard.

The graphs below show the estimated proportion of the nation's lakes in each condition class and for some indicators, the proportion not assessed

A "not assessed" result is the product of the inability to collect or analyze a sample or a field observation. For example, samples can be lost in shipping, or the lake bottom might have a rocky surface that prevents sample collection.

. Each estimate is accompanied by a 95% confidence interval that conveys the certainty in the estimate. The Technical Support Document explains the underlying assumptions and analyses.

The graphs present national data, but each graph contains a customized link to ecoregional data. Visit EPA's NARS ecoregions page for maps and characteristics of each ecoregion.

TROPHIC STATE INDICATOR

Trophic state is commonly used for classifying the biological productivity of lakes. It is a measure of the total algal abundance, or algal biomass, estimated using chlorophyll *a*. Lakes with high nutrient levels and high productivity are termed eutrophic, whereas lakes that have low concentrations of nutrients, low rates of productivity, and generally low biomass, such as alpine lakes, are termed oligotrophic. Lakes that fall in between these two states are called mesotrophic.

Eutrophic lakes may have dense vegetation and noticeable macroscopic algal growth. *Environmental Institute of Houston, University of Houston-Clear Lake.*

Hypereutrophic conditions

> Hypereutrophic lakes have extreme primary production (high levels of photosynthesis), reduced biological diversity, and reduced metabolism, which results in an imbalanced lake ecosystem.

are usually the result of human activity and can be an indicator of stress conditions.

Eutrophication occurs naturally as lakes age, on timescales of thousands of years. However, human activities can accelerate eutrophication and cause hypereutrophication and its undesirable effects, including nuisance algae, excessive plant growth, murky water, lower levels of dissolved oxygen, odor, and fish kills.

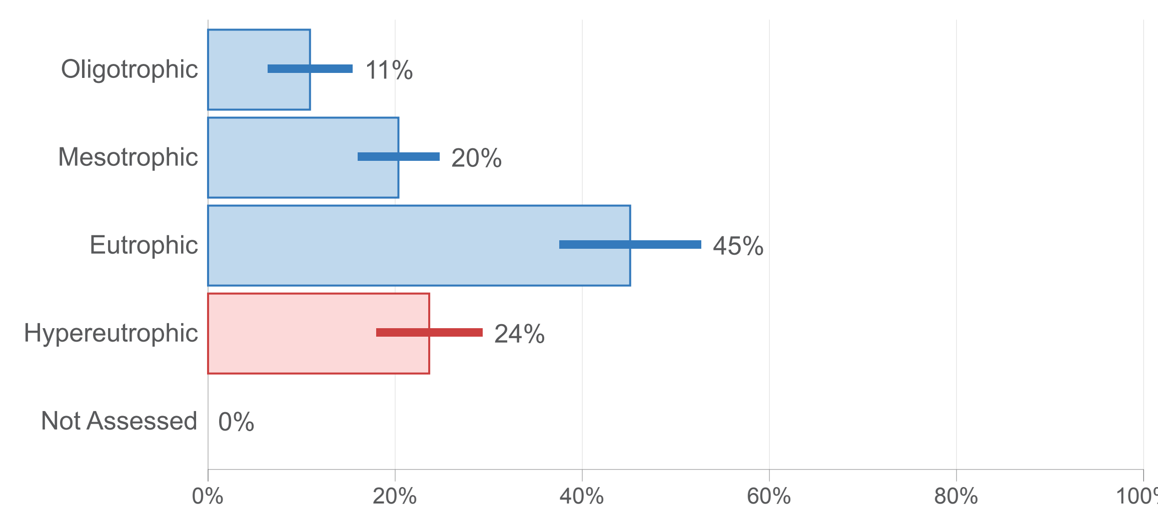
To estimate the trophic status of lakes, EPA analysts compared chlorophyll *a* concentrations to literature-based benchmarks. The trophic state benchmark categories are listed below.

- Oligotrophic: chlorophyll *a* concentrations of ≤2 ppb.
- Mesotrophic: >2 ppb but ≤7 ppb.
- Eutrophic: >7 ppb but ≤30 ppb.
- Hypereutrophic: >30 ppb.

What was the condition in 2017?

Eutrophication was widespread in NLA 2017: 24% of lakes were hypereutrophic, and 45% were eutrophic. Oligotrophic lakes made up 11% of lakes.

Exhibit 7: Trophic State Indicator Condition (2017)
Percentage of lakes in each condition category nationally

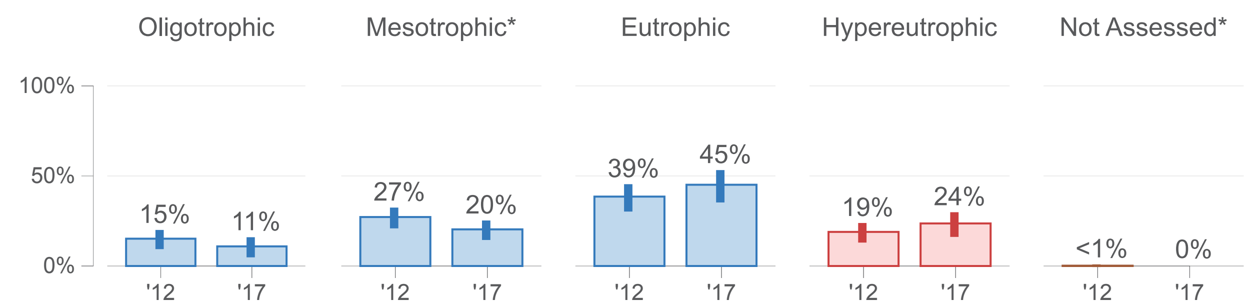


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on trophic state indicator.

Did the condition change?

The percentage of lakes in mesotrophic condition declined from 27% to 20%; this change was statistically significant. All other changes in trophic state were not significant nationally. In the Upper Midwest ecoregion, statistically significant changes in trophic condition included a decline in mesotrophic condition (change from 47% to 31%) and an increase in hypereutrophic condition (change from 5% to 14%).

Exhibit 8: Change in Trophic State Indicator Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on trophic state indicator.

BIOLOGICAL INDICATORS

The biology of a water body (the biological condition) can be characterized by the presence, number, and diversity of macroinvertebrates, algae, vascular plants, and other organisms. Together, they provide information about the health and productivity of the ecosystem. For NLA 2017, EPA assessed three biological indicators: chlorophyll *a*, benthic macroinvertebrates, and zooplankton. EPA continues to research the sensitivity of these indicators to environmental factors (e.g., the effect of soft sediment versus cobble/rocky substrate) and biological variables (e.g., the effect of fish predation). In future assessments, EPA may revise and refine these indicators to reflect new scientific understanding.

Chlorophyll *a*

Chlorophyll allows plants, algae, and cyanobacteria to photosynthesize. Chlorophyll *a* is the predominant type of chlorophyll used by algae and cyanobacteria for growth. It can therefore be used to measure the quantity of these organisms in a lake, as well as to classify trophic state. Although algae and cyanobacteria are a natural part of freshwater ecosystems, at high levels they can cause aesthetic problems such as green scums and odors and can negatively affect dissolved oxygen levels. Some algae and cyanobacteria also produce toxins that can be of public health concern at high concentrations. Waters with high levels of nutrients from fertilizers, manure, septic systems, sewage treatment plants, and urban runoff may have high concentrations of chlorophyll *a*, algae, and cyanobacteria.

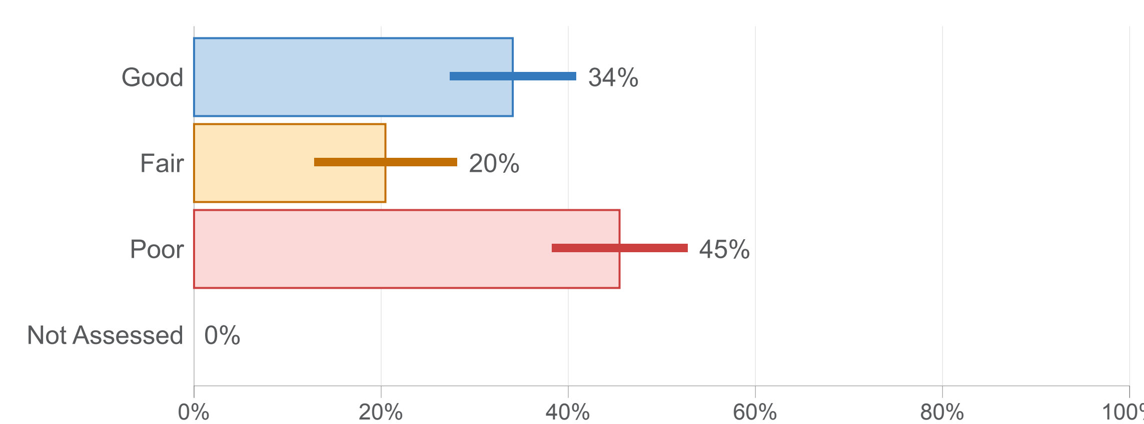
Field crew members collecting a water sample to be analyzed for chlorophyll *a*, nutrients, and atrazine. *EPA*.

For NLA 2017, EPA compared chlorophyll *a* concentrations to regional benchmarks, in addition to the trophic state chlorophyll *a* literature-based benchmarks mentioned in the previous section. Comparing chlorophyll *a* concentrations to regional benchmarks provides an understanding of lake productivity as it relates to the natural conditions that influence algal growth (such as nutrients, temperature, and turbidity) and are expected to vary nationally.

What was the condition in 2017?

In 2017, 34% of lakes were rated good for chlorophyll *a*, 20% were rated fair, and 45% were rated poor. The Northern Appalachians ecoregion had a greater percentage of lakes rated good for chlorophyll *a* (62%) compared to national results.

Exhibit 9: Chlorophyll *a* Condition (2017)
Percentage of lakes in each condition category nationally

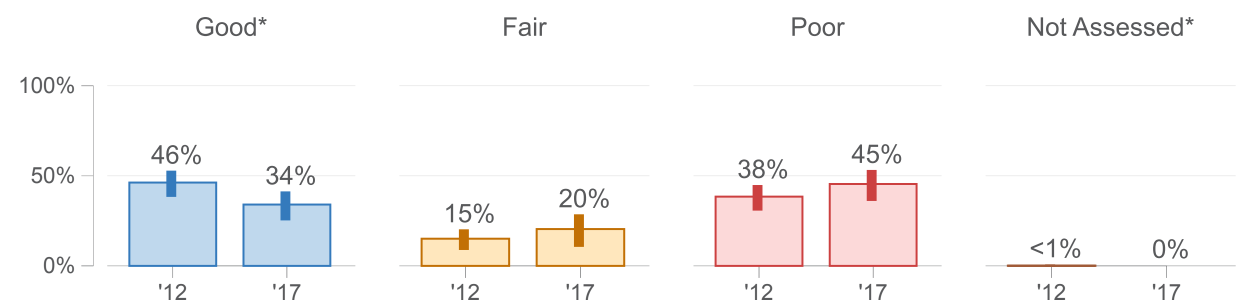


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on chlorophyll *a*.

Did the condition change?

The percentage of lakes in good condition decreased significantly from 46% to 34%. Changes in fair and poor condition were not significant. The significant decline in good condition was prominently observed in the Temperate Plains ecoregion, which decreased from 49% to 17%.

Exhibit 10: Change in Chlorophyll *a* Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on chlorophyll *a*.

Benthic Macroinvertebrates

Benthic macroinvertebrates include aquatic insect larvae and nymphs, small aquatic mollusks, crustaceans such as crayfish, aquatic worms, and leeches. They live among the rocks, sediments, and vegetation on the lake bottom. These organisms were selected as indicators of biological condition because they spend most of their lives in water and their community structure responds to human disturbance. Given their broad geographic distribution, abundance, and food web connections, they serve as good indicators of the biological quality of shoreline habitats in lakes.

The nymph of the common green darner (a type of dragonfly) is commonly found on the lake bottom. *Brad Carlson. "Beautiful dragonfly larva."* Flickr, CC BY-NC 2.0.

The benthic macroinvertebrate indicator uses an index combining six different aspects of macroinvertebrate community structure: taxonomic composition

The proportional abundance of certain taxonomic groups within a sample. Certain taxonomic groups are indicative of either highly disturbed or least-disturbed conditions, so their proportions within a sample serve as good indicators of condition.

; taxonomic diversity

The distribution of the number of taxa and the number of organisms among all the taxonomic groups. Healthy lakes have many organisms from many different taxa; unhealthy lakes are often dominated by a high abundance of organisms in a small number of taxa.

; feeding groups

The distribution of macroinvertebrates by the strategies they use to capture and process food from their aquatic environment (e.g., filtering, scraping, grazing, or predation). As a lake degrades from its natural condition, the distribution of animals among the different feeding groups will change, reflecting changes in available food sources.

; habits/habitats

The distribution of macroinvertebrates by how they move and where they live. A lake with a diversity of habitat types will support animals with diverse habits, such as burrowing under lakebed sediments, clinging to rocks, swimming, and crawling. Unhealthy systems, such as those laden with silt, will have fewer habitat types and macroinvertebrate taxa with less diverse habits (e.g., will be dominated by burrowers).

; taxonomic richness

The number of distinct families or genera within different taxonomic groups of organisms, within a sample. A sample with many different families or genera, particularly within those groups that are sensitive to pollution, indicates least-disturbed physical habitat and water quality and an environment that is not stressed.

; and pollution tolerance

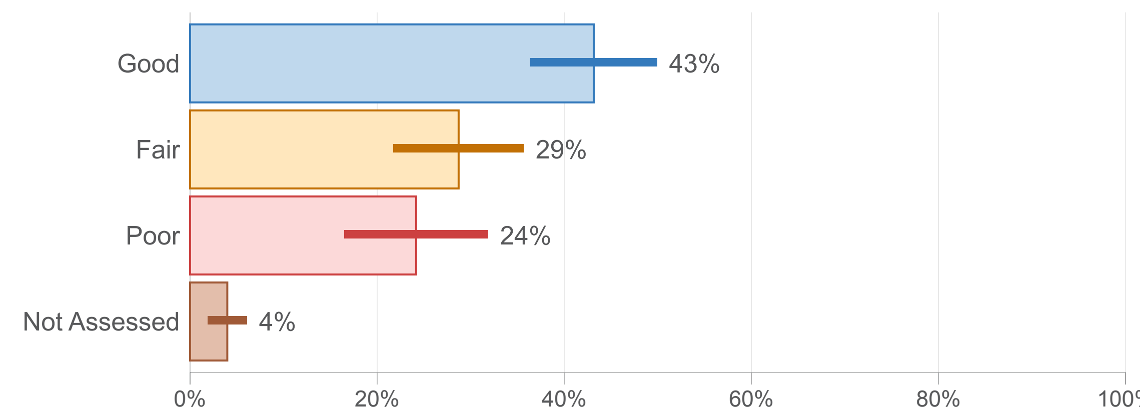
The distribution of macroinvertebrates by the specific range of contamination they can tolerate. Highly sensitive taxa, or those with a low tolerance to pollution, are found only in lakes with good water quality. Waters with poor quality will support more pollution-tolerant species.

. The measures chosen for each of these aspects vary between ecoregions.

What was the condition in 2017?

Less than half of U.S. lakes, 43%, were rated good based on the benthic macroinvertebrate index, as shown below. Note that 4% of lakes were not assessed due to difficulties collecting samples from the nearshore area (for example, the lake bottom may have been bedrock, the nearshore area may have been too deep, or other impediments may have prevented sampling).

Exhibit 11: Benthic Macroinvertebrates Condition (2017)
Percentage of lakes in each condition category nationally

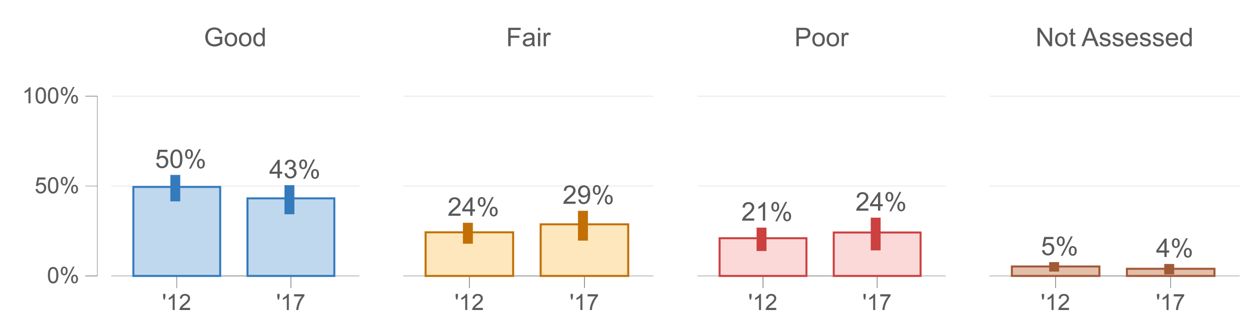


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on benthic macroinvertebrates.

Did the condition change?

No statistically significant changes occurred nationally. Statistically significant changes in lake condition were observed for some survey subpopulations, however, and are shown in the NLA dashboard.

Exhibit 12: Change in Benthic Macroinvertebrates Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on benthic macroinvertebrates.

Zooplankton

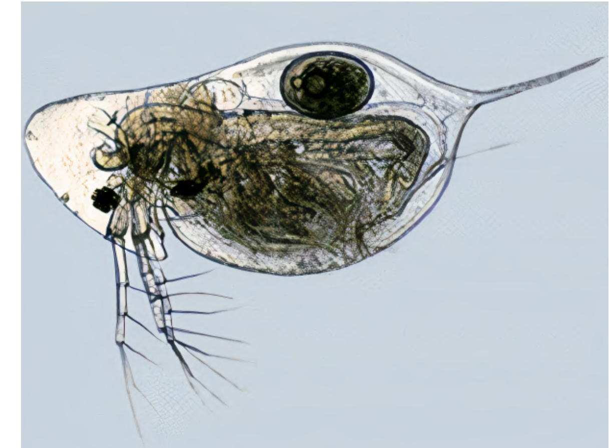
Zooplankton are small, often microscopic, animals in the water column that constitute an important element of the aquatic food web. These organisms serve an intermediary role in lake food webs, transferring energy from algae to larger invertebrate predators and fish. Zooplankton are sensitive to changes in the lake ecosystem. Given their broad geographic distribution, abundance, and food web connections, these organisms may serve as good indicators of the biological quality of open water in lakes. To determine the zooplankton indicator score, NLA analysts combined six measures of community structure: abundance, taxonomic richness, trophic guild

Whether a species is a herbivore, omnivore, or carnivore.

, and data for three zooplankton taxa

Cladocerans (also called water fleas), copepods, and rotifers.

. The specific metrics chosen varied between the ecoregions.

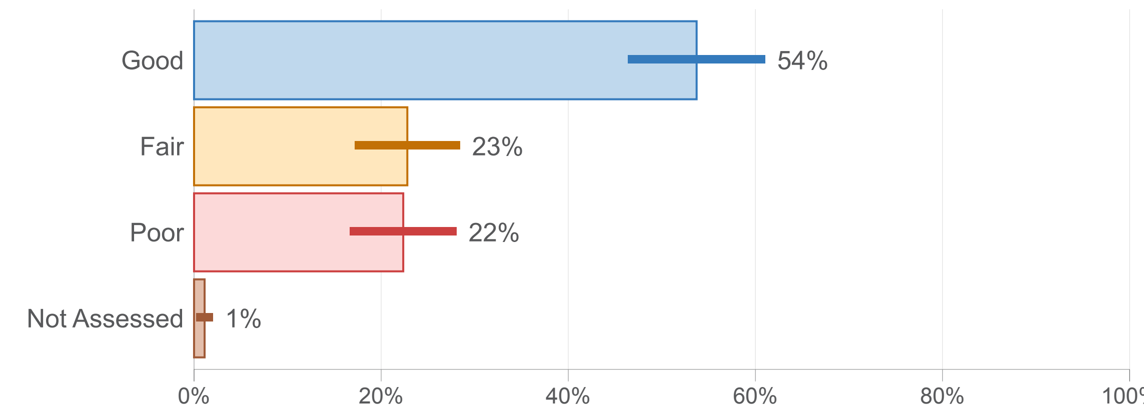


Cladocerans (water fleas) are a type of crustacean counted as part of the zooplankton indicator score calculation. EPA calculates their abundance and the number of species present in a sample. *National Oceanic and Atmospheric Administration — Great Lakes Environmental Research Laboratory*.

What was the condition in 2017?

Zooplankton condition was slightly better than benthic macroinvertebrate condition, with 54% of lakes in good condition.

Exhibit 13: Zooplankton Condition (2017)
Percentage of lakes in each condition category nationally

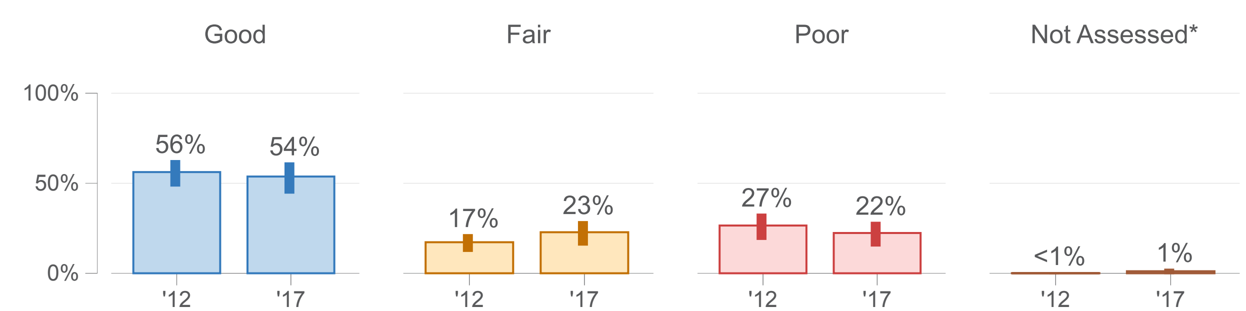


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on zooplankton.

Did the condition change?

There was no statistically significant change in condition nationally for zooplankton. However, there were significant changes in several ecoregions. For instance, in the Southern Plains, the number of lakes in poor condition increased by 31 percentage points, from 9% to 40%.

Exhibit 14: Change in Zooplankton Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on zooplankton.

CHEMICAL INDICATORS

For NLA 2017, EPA assessed six chemical indicators: nutrient concentrations, oxygen content, acidification of lakes, the herbicide atrazine, and microcystins. EPA compared sample results either to nationally consistent literature-based benchmarks (for dissolved oxygen, acidification, atrazine and microcystins) or to regional benchmarks developed from a set of reference lakes in each ecoregion (for nutrients).

Acidification

Vermont lakes like this one have historically been susceptible to acidification. *Vermont Dept. of Environmental Conservation*.

Acid rain and acid mine drainage are major sources of acidifying compounds that can change the pH of lake water, impacting fish and other aquatic life. High acidity, for instance, can hinder shell formation in mollusks and crustaceans. Acid-neutralizing capacity (ANC) serves as an indicator of sensitivity to changes in pH and is determined by the soil and underlying geology of the surrounding watershed. Lakes with high levels of dissolved bicarbonate ions (e.g., limestone watersheds) are able to neutralize acid depositions and buffer the effects of acid rain. Conversely, watersheds that are rich in granites and sandstones contain fewer acid-neutralizing ions and have low ANC; these systems have a predisposition to acidification.

Most aquatic organisms function at the optimal pH range of 6.5 to 8.5. Sufficient ANC in surface waters will buffer acid rain and prevent pH levels from straying outside this range. In naturally acidic lakes, the ANC may be quite low, but the presence of natural organic compounds in the form of dissolved organic carbon (DOC) can mitigate the effects of pH fluctuations.

ANC is measured using concentration units of microequivalents per liter (µeq/L), which account for the charges of the ions dissolved in the water. To classify lakes for acidification, EPA considered ANC measurements along with DOC concentrations. Condition categories used in all ecoregions are defined below:

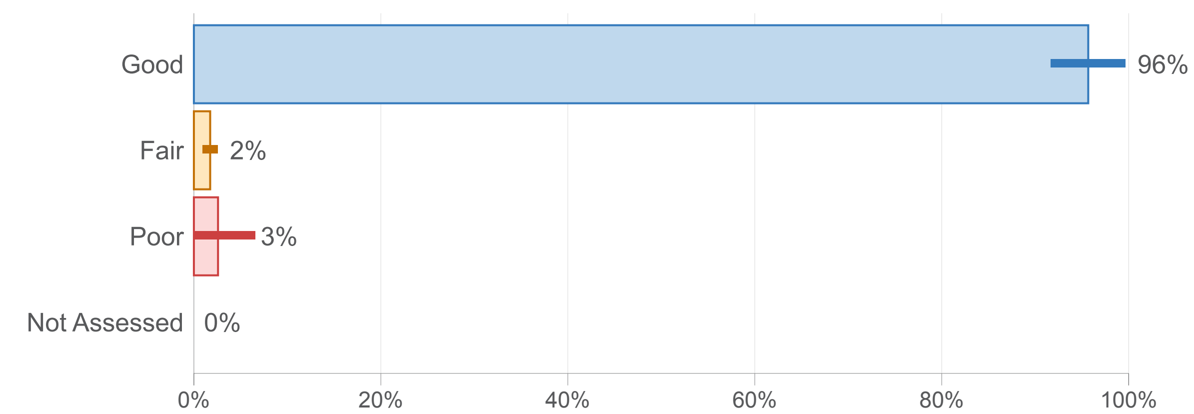
- Good: Lakes with ANC >50 µeq/L, or naturally acidic lakes with ANC ≤50 µeq/L and DOC ≥6 parts per million (ppm). Naturally acidic lakes are often associated with bog wetlands or certain types of swamps.
- Fair: Lakes with ANC >0 µeq/L but ≤50 µeq/L and DOC <6 ppm. These sites may become acidic occasionally, during periods of high precipitation.
- Poor: Lakes with ANC ≤0 µeq/L and DOC < 6 ppm.

What was the condition in 2017?

Most lakes were in good condition for acidification. A small amount were in fair (2%) and poor (3%) condition. The Northern Appalachian ecoregion had the greatest percent of lakes in fair condition (14%) for acidification, and the Coastal Plains had the greatest percent of lakes in poor condition (11%).

Exhibit 15: Acidification Condition (2017)

Percentage of lakes in each condition category nationally



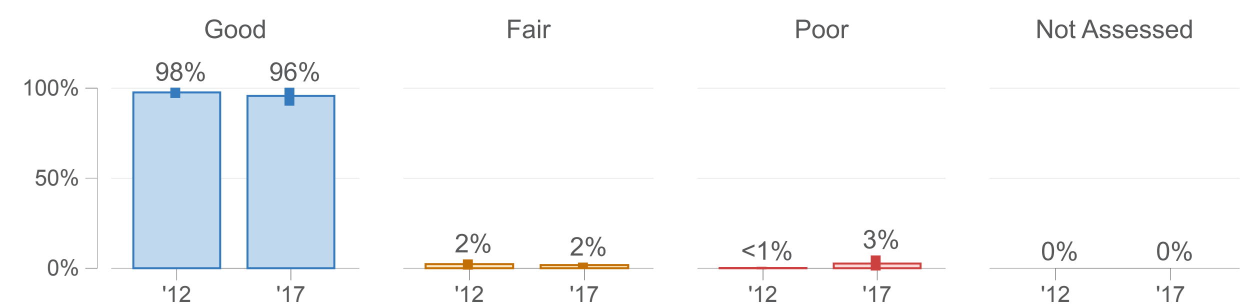
For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on acidification.

Did the condition change?

No statistically significant changes occurred at the national level.

Exhibit 16: Change in Acidification Condition (2012 to 2017)

Percentage of lakes in each condition category nationally



For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on acidification.

Atrazine

Atrazine is an agricultural herbicide applied before and after planting to control broadleaf and grassy weeds. According to studies by the U.S. Geological Survey, atrazine is one of the most widely used herbicides and one of the most frequently detected in U.S. streams and shallow groundwater (Gilliom et al. 2006). Atrazine can also end up in lakes. Atrazine can affect plant growth and may be toxic to wildlife and humans. See EPA's atrazine indicator page for more information. The atrazine benchmark used in NLA 2017 is designed to ensure that atrazine levels will not cause significant changes in aquatic plant community structure, function, and productivity. EPA first included atrazine in the NLA in 2012.

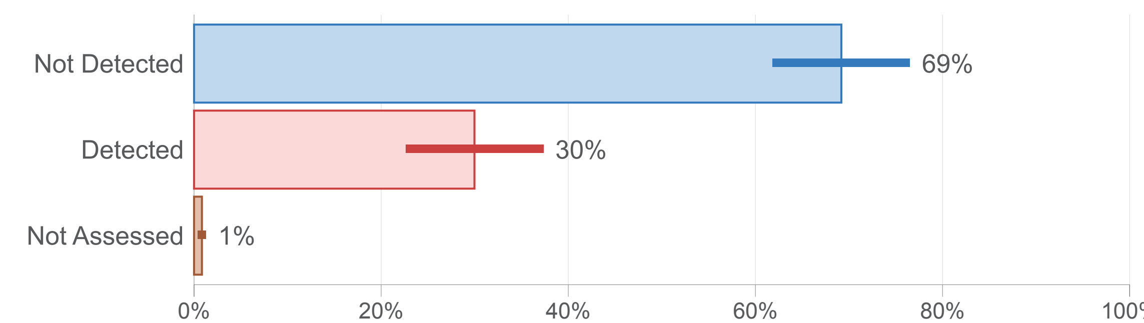
Atrazine is widely used in growing corn and sorghum. *Phil Roeder. "Corn."* Flickr, CC by 2.0. Cropped.

What was the condition in 2017?

Nationally, atrazine was detected in 30% of lakes in NLA 2017. By ecoregion, detection ranged from <0.5% in the Western Mountains to 77% in the Temperate Plains. However, it was detected in 0.5% of lakes (about 1,200 lakes) at levels that pose a risk of affecting aquatic plant communities (according to the EPA concentration equivalent level of concern, 3.4 ppb, used to determine risk) (Farruggia et al. 2016). Just over half of these exceedances occurred in the Temperate Plains.

Exhibit 17: Atrazine Detection Condition (2017)

Percentage of lakes in each condition category nationally

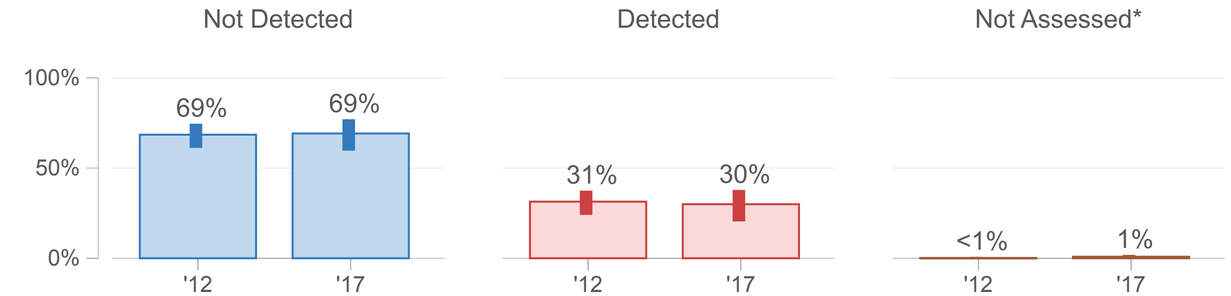


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on atrazine detection.

Did the condition change?

The percentage of lakes where atrazine was detected did not change significantly.

Exhibit 18: Change in Atrazine Detection Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on atrazine detection.

Microcystins

Cyanobacterial blooms such as this one may produce microcystins. *Megan O'Brien, EPA.*

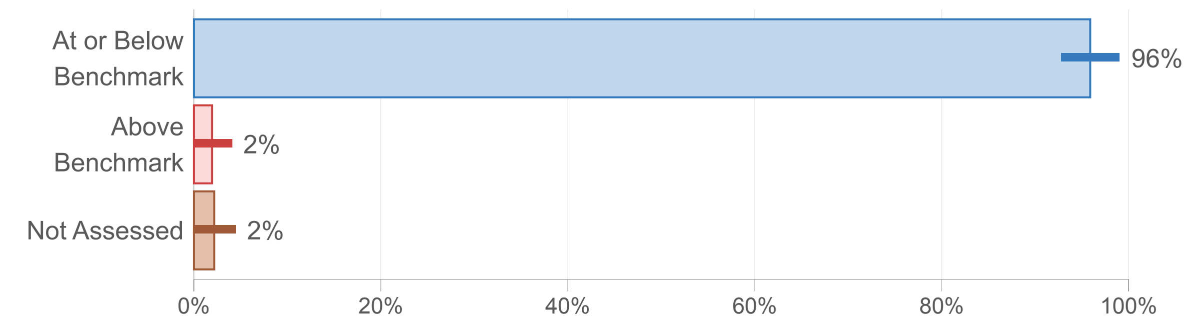
Cyanobacteria are one-celled photosynthetic organisms that normally occur at low levels. Under eutrophic conditions, cyanobacteria can multiply rapidly (see trophic state and chlorophyll *a* above). Not all cyanobacterial blooms are toxic, but some may release toxins, such as microcystins. Recreational exposure is typically a result of inhalation, skin contact or accidental ingestion. Health effects of exposure include skin rashes, eye irritation, respiratory symptoms, gastroenteritis, and in severe cases, liver or kidney failure and death. Microcystins are suspected carcinogens. See EPA's microcystins page for more information.

Microcystins results were compared to the EPA's recreational water quality criterion and swimming advisory recommendation of 8 ppb (U.S. EPA 2019). Note that some types of algae release other toxins not monitored under the NLA. The NLA assesses risk of exposure to microcystins at national and regional levels. For information about risks at specific locations, recreational water users should check with state, tribal, or local governments.

What was the condition in 2017?

Microcystins were detected in 21% of lakes in 2017. The detection of microcystins in the ecoregions ranged from 2% to 58%. Levels exceeded EPA's recreational criterion in 2% of lakes, representing 4,400 lakes nationally, as shown below.

Exhibit 19: Microcystins Risk Condition (2017)
Percentage of lakes in each condition category nationally

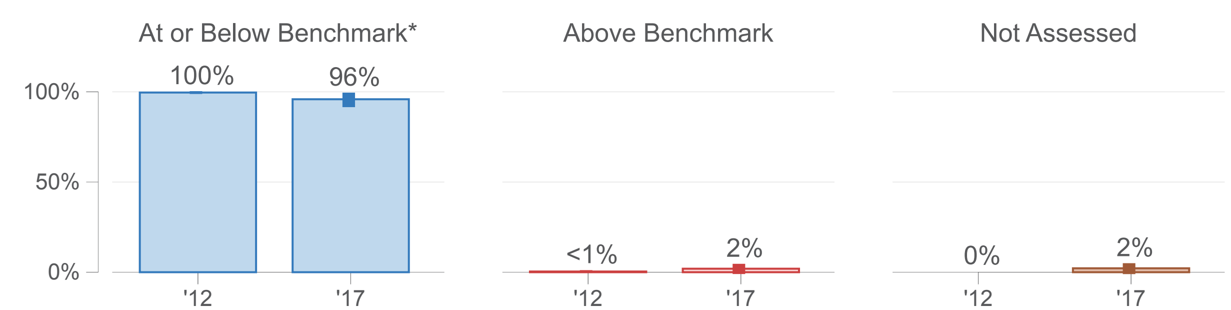


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on microcystins risk.

Did the condition change?

The percentage of lakes where microcystins were detected decreased, down from 37% in 2012 (see the dashboard). The percentage of lakes at or below the EPA criterion decreased by 4 percentage points. Both of these changes were statistically significant.

Exhibit 20: Change in Microcystins Risk Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on microcystins risk.

Dissolved Oxygen

Dissolved oxygen is considered an important measurement of water quality because it is essential for aquatic communities. Without oxygen, a lake would be devoid of all animal life. Changes in dissolved oxygen levels can occur for a variety of reasons, including water temperature, wind action, and the amount of algae and aquatic plants in the lake. When algae and aquatic plants decay, the bacteria that decompose them use up dissolved oxygen. Excess algae can result in extensive bacterial growth and accompanying low oxygen levels. While fish can often swim away from areas with low oxygen, benthic macroinvertebrates may be trapped in low-oxygen zones. EPA used the mean surface concentration (from the top 2 meters) to determine the condition class, using the same benchmarks in all ecoregions:

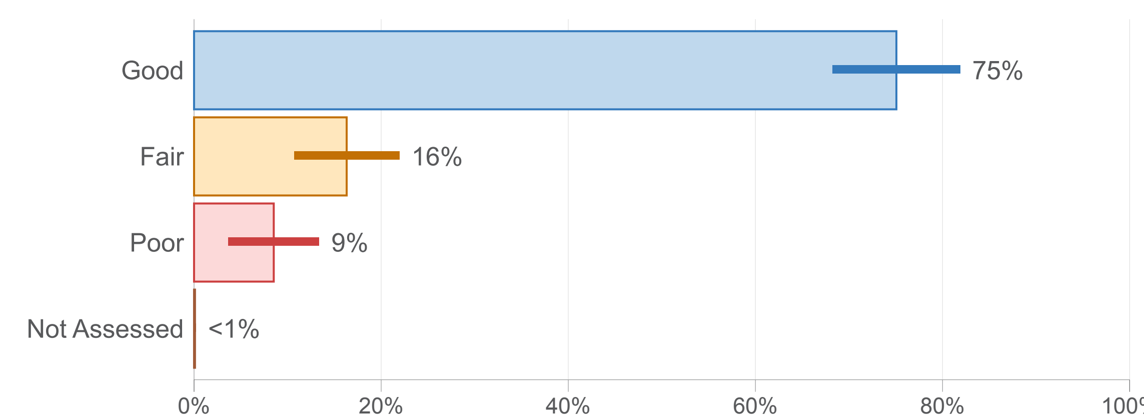
- Good: ≥5 ppm.
- Fair: >3 ppm but <5 ppm.
- Poor: ≤3 ppm.

Cool temperatures and winds tend to keep alpine lakes highly oxygenated. *Great Lakes Environmental Center*.

What was the condition in 2017?

Although 75% of lakes had good oxygen levels in surface waters, 9% had poor levels nationally. The Western Mountains (96%) and Xeric ecoregions (100%) had a greater percent of lakes with good oxygen levels in surface waters, compared to the national results.

Exhibit 21: Oxygen (Dissolved) Condition (2017)
Percentage of lakes in each condition category nationally

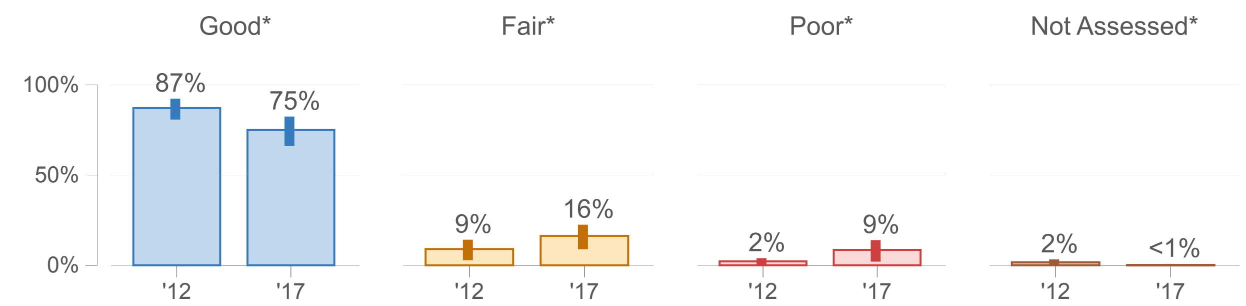


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on oxygen (dissolved).

Did the condition change?

Dissolved oxygen results changed significantly in all categories. Lakes with good oxygen levels decreased from 87% to 75%, and lakes with poor levels increased from 2% to 9%.

Exhibit 22: Change in Oxygen (Dissolved) Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on oxygen (dissolved).

Nutrients

Excess nutrients can cause excess plant (and algae) growth, clogging lake waters. *Chris Quinn. "A very young gator at Lake Apopka Wildlife Drive March 2016."* Flickr, CC BY 2.0. Modified from original.

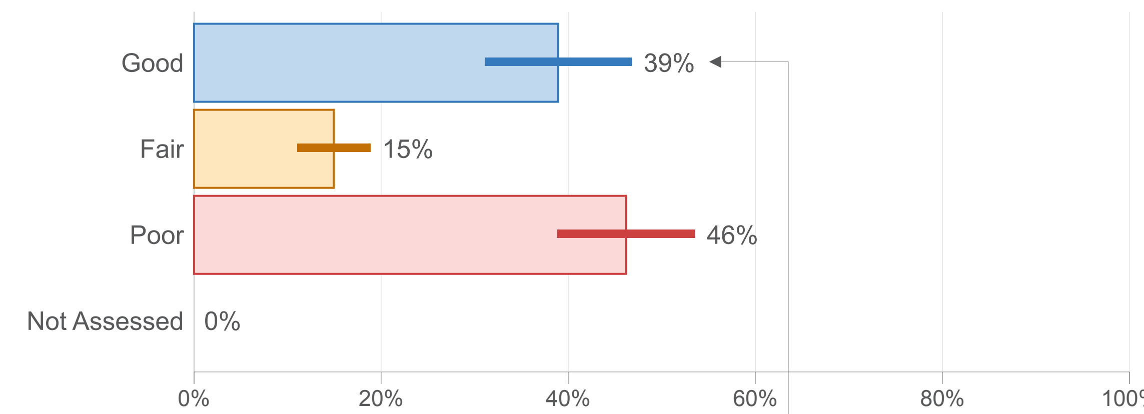
For this assessment, EPA evaluated total phosphorus and total nitrogen, which are critical nutrients required for all aquatic life. In appropriate quantities, these nutrients power the primary algal production necessary to support lake food webs. Phosphorus and nitrogen are linked; they jointly influence both the concentrations of algae (and cyanobacteria) in a lake and the clarity of water. In many lakes, phosphorus is considered the limiting nutrient, meaning that the available quantity of this nutrient controls the pace at which algae are produced. This also means that modest increases in available phosphorus can cause rapid increases in algal growth. The naturally occurring levels of these indicators vary regionally, as does their relationship with turbidity and algal growth. For phosphorus and nitrogen, lakes were assessed relative to NLA-specific regional benchmarks.

Common sources of excess nutrients include sewage treatment plant discharge, septic systems, fertilizer used on lawns and farms, and animal waste. For more information see EPA's nitrogen and phosphorus indicator pages.

What was the condition in 2017?

More lakes were in poor condition for nitrogen (46%) than in good condition (39%). In the Southern Appalachian ecoregion, only 2% of lakes were in good condition for nitrogen, and 89% of lakes were in poor condition.

Exhibit 23: Nitrogen (Total) Condition (2017)
Percentage of lakes in each condition category nationally

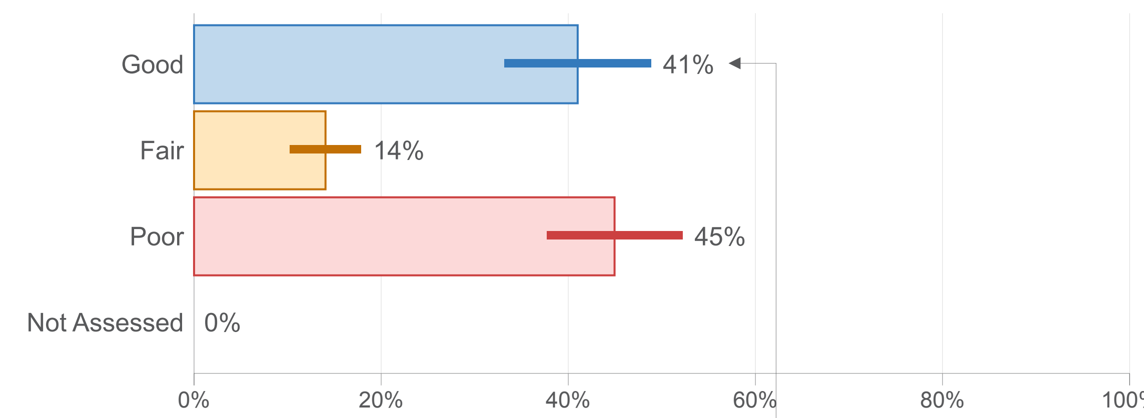


Only 39% of lakes had waters in good condition for nitrogen. This percentage was the lowest of any of the chemical indicators.

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on nitrogen (total).

Phosphorus results were similar to nitrogen results, with 41% of lakes rated good and 45% rated poor. The percentage of lakes rated good ranged from 9% in the Southern Appalachians to 65% in the Upper Midwest and Western Mountain ecoregions.

Exhibit 24: Phosphorus (Total) Condition (2017)
Percentage of lakes in each condition category nationally



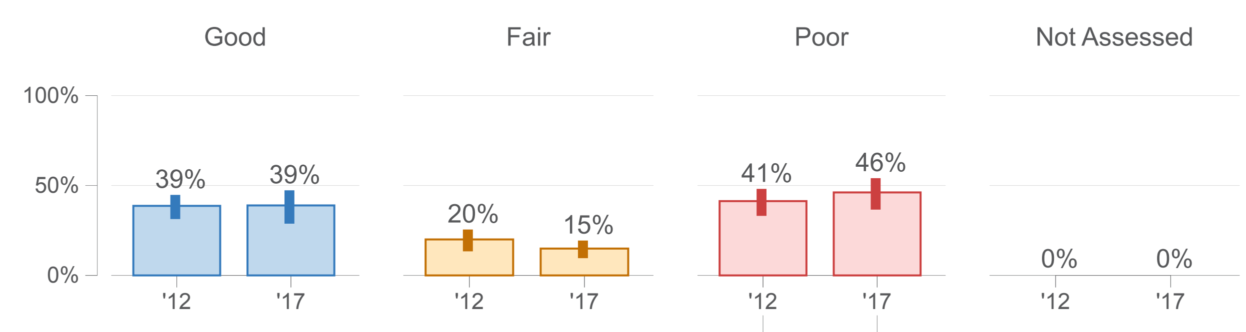
Only 41% of lakes had waters in good condition for phosphorus. This percentage was the second lowest of the chemical indicators.

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on phosphorus (total).

Did the condition change?

The percentage of lakes in good, fair, and poor condition for nitrogen did not change significantly from 2012 to 2017. Statistically significant changes in condition were observed for survey subpopulations, and these can be viewed in the NLA dashboard.

Exhibit 25: Change in Nitrogen (Total) Condition (2012 to 2017)
Percentage of lakes in each condition category nationally

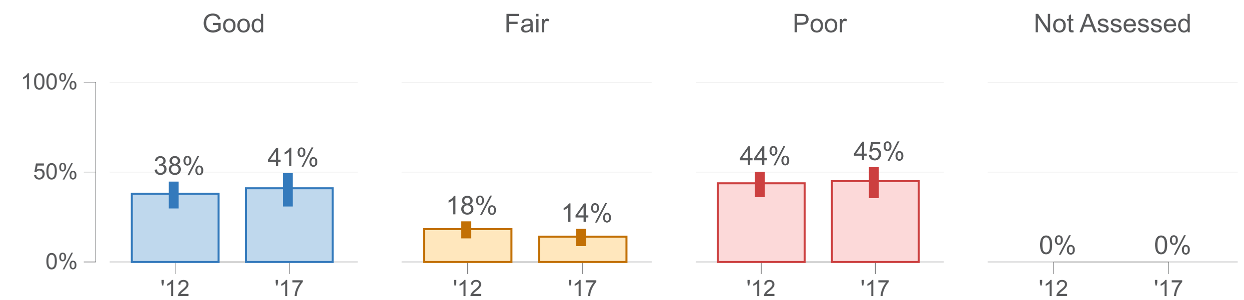


The change in percentage of lakes in poor condition was not statistically significant.

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on nitrogen (total).

Nationally, the changes in condition observed for phosphorus were not statistically significant. Statistically significant changes were observed in survey subpopulations and can be viewed in the NLA dashboard.

Exhibit 26: Change in Phosphorus (Total) Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on phosphorus (total).

PHYSICAL INDICATORS

The condition of lakeshore habitat provides important information relevant to lake biological health. For NLA 2017, physical habitat condition was assessed based on field crew observations using five indicators: lake drawdown (lowering or fluctuation of lake levels), lakeshore disturbance, riparian (lakeshore) vegetation cover, shallow water habitat, and habitat complexity (a combined index of condition at the land-water interface).

Lake Drawdown Exposure

Lake drawdown can occur in both natural lakes and reservoirs. In many lakes, small amounts of drawdown may occur seasonally every year. Large drawdowns may result from direct or indirect manipulation of water levels for lake management purposes or from natural and human-caused climate changes that alter temperature, precipitation, or runoff. Changing or significantly lowered lake water levels can adversely affect littoral and riparian habitat conditions and therefore can also have an impact on biological communities. The NLA lake drawdown indicator measures whether

Large drawdowns like those at Lake Mead can result in temperature and chemistry changes that alter lake ecology and reduce habitat availability, as well as reduce water available for human use. *cisko66*. Wikimedia, CC BY 3.0. Cropped.

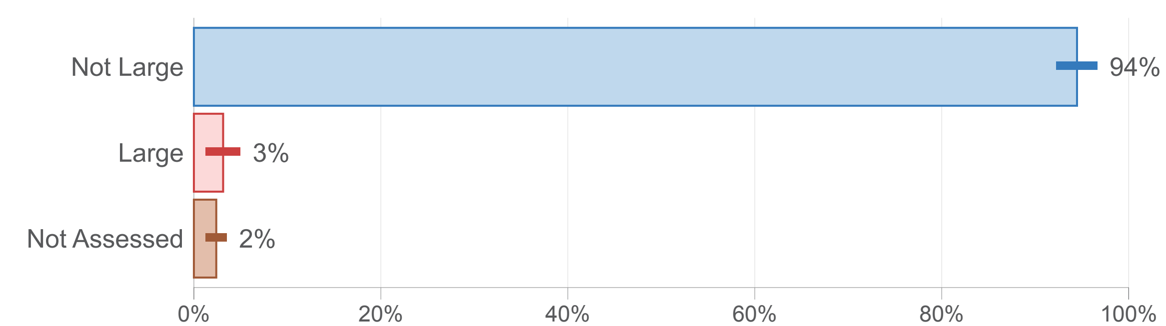
water levels are lower than their full-lake stage.

What was the condition in 2017?

Lake drawdown was not large in most cases. Only 3% of lakes had large drawdowns. Note that lake drawdown exposure results for 2017 include two condition classes (large and not large) rather than three classes. See the appendix for details.

Exhibit 27: Lake Drawdown Exposure Condition (2017)

Percentage of lakes in each condition category nationally

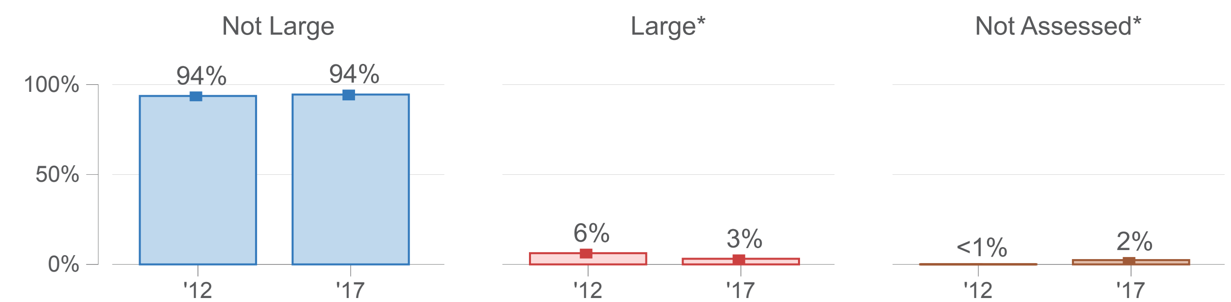


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on lake drawdown exposure.

Did the condition change?

While the percentage of lakes with large drawdowns decreased slightly from 2012, the percentage of lakes with "not large" drawdowns did not change. For most ecoregions, it is possible that the decrease in lakes with large drawdowns was due to an increase in the number of unassessed lakes rather than actual improved condition. In the Southern Plains ecoregion, however, not large drawdown significantly increased while large drawdown significantly decreased, and the increase in unassessed lakes, although statistically significant, was relatively small.

Exhibit 28: Change in Lake Drawdown Exposure Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on lake drawdown exposure.

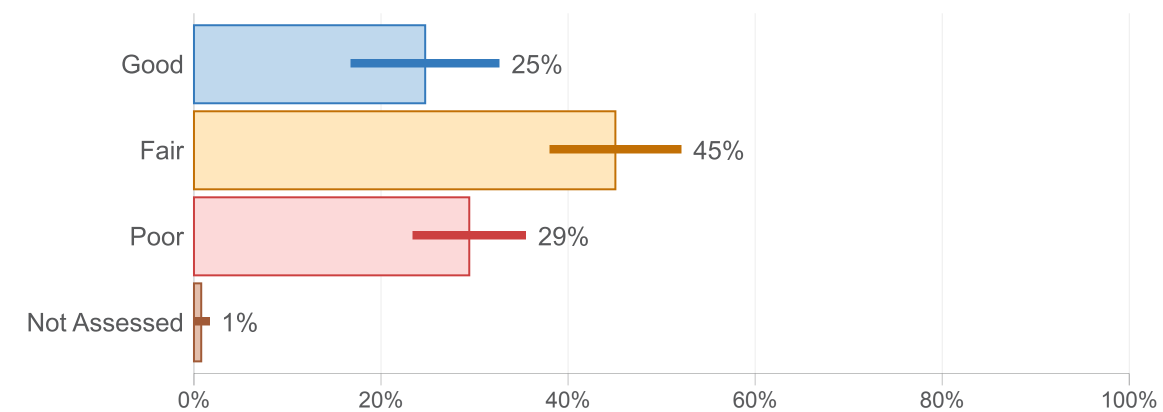
Lakeshore Disturbance

The lakeshore disturbance indicator reflects the extent and intensity of direct human alteration of the lakeshore itself. These disturbances can range from minor changes, such as the removal of a few trees to develop a picnic area, to major alterations, such as the construction of a large lakeshore residential complex. The effects of lakeshore development on the quality of lakes include excess sedimentation, loss of native plants, alteration of native plant communities, loss of vegetation structure and complexity, and modifications to substrate types. These impacts, in turn, can negatively affect fish, wildlife, and other aquatic communities.

What was the condition in 2017?

Lakeshore disturbance was widespread. Only 25% of lakes were rated good (had low levels of human disturbance), 45% were in fair condition, and 29% were in poor condition. The percentage of lakes in good condition by ecoregion ranged from 5% (Southern Plains) to 47% (Northern Appalachians).

Exhibit 29: Lakeshore Disturbance Condition (2017)
Percentage of lakes in each condition category nationally

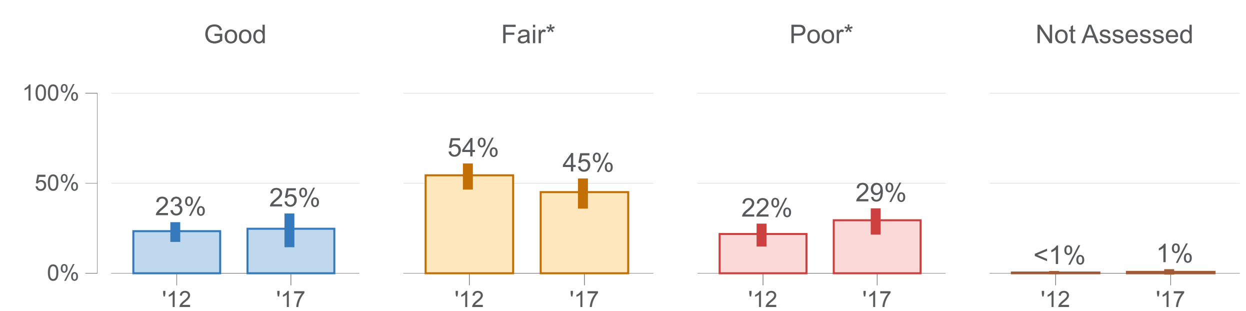


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on lakeshore disturbance.

Did the condition change?

Lakeshore disturbance increased nationally. The percentage of lakes in fair condition decreased, and those with poor condition (high levels of lakeshore disturbance) increased from 22% to 29%. These changes were statistically significant.

Exhibit 30: Change in Lakeshore Disturbance Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on lakeshore disturbance.

Development along a lake can lead to increased nutrient and sediment input and increased runoff volumes. Associated decreases in riparian and shoreline vegetation can reduce available habitat. *Rhode Island Dept. of Environmental Management*.

Riparian Vegetation Cover

Evaluation of riparian or lakeshore vegetation cover is based on observations of three layers of vegetation — understory grasses and forbs

Herbaceous flowering plants that are not grasses.

, mid-story woody and non-woody shrubs, and overstory trees. Generally, shorelines are in better condition when vegetation cover is high in all layers; however, not all three layers occur in all areas of the country. For example, in the Northern Plains there is typically no natural overstory tree cover; in the West, steep rocky shores are the norm for high-

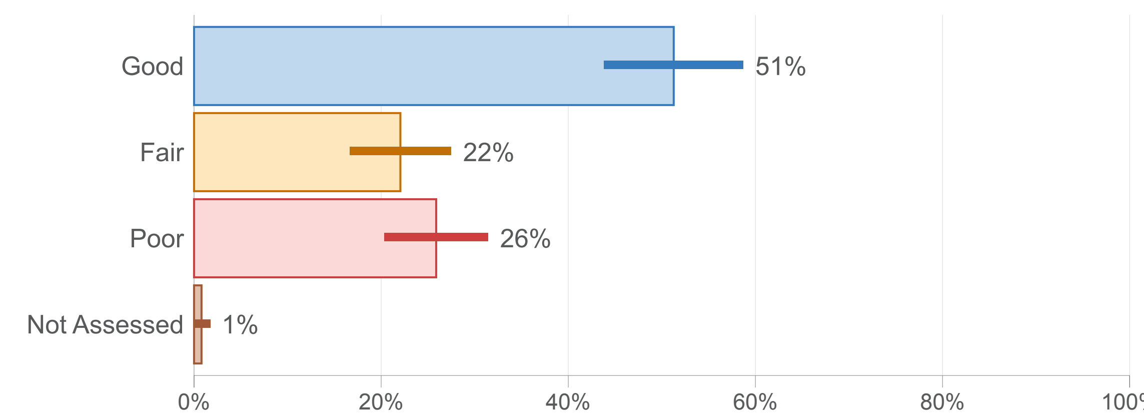
Riparian vegetation can vary in complexity; in arid parts of Texas, for instance, trees will not usually be present. Ecoregional benchmarks account for such variation. *Environmental Institute of Houston, University of Houston-Clear Lake*.

mountain or canyon lakes. These natural features have been factored into the calculation of the riparian vegetation cover indicator score.

What was the condition in 2017?

Just over half of lakes (51%) had high (good) levels of riparian vegetation cover; 26% had low (poor) cover. In the Northern Plains ecoregion, only 7% of lakes had high levels of riparian vegetation cover, and 83% had low cover.

Exhibit 31: Riparian Vegetation Cover Condition (2017)
Percentage of lakes in each condition category nationally

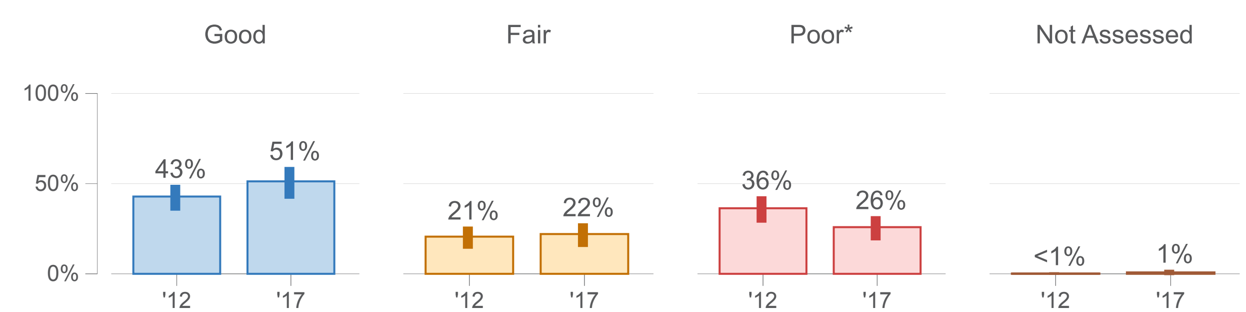


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on riparian vegetation cover.

Did the condition change?

Lake vegetation improved; the percentage of lakes with poor levels of coverage decreased from 36% to 26%. This change was statistically significant.

Exhibit 32: Change in Riparian Vegetation Cover Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on riparian vegetation cover.

Shallow Water Habitat

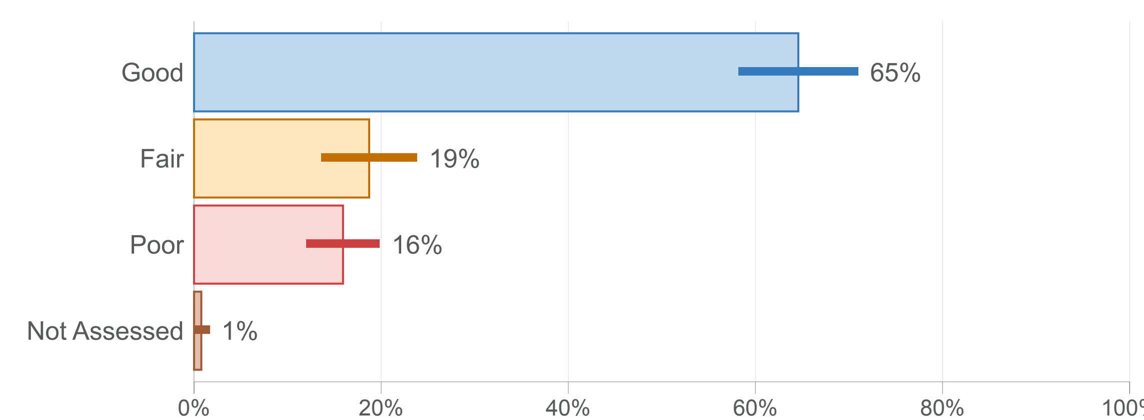
Shallow water vegetation provides shelter for fish and includes plants such as these lily pads floating in a Minnesota lake. *Courtney Celley, U.S. Fish and Wildlife Service.* Flickr.

The shallow water habitat indicator examines the quality of the shallow edge of the lake, or littoral zone, by using data on the presence of living and non-living features such as overhanging vegetation, aquatic plants, large woody snags, brush, boulders, and rock ledges. Lakes with greater and more varied shallow water habitat typically support aquatic life more effectively because they have many complex ecological niches. Like the riparian vegetation cover indicator, the shallow water indicator is based on conditions in reference lakes and is modified regionally to account for differing expectations of natural condition.

What was the condition in 2017?

Shallow water habitat in lakes was better than riparian cover; 65% of lakes were rated good for shallow water habitat, vs. 51% for riparian vegetation cover. The Upper Midwest ecoregion had the greatest percentage of lakes (79%) rated good for shallow water habitat.

Exhibit 33: Shallow Water Habitat Condition (2017)
Percentage of lakes in each condition category nationally

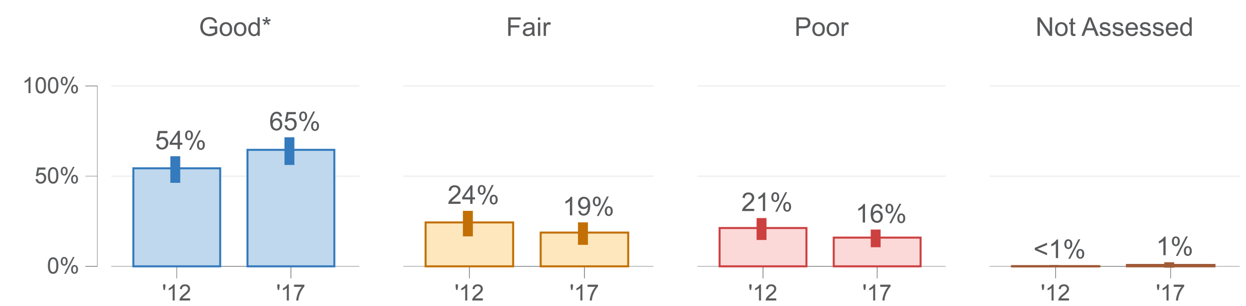


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on shallow water habitat.

Did the condition change?

Shallow water habitat improved; the percentage of lakes with good condition increased from 54% to 65%. This change was statistically significant.

Exhibit 34: Change in Shallow Water Habitat Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



* *Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on shallow water habitat.

Lake Habitat Complexity

The habitat complexity indicator combines riparian vegetation cover and shallow water habitat indicators described above to estimate the amount and variety of all cover types at the water's edge (on land and in water). High complexity indicates the availability of more ecological niches for macroinvertebrates and fish.

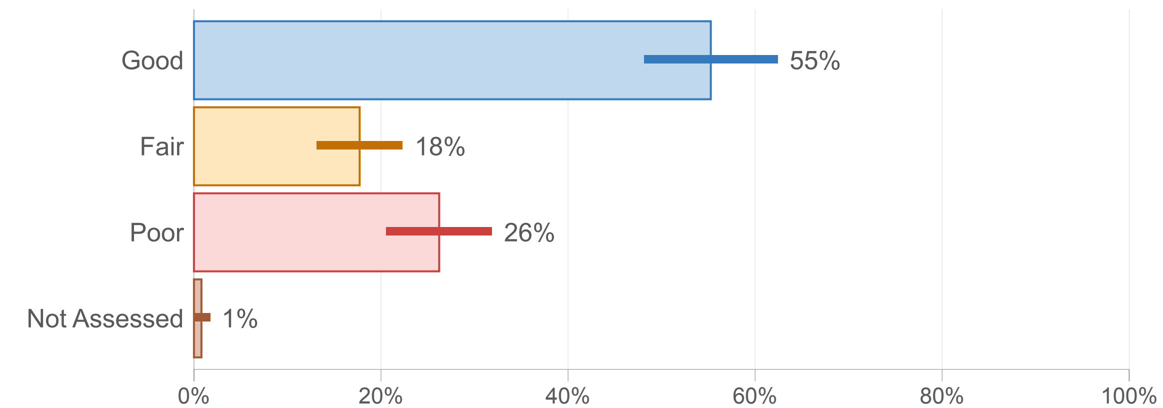
This Colorado mountain lake features good shallow water habitat such as boulders and good riparian herbaceous and tree cover. *Great Lakes Environmental Center*.

Like the two indicators that comprise the habitat complexity indicator, this indicator is based on conditions in reference lakes and is modified regionally to account for differing expectations of natural condition.

What was the condition in 2017?

Fifty-five percent of lakes had high (good) habitat complexity scores, but 26% had low scores.

Exhibit 35: Lake Habitat Complexity Condition (2017)
Percentage of lakes in each condition category nationally

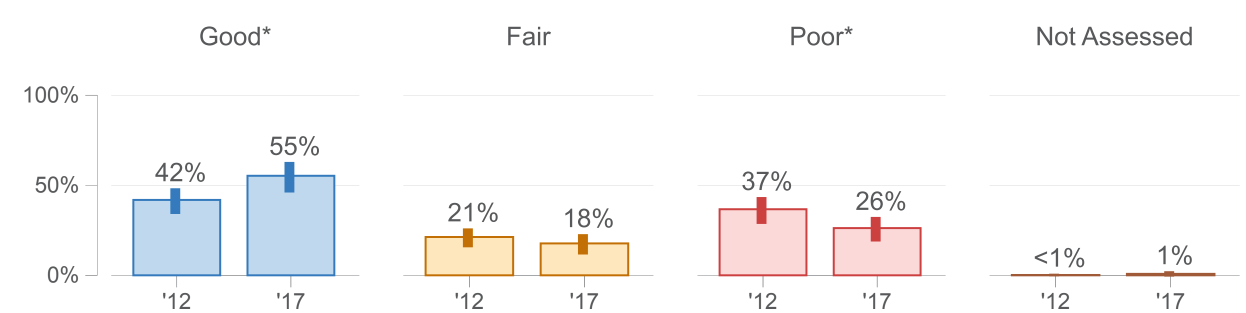


For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on lake habitat complexity.

Did the condition change?

Habitat complexity improved considerably. The percentage of lakes with high complexity (i.e., rated good) increased from 42% to 55%, and the percentage with low complexity (lakes rated poor) decreased from 37% to 26%. These changes were statistically significant and reflect improvements in both riparian and shallow water habitats. Statistically significant increases in good condition were observed in the Southern Plains, Temperate Plains, and Upper Midwest ecoregions.

Exhibit 36: Change in Lake Habitat Complexity Condition (2012 to 2017)
Percentage of lakes in each condition category nationally



** Indicates statistically significant difference (95% confidence) between 2012 and 2017.*

For more details, download the data for this chart, or visit the NLA dashboards for ecoregional data on lake habitat complexity.

Associations Between Stressors and Biological Condition

Restoring lake quality requires not only an understanding of current condition and change over time, but also of stressors

Stressors include physical, chemical, and biological entities or processes that adversely affect the ecological condition of a natural ecosystem.

associated with degraded biological condition and the potential for improved conditions when stressors are reduced. This knowledge can help decision makers prioritize stressors for reduction.

A canoe loaded with research equipment, Oak Patch Lake, Washington. *Washington Dept. of Ecology*.

Stressors for the NLA included the chemical and physical measures characterized by the indicators in the previous chapter, along with the biological indicator chlorophyll *a*. Microcystins and atrazine detection were included, but microcystins and atrazine benchmark exceedances were not, as these benchmarks do not measure effects on benthic macroinvertebrates or zooplankton. At the national and regional level, EPA performed three calculations for each stressor.

1. First, EPA determined the extent of lakes in poor condition for each stressor. This is the relative extent.
2. Then, EPA evaluated the extent to which poor biological condition was more likely when a stressor or indicator was rated poor. This is the relative risk.
3. Lastly, EPA assessed the potential improvement that could be achieved by reducing or eliminating the stressor. This is the attributable risk.

Highlights of the national results on attributable risk for benthic macroinvertebrates (as indicators of biological condition) are described below, along with highlights on selected subpopulations. Note that only stressors for which the attributable risk was above zero are shown. Visit the NLA dashboards to further explore risk results nationally and for the following survey subpopulations: the Mississippi River basin, three aggregated ecoregions, and natural lakes and reservoirs. For more information on these analyses visit the NARS risk web page.

Zooplankton samples from a Texas lake. *Environmental Institute of Houston, University of Houston-Clear Lake*.

The NLA indicators with the highest relative extent estimate nationally were nitrogen (46%), phosphorus (45%), chlorophyll *a* (45%), and lakeshore disturbance (29%). These were the most widespread stressors.

Total phosphorus was the stressor with the highest relative risk estimate nationally (2.3). That is, lakes with poor ratings for phosphorus were about 2.3 times more likely to have poor benthic macroinvertebrate condition. Atrazine detection, dissolved oxygen, total nitrogen, and shallow water habitat had relative risks of 2.0 or greater. When calculated for survey subpopulations rather than at the national level, relative risk estimates were as high as 6.9 (for total phosphorus in natural lakes).

Combining the relative extent and relative risk values for each indicator into a single value provides us with attributable risk. Attributable risk is the percentage of lakes in poor biological condition that could be improved (that is, moved into either good or fair biological condition) if the stressor condition were improved from poor.

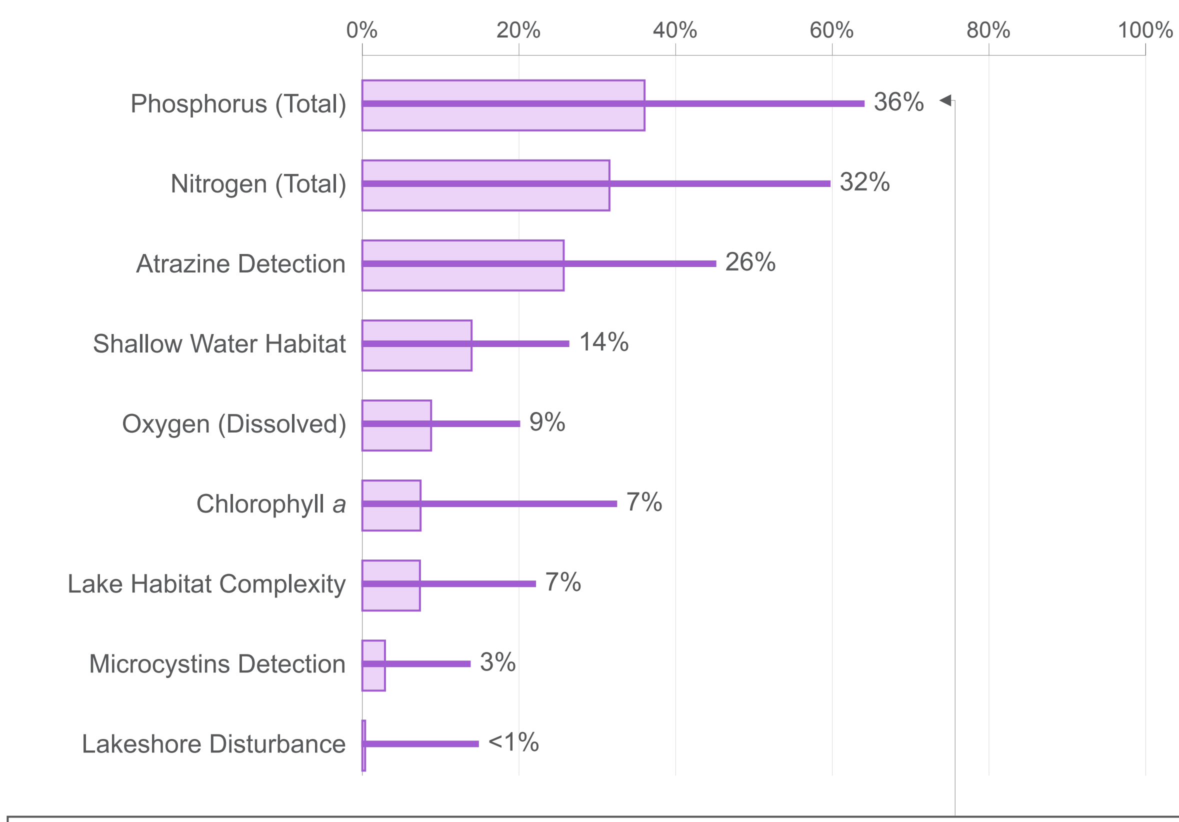
Calculating attributable risk involves assumptions, including: 1) that a causal relationship between stressors and biological condition exists; 2) that a lake's poor biological condition would be reversed if the stressor were improved to fair or good levels; and 3) that the stressor's impact on a lake's biological condition is independent of other stressors. Despite these limitations, attributable risk can provide general guidance as to which stressors might be higher priorities for management nationally or regionally.

EPA found that reducing phosphorus and nitrogen could result in the greatest benefit to benthic macroinvertebrate condition nationally, as shown in Exhibit 37.

This exhibit shows attributable risk (including point estimates and 95% confidence intervals) for each stressor. If poor phosphorus condition were improved to fair or good, a 36% reduction in poor benthic macroinvertebrate condition could occur. For nitrogen, the improvement in poor benthic macroinvertebrate condition could be 32%.

Exhibit 37: Attributable Risk From Exposure to Stressors Across All Lake Types (2017)

Risk to Response nationally

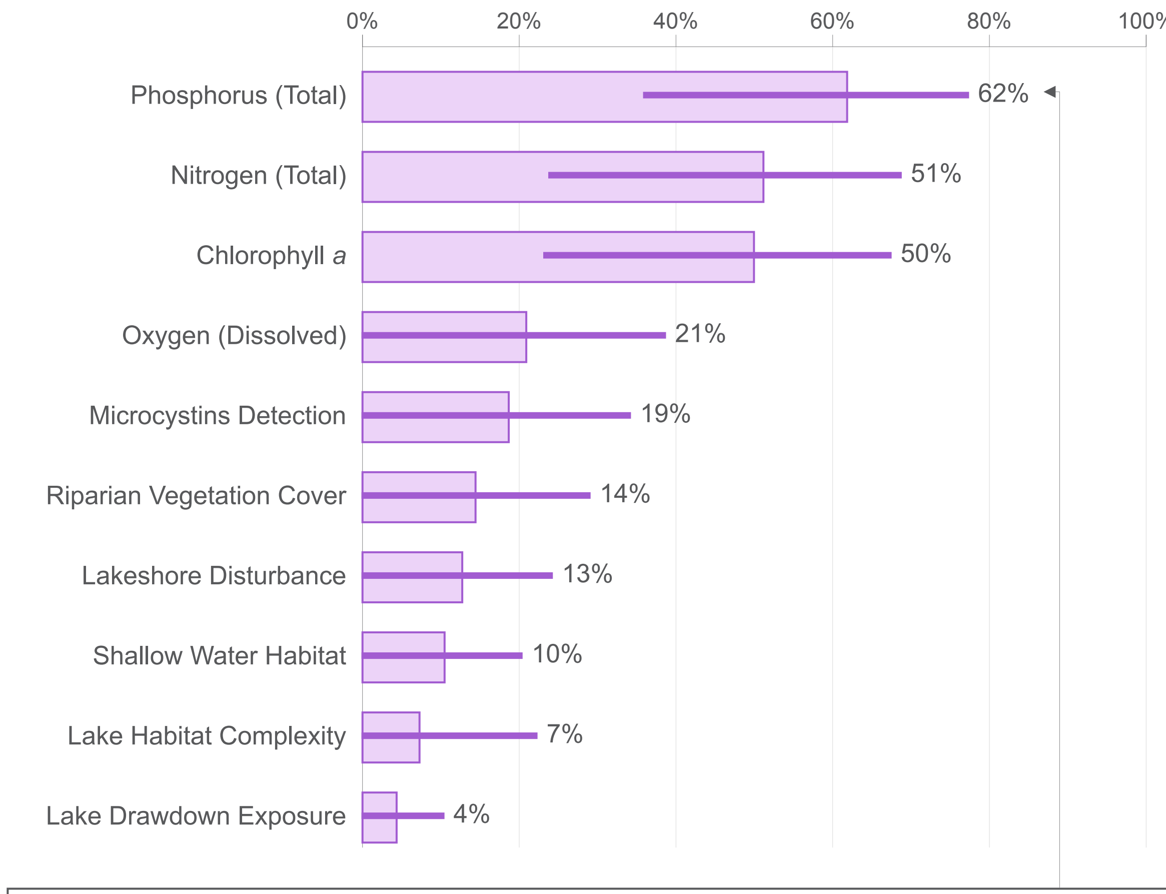


EPA estimates that the risk to benthic macroinvertebrates attributable to total phosphorus is 36%, as shown by the lighter, shorter bar. The longer, darker bar represents the margin of error around each estimate. EPA is 95% confident that the attributable risk value in the national population falls within this confidence interval.

For more details, download the chart data, or visit the NLA dashboards for additional risk data.

The potential for improved biological condition in a given subpopulation will differ from the national potential due to differences in poor biological condition and relative risk results. For example, attributable risk results for some lake subpopulations (i.e., natural lakes and reservoirs) suggest that a greater percentage of natural lakes in poor biological condition (compared to lakes nationally) might improve if poor nutrient conditions were improved (62% for total phosphorus and 51% for total nitrogen) (Exhibit 38).

Exhibit 38: Attributable Risk From Exposure to Stressors in Natural Lakes (2017)
Risk to Response nationally



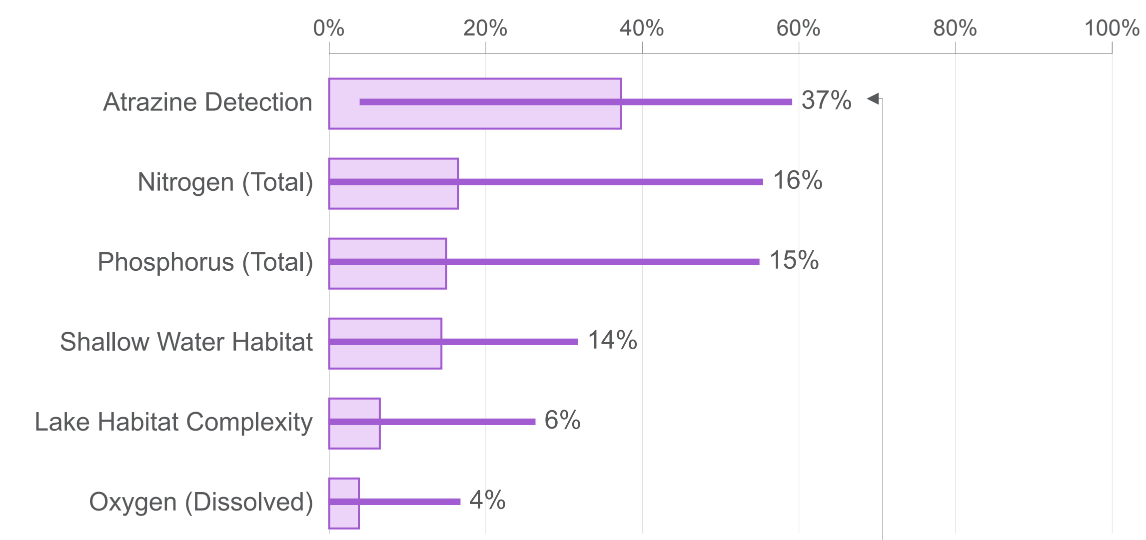
In natural lakes, reducing phosphorus levels (by improving poor condition to fair or good) could reduce the number of lakes in poor condition for benthic macroinvertebrates by 62%. Attributable risk is calculated using values for relative extent and relative risk.

For more details, download the chart data, or visit the NLA dashboards for additional risk data.

In reservoirs, poor biological condition might be improved by targeted management of agricultural influences, as suggested by the attributable risk estimate of 37% for atrazine detection (Exhibit 39). Atrazine is a commonly used herbicide and can be an indicator of agricultural activity in a watershed.

Exhibit 39: Attributable Risk From Exposure to Stressors in Reservoirs (2017)

Risk to Response nationally



In reservoirs, increased management of agricultural stressors in the watershed, such as atrazine, could reduce the number of lakes in poor condition.

For more details, download the chart data, or visit the NLA dashboards for additional risk data.

To see graphs for relative extent, relative risk, and attributable risk together, visit the risk estimate section of the NLA dashboard.

EPA also evaluated attributable risk for zooplankton nationally. As with benthic macroinvertebrates, phosphorus and nitrogen had the highest attributable risk, at 39% and 35%, respectively. However, dissolved oxygen (as measured near the surface) was also an important stressor for zooplankton. Improving dissolved oxygen levels from poor to fair or good could reduce the number of lakes with poor zooplankton condition by 19%. Additional zooplankton attributable risk results are available on the NLA dashboard.

Conclusion

The NLA provides findings that lake managers can use to inform resource management priorities and strategies. Nationally, 46% of lakes were in poor condition for nitrogen, while 45% of lakes exhibited poor conditions for phosphorus and chlorophyll *a*. Other widespread stressors include lakeshore disturbance, lake habitat complexity, and riparian vegetation cover (29%, 26%, and 26% of lakes were in poor condition, respectively).

While the survey results provide national and regional estimates of lake condition, they do not address all information needs at all scales. For example, the survey does not measure all stressors and cannot be used to infer local condition. In-depth monitoring and analysis of individual lakes and watersheds are required to support specific restoration and protection efforts.

EPA is continually refining the NLA, using the 2017 results to determine the need for changes to the design, indicators, field methods, laboratory methods, and analysis procedures in the next NLA. Sampling for the fourth NLA will take place in the summer of 2022.

Field crew members pause while collecting sediment core samples on a Rhode Island lake. *Rhode Island Dept. of Environmental Management*.

NLA 2017 would not have been possible without the involvement of state and tribal scientists and resource managers. EPA will continue to work with state and tribal partners to translate the expertise gained through these national surveys to studies of their own waters. Additionally, EPA will support use of the NLA data to evaluate the success of efforts to protect and restore water quality.

Other National Aquatic Resource Surveys

In addition to the NLA, the NARS program also includes the following surveys:

- The National Coastal Condition Assessment (2005, 2010, and 2015)
- The National Rivers and Streams Assessment (2008-09, 2013-14, and 2018-19)
- The National Wetland Condition Assessment (2011 and 2016)

Reports on surveys through 2015 are available at the NARS home page. EPA will post additional reports and data as they become available.

About This Report

This is the final version of the report, published in May 2022. Any corrections or updates to the final report will be described in this section. Results presented in the report and NLA dashboard were last updated 03/02/2022.

A suggested citation for the report is provided below: U.S. Environmental Protection Agency. 2022. *National Lakes Assessment: The Third Collaborative Survey of Lakes*

in the United States. EPA 841-R-22-002. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development. https://nationallakesassessment.epa.gov/webreport

Appendix: Changes to the NLA Survey Since 2012

Although most aspects of the survey remained the same in 2017, EPA implemented some improvements for this iteration of the survey and report. This appendix describes changes since NLA 2012. They include changes to indicators, benchmarks, and the way survey results are calculated. For details on these updates, see the NLA 2017 Technical Support Document.

The most comprehensive change to the report was the way the results from the 1,005 sampled lakes were used to estimate the condition of a larger population of lakes. In 2017, EPA determined it was appropriate to adjust the site weights that are used to calculate condition estimates (percentages) to reflect the full target population (224,916 lakes). In 2012, the site weights used to calculate condition estimates reflected the subset of the target population that could be sampled. See the survey design section of the Technical Support Document for further details.

For NLA 2017, EPA temporarily paused reporting on one indicator and added another, as described below:

- **Mercury.** The NLA 2012 report contained results for mercury in lake sediment. For 2017, EPA revised its sediment sampling method to allow a deeper sediment core; results from NLA 2017 are thus not comparable with earlier results and are not included in this report. EPA is preparing a separate publication of the 2017 sediment quality results. Raw data for mercury are available on the NARS data page.

- **Chlorophyll *a*.** For 2017, EPA reintroduced chlorophyll *a* condition results calculated using ecoregional chlorophyll *a* benchmarks. Although EPA did not present these results in the NLA 2012 report, they were previously presented in the NLA 2007 report. (In 2012, EPA focused its reporting on chlorophyll *a* benchmarks from the World Health Organization (WHO) (see discussion of microcystins below)).

Additionally, EPA updated benchmarks for the following indicators in 2017, as described below.

- **Atrazine.** The atrazine risk benchmark continued to be based on EPA's aquatic plant concentration equivalent level of concern (CE-LOC); however, the NLA benchmark was updated to the CE-LOC of 3.4 ppb recommended in EPA's 2016 refined ecological risk assessment.

- **Microcystins.** For NLA 2017, EPA compared microcystins concentrations to the EPA recreational water quality criterion and swimming advisory recommendation (8 ppb) (U.S. EPA 2019). In NLA 2012, recreation risk results were based on WHO benchmarks for microcystins as well as WHO risk benchmarks for cyanobacteria and chlorophyll *a*, where chlorophyll *a* was used as an indicator for cyanobacteria (WHO 2003). Cyanobacteria data from 2017 are not included in this report, but raw data are available on the NARS data page.

- **Nutrients and biological indicators.** EPA identified new reference lakes in 2017 and added them to the reference site pool used to determine the NLA ecoregional benchmarks. The addition of data from these sites resulted in updated benchmarks for benthic macroinvertebrates, zooplankton, chlorophyll *a*, and nutrients in most ecoregions. The zooplankton benchmark was also updated to include corrections and clarifications to the zooplankton index identified after publication of the NLA 2012 Technical Report.

- **Lake drawdown.** Lake drawdown exposure results are presented as "large" or "not large" in 2017 because data from hundreds of lakes did not allow data analysts to distinguish medium from small drawdown classes. In 2012, lake drawdown results were presented as "least disturbed," "moderately disturbed," and "most disturbed" condition.

For this report, EPA recalculated the 2012 results, taking all the changes above into account, to facilitate comparison between the 2012 and 2017 results. The 2012 results presented in this report therefore differ from the results presented in the NLA 2012 report. Readers wishing to compare 2017 results to 2012 should use this report and the NLA 2017 dashboard, not the 2012 report.

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- California Department of Fish and Wildlife
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The Third Collaborative Survey of Lakes in the United States