NEW YORK
STATE OF
OPPORTUNITY.

Department of
Environmental
Conservation

2017 MOHAWK REGIONAL LAKES REPORT

Summary of NYSDEC DOW Lakes Data 2012-2016

August, 2017

LAKE MONITORING AND ASSESSMENT SECTION

DIVISION OF WATER

625 Broadway, Albany New York

www.dec.ny.gov

2017 Mohawk Regional Lakes Report

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625 Broadway, 4th Floor

Albany, NY 12233

(518) 402-8179

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Chapter 1: Introduction to the Regional Report

The New York State Department of Environmental Conservation (NYSDEC) is responsible for reporting on the condition of water resources on a regular basis. Information about the state of lakes, ponds and reservoirs in New York state is gathered in several ways. There are many lake sampling programs conducted throughout New York state by government agencies, academic institutions, consultants, and citizen scientists. Some of this data is collected to identify a specific water quality problem, in support of fish stocking, beach operation, or other resource management activity, or to support student or public education, while a primary use of lake data by the NYSDEC is to determine whether these lakes are meeting their best intended use. The data generated from many of these programs are invaluable, but there are enormous challenges in evaluating this information in a standardized way.

This report provides information about lake sampling results from several of these lake monitoring programs, but primarily summarizes the 2012 to 2016 results from the two major NYSDEC lake monitoring programs: the New York Citizens Statewide Lake Assessment Program (CSLAP) and the Lake Classification and Inventory Survey (LCI). These programs differ from each other, as described below, but both are unique among the various lake water quality monitoring programs conducted in New York state for several important reasons:

1. *Statewide scope*. These two programs involve lake sampling throughout the state, at least over five year periods. CSLAP involves a core set of lakes sampled every year ("index" lakes) or sampled in five consecutive years followed by a single year removed from sampling. LCI involves lakes sampled for no more than two years in a few of the (16) major New York state drainage basins. However, the LCI is among several DEC water monitoring programs that operates on a five year rotational schedule, so the entire state is sampled within any five year increment. Most of the other lake monitoring programs in New York, cited briefly in this program, are limited to a confined geographic region, such as the Adirondack Park or Finger Lakes.
2. *Sanctioned by NYSDEC*. CSLAP and the LCI are conducted under the authority of the state of New York. Both programs, along with other state-funded and -operated monitoring programs, require the use of laboratories certified under the Environmental Laboratory Approval Program (ELAP) run by the New York State Department of Health. ELAP certification is required under the New York Public Health Law for environmental sampling results used by the NYSDEC. CSLAP and LCI activities are also governed by Quality Assurance Program Plans (QAPPs) approved by the NYSDEC Quality Assurance staff to validate the sampling and analytical methodologies used to generate sampling data. Most other lake monitoring programs conducted in New York state do not include both ELAP-certified laboratories and approval QAPPs. The use ELAP-certified results and approved QAPPs provide an additional assurance that these data can

support a number of NYSDEC activities, including waterbody assessments (Chapter 10).

3. *Data frequency*. CSLAP lakes are sampled biweekly (every other week) for a fifteen week period between late May and late September, with nearly all lakes sampled during an “index” window between mid-June and mid-September corresponding to a period of consistent thermal stratification for most lakes greater than 6 meters deep. The LCI involves monthly sampling from June through September during the second year of monitoring within each sampled basin. Most other New York lake monitoring programs involve less frequent sampling, and are less likely to result in *known* assessments discussed in Chapter 10.
4. *Standard indicators*. CSLAP and the LCI were developed explicitly to support the NYSDEC lake assessment program, and therefore share a suite of common water quality indicators used to evaluate whether these lakes are supporting their designated uses, particularly recreation and aquatic life.
5. *Data duration*. Although the report will focus primarily on the most recent five-year period, for consistency with the timeframe for the present NYSDEC assessment process, many CSLAP lakes have been sampled for much longer- in some cases more than 30 consecutive years. This extended sampling window provides an opportunity to evaluate long-term water quality trends. Most other lakes have not been sampled for a long enough time period to evaluate trends.
6. *Local knowledge.* In addition to providing an opportunity to sample more waterbodies and fill in data gaps, citizen scientists can draw from local knowledge about and access to portions of lakes unavailable to professional monitors. Citizen scientists usually live on the lake shore and are familiar with “normal” conditions, and they have the ability to provide observations and collect samples from many locations and at times when ephemeral conditions (such as harmful algae blooms) are reported. CSLAP gathers some of this information through standardized user perception surveys, and as part of the DEC shoreline HABs surveillance and monitoring program.
7. *Focus on water quality, HABs and AIS.* Many of the other lake monitoring programs in New York state have a limited emphasis on water quality issues such as eutrophication or acidification, surveillance for aquatic invasive species (AIS) or harmful algae blooms (HABs), or other lake issues. CSLAP and the LCI are primarily water quality monitoring programs focusing on eutrophication, but these programs also gather information about acidification, AIS, HABs and other lake indicators.

CSLAP and the LCI

The two programs that form the basis for this report are CSLAP and the LCI:

CSLAP is the state volunteer lake monitoring program conducted by the NYSDEC and the NY Federation of Lake Associations (NYSFOLA), a statewide coalition of lake associations, organizations, and individuals dedicated to lake protection and management throughout New York state. CSLAP has been run continuously since 1986, and presently involves biweekly water quality monitoring and lake evaluation on more than 125 public and private lakes and ponds. These range from small ponds to large multipurpose lakes serving recreational, drinking water and habitat needs for lake communities and a diversity of aquatic life. Water quality samples are collected from the surface and bottom of the deepest part of the lake, and analyzed for several standard water quality indicators by Upstate Freshwater Institute (UFI) in Syracuse, a research laboratory with a long history of water quality analysis and evaluation. Open water and periodic shoreline samples are also analyzed by the State University of New York College of Environmental Sciences and Forestry (SUNY ESF) for indicators of cyanobacteria blooms (aka HABs) and cyanotoxins. Aquatic plant samples are collected at some lakes and identified by NYSDEC. Sampling volunteers are members of NYSFOLA-member lake associations, and are trained by NYSDEC and NYSFOLA using standardized sampling equipment and sampling procedures.

The LCI is the state ambient lake monitoring program conducted by the NYSDEC Division of Water in Albany. Lakes and ponds are sampled in a rotating basin schedule in which ponded and flowing waters in 4-6 of the 17 major drainage basins are sampled each year for several water quality indicators in two year cycles. In the first year, a large number of lakes are screened during a single visit in late summer to evaluate lake conditions, with a subset of these lakes sampled monthly from June through September in the second year of the cycle. Lakes and ponds are chosen for sampling for screening based on a lack of historical data, and for monthly sampling based on evidence of problems requiring further evaluation. Over the last five years, all LCI lakes have some degree of public access. All samples are analyzed by the NYSDEC contract laboratory.

Are they representative?

Ideally an evaluation of lake conditions in New York would include representative information for all lakes, ponds and reservoirs in the state, from a geographic, morphological (size and depth), and water quality perspective. The CSLAP and LCI datasets can be evaluated from each of these perspectives:

Table 1.1: Size distribution of New York state, LCI and CSLAP lakes

Surface Area (ac)	% NYS Lakes	% LCI & CSLAP Lakes
< 1	19.9%	0.0%
1-5	52.9%	10.7%
5-10	9.1%	3.4%
10-25	8.5%	11.9%
25-50	4.0%	15.4%
50-100	2.3%	11.6%
100-250	1.8%	24.5%
250-500	0.7%	10.7%
500-1000	0.3%	4.7%
1000-2500	0.2%	3.1%
>2500	0.2%	4.1%

Size

New York state has not defined what is a lake (or pond or reservoir), but it has created an inventory of those ponded waterbodies greater than 0.1 acre in size. Given that there are more than 16,000 of these ponded waters in the state, many of which are very small and on private property, these evaluations will by necessity come from a subsample of these waterbodies. This subsample should either be a representative cross section of these waterbodies, or the evaluation should be limited to the subset of waterbodies adequately represented by this subsample.

Table 1.1 shows that most ponded waters in New York state are less than 5 acres in size, and more than 90% have a surface area less than 25 acres. The distribution of lakes sampled in all monitoring programs, including CSLAP and the LCI, are different than the overall statewide distribution, with a greater emphasis on larger lakes. This is largely a function of the “screening” criteria used to select program lakes- CSLAP lakes are limited to those with lake associations (and by extension support lake communities and their associated requirements, including roads and septic or other wastewater systems), and LCI lakes are limited to those with public access or usage associated with parks, boat launches, or public drinking water intakes. The most significant distribution of CSLAP and LCI sampled lakes falls within the 10-500 acre size range- this represents less than 20% of New York state lakes, but about 75% of sampled lakes. This distribution is even more concentrated in the 25 to 250 acre range. However, the distribution of lakes in these monitoring programs is likely to be more representative of those lakes that support public usage, even if that usage is vested within private lake residential communities.

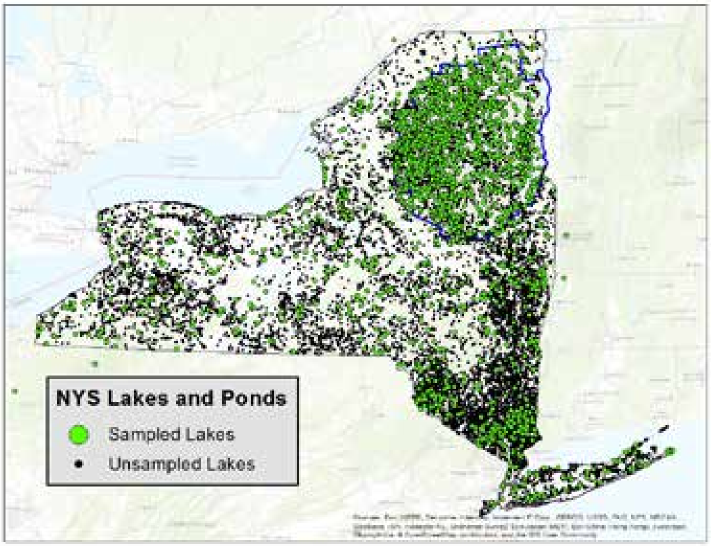


Figure 1.1: Distribution of sampled and unsampled New York state lakes

Geographic

Figure 1.1 shows the distribution of sampled and unsampled lakes in New York state since the early 1970s. A large number of lakes were sampled within the Adirondack Park as part of the Adirondack Lake Survey Corporation (ALSC) study of more than 1500 lakes in the Adirondacks and high elevation regions downstate. An additional 1000 or so lakes have been sampled outside of the ALSC survey, mostly through federal or state sampling programs dedicated to acid rain, eutrophication, or fisheries management sampling, or regional programs in the Adirondacks and Finger Lakes region. In most regions, this left many mostly smaller unsampled lakes. Figure 1.2 shows the location of the larger unsampled lakes. These are scattered throughout the state, with a concentration in the central and western Adirondacks and the southern portion of the Hudson River basin and in the Delaware River basin. These figures show that while most of the smaller New York state lakes have not been sampled by any of the major state programs, there are far fewer unsampled larger lakes.

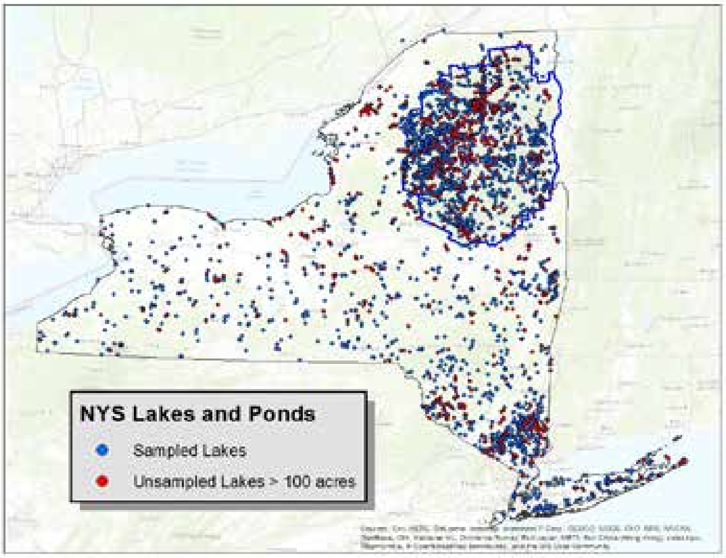


Figure 1.2: Distribution of sampled and larger unsampled New York state lakes

Table 1.2 identifies the types of waterbodies under- and over-represented by CSLAP and LCI in each of the nine New York state regions included in this report. Figure 1.3 shows the distribution of the lakes sampled at least monthly though CSLAP and the LCI from 2012 to 2016. With the exception of slight oversampling of lakes in the Central region (particularly in Madison and Cortland Counties) and undersampling of lakes in the western Adirondack region (particularly power generating reservoirs and small dystrophic lakes),

Table 1.2: Geographic distribution of New York state, LCI and CSLAP lakes

Region	% CSLAP- LCI Lakes	% NYS Lakes	Over-represented*	Under-represented*
Long Island-NYC	6%	6%	None	Urban lakes in NYC and Nassau Co
Lower Hudson	11%	13%	Suburban lakes in Westchester and Putnam Co	Large reservoirs, western Orange Co lakes
Mid Hudson	18%	14%	Rural lakes in Rensselaer Co	Delaware County lakes
Mohawk	7%	9%	Washington County lakes	Schoharie County and small Saratoga County lakes
Eastern Adirondack	13%	11%	Midsized public access lakes	Small private lakes and some larger lakes
Western Adirondack	14%	8%	Midsized public access lakes	Dystrophic high elevation lakes and some larger lakes
Central NY	11%	18%	Madison County	Oswego County and
Finger Lakes	9%	11%	Small public access lakes	Most Finger Lakes
Western NY	11%	10%	Chautauqua County lakes	Urban lakes

*Among all sampled lakes, not just those sampled through CSLAP or the LCI the CSLAP and LCI datasets are highly representative of the geographic distribution of New York state lakes.

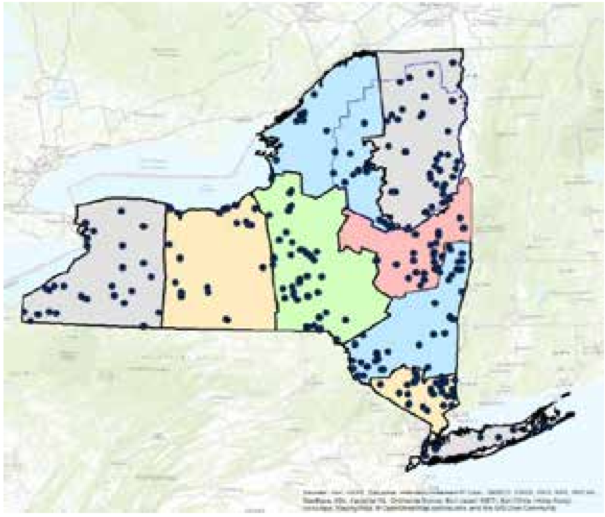


Figure 1.3: Distribution of CSLAP and LCI lakes sampled 2012-2016

It is anticipated that more of these unsampled lakes will be included in CSLAP or the LCI in the coming years.

Regional approach

This report attempts to summarize the results from the two major DEC statewide lake monitoring programs- CSLAP and the LCI- for both individual lakes and from a broader geographic scale. Since the interpretation of information from each lake needs some geographic context, these reports need to be compiled, and available for ready comparison, within that context. However, providing this information (only) on a statewide scale does not allow for a geographic context that acknowledges the many shared characteristics of nearby waterbodies. This “neighborhood” context may truly extend to those waterbodies within shared subwatershed- perhaps even those sharing the same water- but meaningful comparisons requires enough data and waterbodies to separate out small sample differences. In addition, there may be some debate about whether these shared neighborhood contexts are associated with larger watershed, geopolitical boundaries, or even very broad geographic identities (“the Finger Lakes”). This balancing act- identifying regional scales that include enough data to account for natural variability, but not too much data to obscure meaningful shared neighborhood characteristics- creates significant challenges in presenting these data.

This 2016 New York state lakes report divides the state into nine distinct geographic regions. These regions are discussed in more detail in Chapter 2. As demonstrated in Table 1.2, the geographic distribution of CSLAP and LCI lakes is closely aligned with these geographic regions, at least in most regions, although these programs continue to undersample very small lakes and oversample larger lakes, particularly those in the 25 to 250 acre range.

What the report is and isn’t

As noted above, this regional report is intended to provide a summary of regional lake conditions in both broad terms and in an accumulated summary of many individual lake reports. The focus will be on lake eutrophication- the greenness of the water and the associated causes (excessive nutrients) and impacts (effects on water clarity, harmful algae blooms, excessive weeds, and lake perception). Where appropriate, lake trends and ancillary conditions will also be summarized. However, this report is not intended to provide a treatise on conditions in any particular lake, a lengthy historical evaluation through comparison to previous lake reports, an evaluation of lakes sampled in other water quality monitoring programs, or information about lake stressors not measured in these program.

Chapter 2: Description of Regions

This reporting model divides New York state into nine distinct regions as a vehicle for housing individual lake summary reports and to provide some context for interpreting these results. This model resulted from the need to divide nearly 300 individual lake summaries into smaller units for presenting and comparing lakes data, but was also intended to group similar waterbodies. These groupings further needed to include enough waterbodies to provide meaningful statistical analyses and generate a manageable number of reports, but not too many waterbodies within any group to make the regional reports unwieldy.

The most common denominator for New York state lakes, as for real estate, is location (…location, location). Geographic divisions considered for the regional reports was as small as counties, or as large as "directional" drainage basins (lumping waterbodies that flow into the Atlantic Ocean, Gulf of Mexico, and Gulf of St. Lawrence). It was determined that approximately 8-12 major geographic regions represent the proper balance and cover both sufficiently large areas to include many waterbodies and sufficiently small areas to provide some sense of lake "neighborhoods" sharing common traits.

This reporting model ultimately settled on 9 major regions, as described below. As noted in chapter 1, the individual lake reporting and most of the tables in this report will include only those lakes sampled through the NY Citizens Statewide Lake Assessment Program (CSLAP) and the Lake Classification and Inventory (LCI) survey, although some tables also draw from some of the other regional monitoring programs in New York to provide some context. Table 2.1 shows the number of CSLAP and LCI lakes sampled in any of the past five years and in 2016 in these nine regions.

Table 2.1: Number of CSLAP and LCI lakes sampled in 2012-2016 and in 2016 only

Region	#Lakes Sampled Anytime 2012-2016	#Lakes Sampled 2016
New York City/ Long Island	15	6
Lower Hudson	34	23
Mid-Hudson	36	19
Mohawk	24	13
Eastern Adirondack	30	15
Western Adirondack	21	12
Central New York	47	29
Finger Lakes	28	16
Western New York	27	16

New York City/Long Island Region:

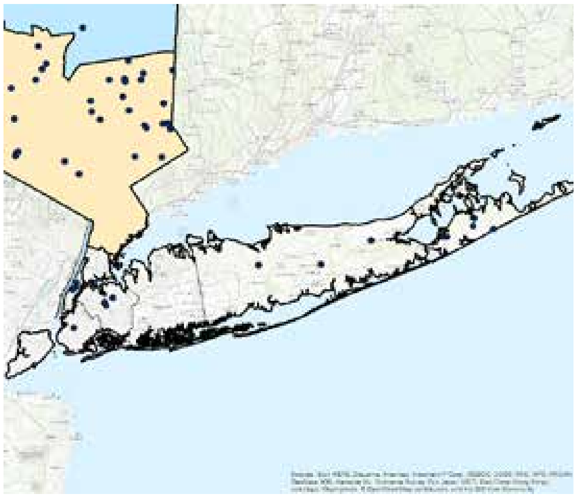


Figure 2.1: CSLAP and LCI lakes in the New York City / Long Island region

This region includes the two counties (Suffolk and Nassau) that comprise Long Island, and the five counties (Bronx, Kings, New York, Queens, and Richmond) associated with the New York City boroughs (Bronx, Brooklyn, Manhattan, Queens, and Staten Island). Although portions of Westchester County drain into Long Island Sound, they are not included in this region. The New York City/Long Island region is characterized by very high population densities, particularly increasing moving from east to west. However, the eastern portion of the region includes many freshwater and tidal wetlands and plains. Most of the lakes in this region are small, shallow, and primarily support aquatic life, fishing, and aesthetics use, typically as “pocket” ponds in parks and suburban to highly urbanized areas. These lakes typically do not support contact or non-contact recreation, although those with lake associations or significant residential frontage are used for boating and swimming.

Figure 2.1 shows the distribution of CSLAP and LCI lakes in the New York City/Long Island region. The lakes sampled through CSLAP or the LCI are found mostly in the suburban to heavily urbanized areas, although these appear to be representative of typical lakes of the region. Several of the representative New York City Parks lakes were sampled through the LCI in 2014, although this represents only a small subset of lakes and ponds within the Parks system. The CSLAP lakes in this region are limited to several private recreational or Greenbelt lakes in the town of Southampton in Suffolk County, although there are many other nearby private recreational lakes not sampled through either CSLAP or the LCI.

Lower Hudson Region

The Lower Hudson River region is comprised of the four counties on either side of the Hudson River between New York City and the Newburgh area- Westchester, Rockland, Putnam, and Orange Counties. Some portions of these counties do not drain into the Hudson River- for example, portions of Orange County drain into Raritan Bay through the Ramapo River. This regional definition also differs from the “Lower Hudson River basin” defined by the NYSDEC as one of the 17 major drainage basins in New York- this larger basin extends up to the Capital District area. However, the Lower Hudson basin defined here represents the area immediately north of New York City and the New York Harbor, and is largely bisected by the Hudson River. The region is characterized by many natural and constructed waterbodies that serve drinking water and suburban residential needs, connected through a labyrinth of transportation and water corridors. However, there is also forested and agricultural land in the northern and western portions of this region, and many of the lakes are small kettle ponds of highly varying depths.

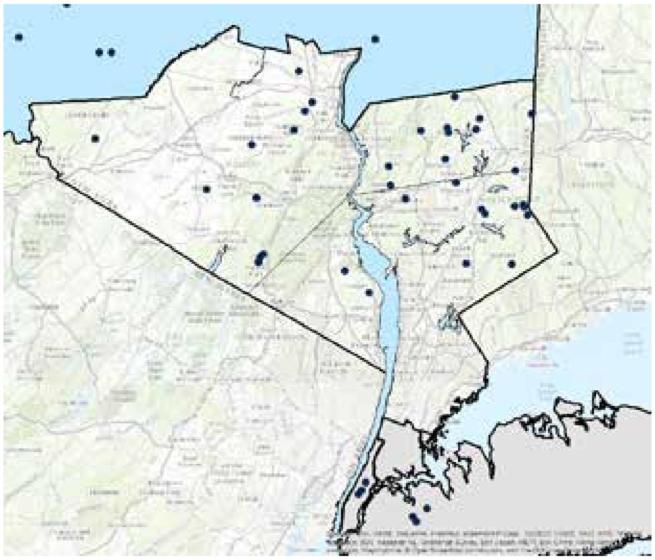


Figure 2.2: CSLAP and LCI lakes in the Lower Hudson region

Figure 2.2 shows a heavy distribution of CSLAP and LCI lakes in northeastern Westchester County, eastern Orange County, and especially in Putnam County. The southern Westchester County, Rockland County and western Orange County areas are not well represented in these more recent monitoring programs. However, many of these areas, particularly northern Rockland County, western and southern Westchester County, and southern Orange County, were sampled through previous NYS monitoring activities and are briefly summarized in the regional monitoring tables presented later in this report.

Mid-Hudson Region

The Mid-Hudson River region is bounded by the Lower Hudson region to the south, by the Mohawk River region to the northeast, by the Central region to the northwest, and to the west and east by the state borders. Specifically, the Mid-Hudson region includes Columbia, Delaware, Dutchess, Greene, Rensselaer and Ulster Counties. The region includes both the northern portion of the “Lower Hudson River” drainage basin cited above, and the southern portion of the Delaware River basin, and is bisected by the Hudson River. The region is characterized by numerous kettle ponds and large reservoirs (power generating and drinking water) in the western areas, and higher population densities in the northern portion of the region. The lake population density is very high in the eastern and western portions of the region, but lower in the central areas (the western portions of Ulster and Greene Counties).

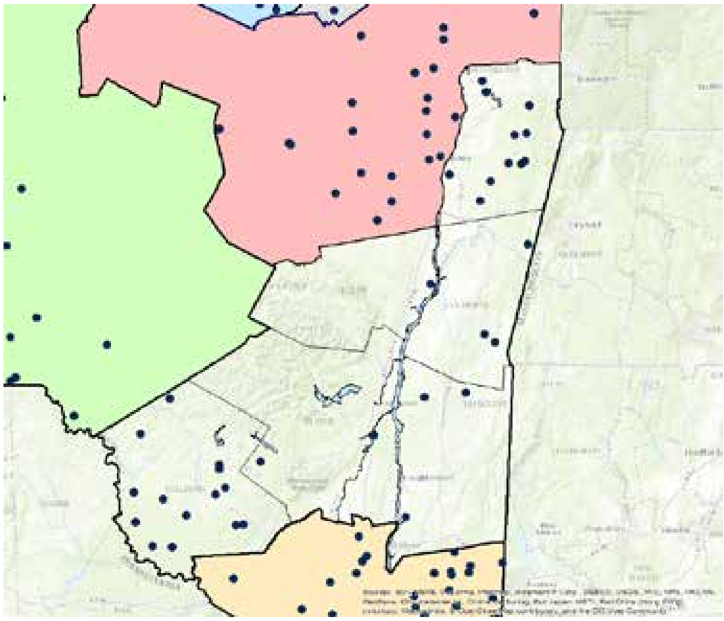


Figure 2.3: CSLAP and LCI lakes in the Mid-Hudson region

The distribution of CSLAP and LCI lakes in the region shown in Figure 2.3 indicates a relatively large number Sullivan County and Columbia County lakes, mostly associated with small to mid-sized lakes, with very limited sampling of Ulster and Greene County lakes (which represent the least lake-rich areas of the region). Previous state monitoring programs, particularly the downstate portion of the ALSC study, included many other Dutchess and Columbia County lakes.

Mohawk Region

The Mohawk River region includes most of the eastern portion of the (actual) Mohawk River drainage basin, as well as the Washington County areas outside of the Adirondack Park. Thus the region is bounded by the Central region to the west, the Mid-Hudson Region to the south, the Adirondack Blue Line to the north, and the state border to the east. This encompasses Albany County, portions of Fulton, Herkimer and Saratoga Counties, Schenectady County, Schoharie County, and portions of Washington County. The region is bisected by the Mohawk River, and is characterized by mostly small kettle lakes and ponds and a moderately high population base, particularly in the eastern portions of the region.

The CSLAP and LCI lakes in the Mohawk basin are mostly clustered around the Capital District in Albany, Saratoga and Schenectady Counties, with some lakes in the hills of Albany and Washington Counties (Figure 2.4). There are no sampled lakes within the Montgomery, Fulton, Oneida, or Otsego County regions outside of the Adirondack Park, but these areas have relatively few lakes and ponds. Many other Schoharie, Schenectady and Fulton County lakes were previously sampled in other state programs, particularly the LCI.

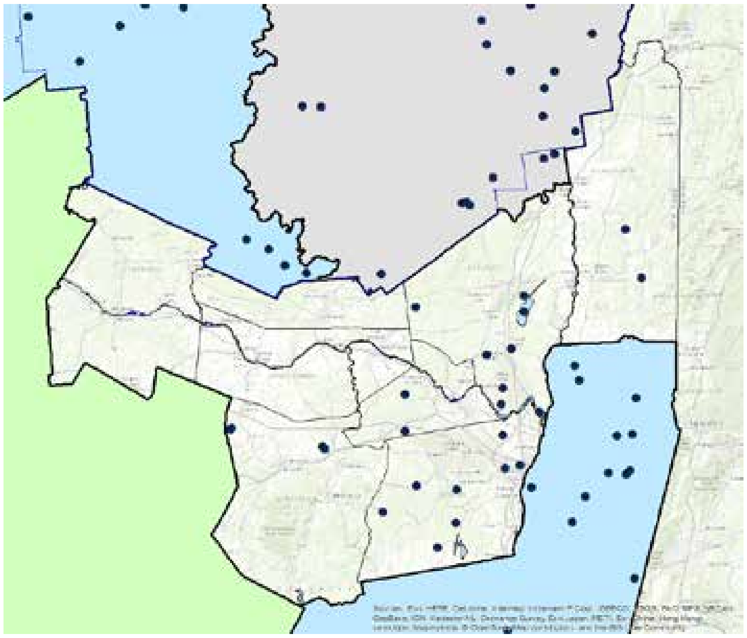


Figure 2.4: CSLAP and LCI lakes in the Mohawk region

Eastern Adirondack Region

The Adirondack Park blue line encompasses a 6 million acre area established by the state Legislature in 1894, representing just under 20% of the land area in New York state. Although the blue line covers much of the northernmost portion of the state, it does not extend completely to the Canadian border at the St. Lawrence River to the west or north, or to Lake Champlain and the Vermont border to the northeast. Therefore, to prevent isolating waterbodies near the outer perimetry of the Blue Line, the "Eastern Adirondack" region extends beyond to the Blue Line to the state borders. The line between the Eastern and

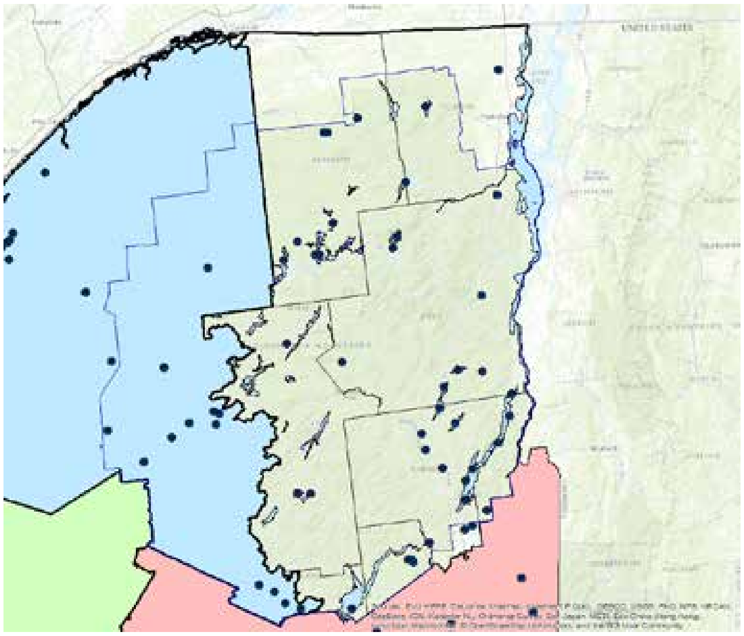


Figure 2.5: CSLAP and LCI Lakes in the Eastern Adirondack region

Western Adirondack region is defined primarily in the southern portion of the region by the boundary between the Upper Hudson River basin and the Black River basin, and along the St. Lawrence County-Franklin County border in the northern portion of the region. The latter mostly follows along the Lake Champlain basin-St. Lawrence River basin dividing line. So the eastern Adirondack region includes Clinton County, Essex County, Franklin County, portions of Hamilton and Saratoga Counties, Warren County, and portions of Washington County. This includes large, deep lakes in the southern areas, a mix of smaller and mid-sized low and high elevation lakes in the central areas, and smaller lakes in the flatter northern regions.

The CSLAP and LCI lakes in the Eastern Adirondack region, shown in Figure 2.5, are concentrated in the southeastern and northwestern portions of the region. However, many other, mostly small, lakes were sampled in Essex, Franklin and eastern Hamilton County thru previous and other contemporary monitoring programs, including the ALSC and the Adirondack Lake Assessment Program (ALAP). Most lake rich areas in the Eastern Adirondack region are well represented in these monitoring programs.

Western Adirondack Region

As noted above, the Western Adirondack region is a somewhat artificial division separating large geographic portions of the Adirondack Park and adjacent areas immediately outside the Park. The Western Adirondack region extends to the St. Lawrence River to the north and west, and is bounded to the southeast by the Mohawk region and to the southwest by the Central region. This region includes portions of Fulton and Herkimer Counties, Jefferson County, Lewis County, portions of Oneida County, and St. Lawrence County. This region includes many small, high elevation, dystrophic (colored) lakes, large power-generating reservoirs in the western areas of the Adirondack Park, and several lakes in Jefferson and St. Lawrence Counties near the St. Lawrence River, including a cluster of lakes in the Indian River Lakes system, used heavily for recreation.

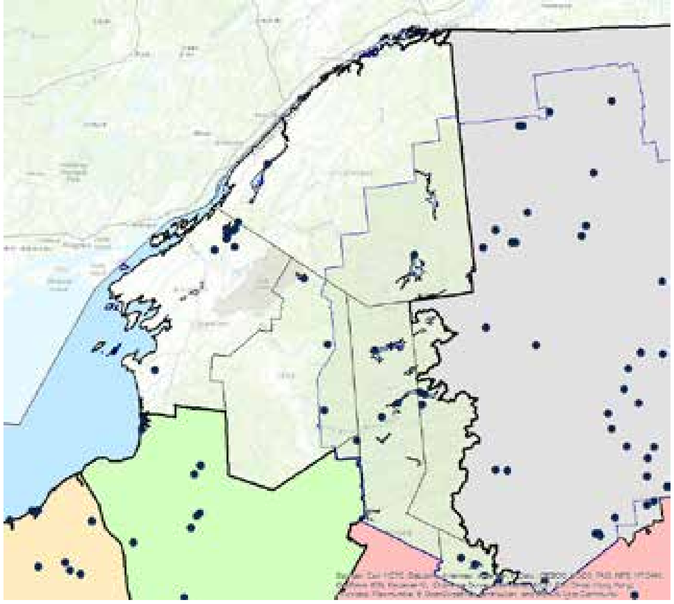


Figure 2.6: CSLAP and LCI lakes in the Western Adirondack region

The CSLAP and LCI lakes in the Western Adirondack region includes most of the lakes and ponds within Indian River Lakes system in northern Jefferson County, and lakes within the eastern and southeastern portion of the region, as shown in Figure 2.6. As with the Eastern Adirondack region, many small high elevation dystrophic lakes were sampled through the ALSC in western Hamilton County, eastern Lewis County and in Herkimer and St. Lawrence Counties. These are particularly lake-rich areas in this region. ALAP also samples some lakes, particularly in the eastern portion of the region. None of the state monitoring program have included lakes in northern St. Lawrence County, although this is not a particularly lake-rich portion of the region.

Central New York Region

The Central region is perhaps the most poorly defined of the nine regions cited in this report. It is not associated with distinct geographic features, although it is often referred to broadly as the Leatherstocking region. The Central region is bounded to the east and south by the Mohawk and Mid-Hudson regions and the state border, to the north by the Western Adirondack region, and to the west by the Finger Lakes region. The latter is defined rather loosely by a mostly north-south boundary connecting the mouth of the Oswego River at Lake Ontario to the Pennsylvania border along the Broome-Tioga Counties boundary. This north south line largely follows the western borders of Onondaga, Cortland and Broome Counties, assuring that the Finger Lakes fall within the eponymous region. This region has been defined to include Broome County, Chenango County, Cortland County, Delaware County, Madison County, most of Oneida County, and Onondaga County.

This region includes many reservoirs created to support the Erie Canal system, small kettle lakes in the central, northern and western portion of the region, and two very large lakes in Oneida Lake and Oswego Lake.

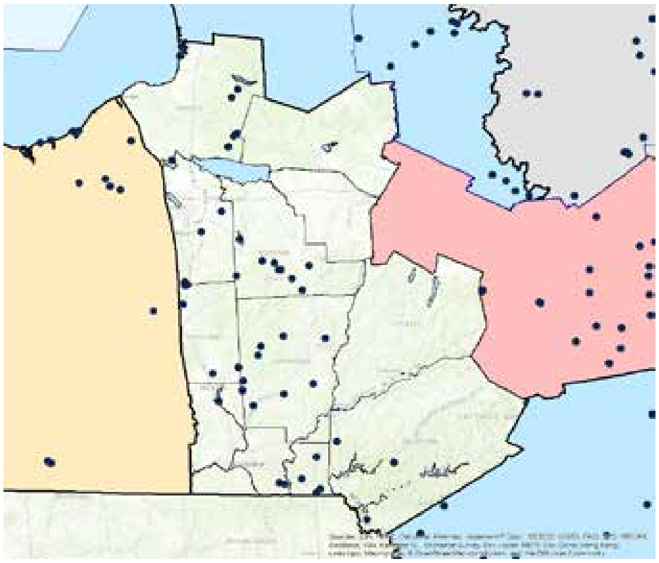


Figure 2.7: CSLAP and LCI lakes in the Central New York region

Figure 2.7 shows that CSLAP and LCI lakes in the region are heavily concentrated in the central and western portion of the regions, particularly in Madison County, Chenango County, and Broome County. Many other lakes sampled were previously sampled through CSLAP and the LCI in Delaware and Otsego Counties. Most of the large number of small lakes and ponds in western Oneida County and northern Onondaga County are private and have not been sampled in any of the major state monitoring programs.

Finger Lakes Region

The Finger Lakes region includes the 11 Finger Lakes, several small to mid-sized ponded embayments of Lake Ontario, and many small kettle or glacial lakes throughout the region. The Finger Lakes region as defined here extends from Lake Ontario to the Pennsylvania border to the north and south, respectively, and is bounded to the east by the western boundary of the Central region as described above. The western boundary is loosely defined as the western boundary of Monroe, Livingston and Steuben Counties, although more precisely the line is defined to include the Rochester area embayments and Conesus Lake. The other counties represented in the region include Cayuga County, Ontario County, Oswego County, Seneca County, Tioga County, Tompkins County, Wayne County, and Yates County.

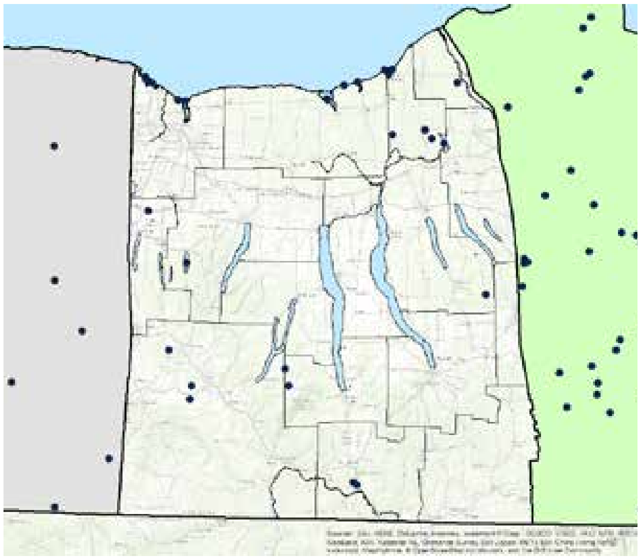


Figure 2.8: CSLAP and LCI lakes in the Finger Lakes region

The lakes in this region are dominated by the 11 Finger Lakes, 9 of which are multi-use reservoirs providing drinking water, recreation and habitat for residents and tourists. Outside of the Lake Ontario embayments, most of the other lakes and ponds in the Finger Lakes region are small and shallow.

Most of the Finger Lakes were previously sampled through CSLAP, and most have been sampled by academic and limited government programs, as noted in Figure 2.8. Most of the aforementioned embayments were sampled through the LCI, and many of the small lakes have been well represented in recent sampling programs. These programs poorly represent the many small lakes in Tioga and Tompkins Counties.

Western New York Region

The Western New York region is bounded to the east by the western boundary of the Finger Lakes region described above, and by state or US boundaries- Lake Ontario to the north, the Niagara River and Lake Erie to the west, and Pennsylvania to the south. This includes Allegany County, Cattaraugus County, Chautauqua County, Erie County, Genesee County, portions of Monroe County, Niagara County, Orleans County and Wyoming County. This region has far fewer large lakes than in most other regions, with a heavy concentration of these larger lakes in the southwestern portion of the region.

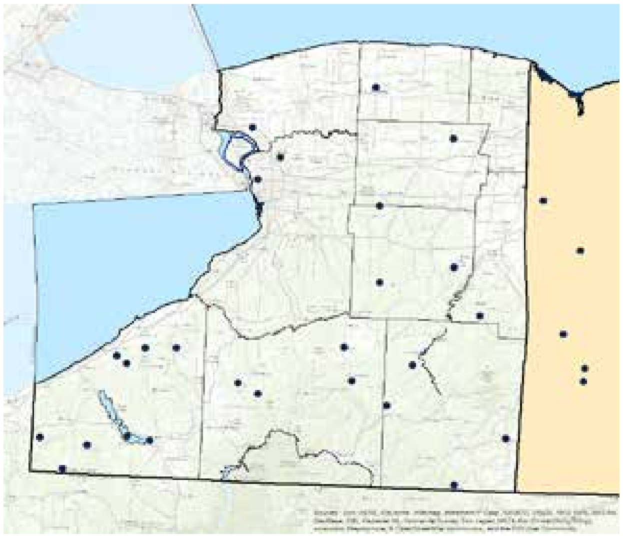


Figure 2.9: CSLAP and LCI lakes in the Western New York region

Most of the larger lakes in region have been well represented in either CSLAP or the LCI, as seen in Figure 2.9. Most of the unsampled lakes in the region are small and private, with very limited public use. However, many of the smaller lakes in eastern Erie County and western Monroe County and in Wyoming County have not been well represented by present or past state monitoring programs.

Chapter 3: Mohawk Region CSLAP and LCI Lakes

The CSLAP and LCI lakes in the Mohawk Region are generally mid-sized public lakes used for recreation and (for some lakes) drinking water and supportive of a diversity of aquatic life. Figure 3.1 (reproduced from Chapter 2) shows the geographic distribution of lakes within the region, with a high concentration of lakes and ponds in the eastern portion of the region (southern Saratoga County and Albany County), with other lakes scattered through the region. Washington County, Schoharie County, and the entire western portion of the region are not as well represented in the CSLAP and LCI sampling since 2012, in part because there are relatively few lakes in Montgomery County, and southern Fulton and Oneida Counties (outside of the Adirondacks). As a result, Table 1.2 shows that the percentage of CSLAP and LCI lakes in the Mohawk Region is slightly smaller than the percentage of New York state akes in this region.

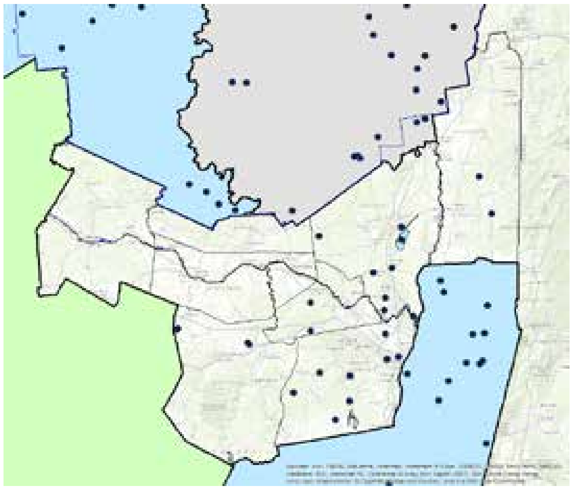


Figure 3.1: 2012-16 CSLAP and LCI lakes in the Mohawk region

Table 3.1: Size distribution of NYS monitored and LCI/CSLAP lakes in the Mohawk Region

Surface Area (ac)	% NYS Lakes	% LCI & CSLAP Lakes
< 1	1.1%	0.0%
1-5	12.6%	6.9%
5-10	8.0%	13.8%
10-25	11.5%	0.0%
25-50	20.7%	13.8%
50-100	17.2%	6.9%
100-250	14.9%	37.9%
250-500	9.2%	13.8%
500-1000	2.3%	6.9%
1000-2500	2.3%	0.0%
>2500	0.0%	0.0%

Table 3.1 shows the size distribution of CSLAP and LCI lakes sampled from 2012 to 2016 compared to all lakes sampled in the Mohawk Region (by all monitoring programs over many years). As noted in Chapter 1, CSLAP and LCI lakes tend to be larger than the typical New York state lake. This is apparent in the Mohawk Region. Table 3.1 shows a higher percentage of sampled lakes in the region that are greater than 100 acres in size relative to the lakes sampled in the region through other monitoring programs. Prior to 2013, many lakes in Washington, Fulton, and Schoharie Counties were sampled through the CSLAP and LCI; these were generally small private lakes.

Tables 3.2 and 3.3 provide additional information about these CSLAP and LCI lakes. These tables show that the CSLAP and LCI lakes in the Mohawk Region include a diversity of sizes and depths, and several of these lakes are classified for use as drinking water supplies (Class A) or otherwise are used by the public. Many of these lakes probably have short retention times, given the relatively small watersheds. This suggests a high susceptibility to in-season increases in nutrient and algae levels from nutrient migration to the surface. The shallower lakes may be susceptible to excessive aquatic plant growth, although weeds are common in the shallower portions of even the larger lakes..

Table 3.2: CSLAP and LCI lakes in the Mohawk region, 2012-16, Part 1

Lake Name	Program	Town or City	County	Latitude	Longitude	Years Sampled
Ann Lee Pond	LCI	Albany	Albany	42.738	-73.812	2013
Ballston Lake	CSLAP	Ballston	Saratoga	42.92018	-73.85863	1991-2016
Ballston Lake-s	CSLAP	Ballston	Saratoga	42.93834	-73.85786	2007-2016
Basic Creek Reservoir	LCI	Westerlo	Albany	42.484822	-74.01627	2013
Buckingham Lake	CSLAP	Albany	Albany	42.66355	-73.80714	2011-2014
Central Bridge Reservoir- Lower	LCI	Howes Cave	Schoharie	42.711579	-74.36017	2016
Central Bridge Reservoir- Upper	LCI	Howes Cave	Schoharie	42.715647	-74.36615	2016
Cossayuna Lake	CSLAP	Argyle	Washington	43.20060	-73.42340	1992-1996, 1998-1999, 2001-2010, 2012-2016
Duane Lake	CSLAP	Duanesburg	Schenectady	42.74910	-74.11260	1990-2016
Engleville Pond - Lower	LCI	Sharon	Schoharie	42.76022	-74.64737	2014
Engleville Pond - Upper	LCI	Sharon	Schoharie	42.7561	-74.6519	2014
Galway Lake	CSLAP	Galway	Saratoga	43.03070	-74.07450	1990-1997, 2000-2010, 2012-2016
Lake Lauderdale	LCI	Salem	Washington	43.05326	-73.7422	1989-1993, 1995, 1997, 2012 (L)
Lake Lonely	LCI	Saratoga Springs	Saratoga	42.54039	-73.9595	2012
Lawson Lake	LCI	Feura Bush	Albany	42.83370	-74.11190	2014-2015
Mariaville Lake	CSLAP	Duanesburg	Schenectady	42.844318	-73.80963	1999-2011, 2014-2016
Murphy Pond	LCI	Clifton Park	Saratoga	42.933633	-73.7823	2015-2016
Round Lake-S	LCI	Round Lake	Saratoga	42.807267	-73.81617	2012
Saratoga Lake	CSLAP	Saratoga, Malta, Stillwater	Saratoga	42.788677	-73.69813	1993-1997, 2005-2011, 2013, 2015-2016
Stony Creek Reservoir	LCI	Rexford	Saratoga	43.21020	-73.46320	2015
Sugarloaf Pond	LCI	Waterford	Saratoga	42.65013	-74.04256	2015-2016
Tivoli Lake	LCI	Albany	Albany	42.670151	-73.76136	2015
Vly Creek Reservoir	LCI	Voorheesville	Albany	42.615518	-73.9555	2016
Warners Lake	LCI	East Berne	Albany	42.625118	-74.07892	2016
Woods Pond	LCI	Berne	Albany	42.56689	-74.18319	2015-2016

Table 3.3: CSLAP and LCI lakes in the Mohawk region, 2012-16, Part 2

Lake Name	Program	WQ Class	Area (ac)	Watershed Area (ac)	Max Depth (ft)
Ann Lee Pond	LCI	C	6	2238	5
Ballston Lake	CSLAP	A	278	6326	116
Ballston Lake-s	CSLAP	A			16
Basic Creek Reservoir	LCI	A	243	11189	18
Buckingham Lake	CSLAP	C	6	158	5
Central Bridge Reservoir- Lower	LCI	A	109	54	15
Central Bridge Reservoir- Upper	LCI	A	218	755	10
Cossayuna Lake	CSLAP	A	659	7562	25
Duane Lake	CSLAP	B	32	323	17
Engleville Pond - Lower	LCI	A	2	27	14
Engleville Pond - Upper	LCI	A	32	634	12
Galway Lake	CSLAP	B	518	5911	21
Lake Lauderdale	LCI	**B**	77	1236	80
Lake Lonely	LCI	B	115	14276	29
Lawson Lake	LCI	B	26	1048	13
Mariaville Lake	CSLAP	B	198	1804	12
Murphy Pond	LCI	C	218	2526	5
Round Lake-S	LCI	B	320	17367	25
Saratoga Lake	CSLAP	A	4032	156174	95
Stony Creek Reservoir	LCI	A	366	7605	34
Sugarloaf Pond	LCI	C	7	NA	3
Tivoli Lake	LCI	C	4	8528	10
Vly Creek Reservoir	LCI	A	165	2122	35
Warners Lake	LCI	B(T)	115	1195	55
Woods Pond	LCI	C	6	159	10

Tables 3.2 and 3.3 also provide information about whether the lake was sampled through CSLAP or LCI since 2012, the overall number of years sampled (primarily through CSLAP), the primary town(s) and county where the lake is located, the size of the lake and the approximate size of the watershed (both listed in acres), and the typical maximum depth of the lake (in feet). Table 3.2 provides the coordinates of the approximate centroid of the lake, and Table 3.3 identifies the water quality classification for the lake. These classifications are discussed in more detail in Chapter 10.

Chapter 4: CSLAP and LCI Quality Measures

As noted in Chapter 1, the Citizens Statewide Lake Assessment Program (CSLAP) and the Lake Classification and Inventory (LCI) survey are the statewide water quality monitoring programs that provide information summarized in this report (along with the harmful algae bloom (HAB) program and iMap invavsives information summarized in Chapters 6 and 8, respectively). These NYSDEC-sponsored programs benefit from numerous quality assurance measures to provide a high level of confidence in the value and representativeness of the data.

All quality measures used in CSLAP and the LCI are documented in DEC-approved Quality Assurance Project Plans associated with each project. These can be found at http://www.dec.ny.gov/chemical/81849.html and http://www.dec.ny.gov/docs/water_pdf/lciqapp1314.pdf, respectively.

These quality measures include the following:

Training

All CSLAP and LCI samplers are trained in standardized methods for collecting accurate and representative samples, consistent with the NYSDEC Lake Monitoring Standard Operating Procedures (http://www.dec.ny.gov/docs/water_pdf/sop20314.pdf). The specific sampling instructions are provided to the trained CSLAP samplers through several methods, including sampling training sessions conducted by NYSDEC and NYFOLA, written sampling protocols (http://www.nysfola.org/cslap), instructional videos (http://www.dec.ny.gov/chemical/81849.html), sampling protocol quizzes (http://www.dec.ny.gov/docs/water_pdf/cslapquiz2.pdf) and in-season “OOPS” sheets outlining specific problem areas to avoid sampling anomalies. LCI samplers are trained by NYSDEC staff during on-site training and two-day training workshops.

Sample collection

Surface and bottom samples are collected in thermally stratified lakes in the deepest portion of the lake in both CSLAP and the LCI. Sample collection methods in these two programs differ slightly. Since 1986, CSLAP samplers have used Kemmerer bottles to collect surface samples at a depth of 1.5 meters, and bottom samples at a depth of 1-2 meters off the lake bottom. LCI samplers (DEC staff) use 2 meter depth integrated samplers- PVC tubes with stopper plugs and ball valves- to collect surface samples and Van Dorn bottles to collect deep samples at a depth of 1-2 meters off the lake bottom. The LCI methodologies are consistent with the National Lake Assessment (NLA) program initiated in 2007. However, it is anticipated that surface and bottom sampling results are comparable in both CSLAP and the LCI, despite the slight differences in sampling methodologies.

HAB samples are drawn from the surface sample in all CSLAP lakes and in LCI lakes with visual evidence of a HAB; surface skim samples are collected from the most intense part of the bloom in other areas, using near the shoreline, if conditions at this site are consistent with a HAB.

Field measurements in both programs are collected using standard limnological procedures. Secchi disk transparency readings in both CSLAP and the LCI are measured using a standard limnological (black and white quartered, 20cm diameter) disc. Water temperatures in CSLAP are measured using a field thermometer; LCI samplers collect one-meter depth profiles for temperature, dissolved oxygen, pH, conductivity, and oxygen reduction potential (ORP) at all lakes using a calibrated Hydrolab multiprobe electronic meter. Field chlorophyll *a* and phycocyanin are measured in some lakes, also in one meter depth profiles, using a higher end Hydrolab electronic meter.

Instructions for completing field forms are provided during all training sessions. Some CSLAP volunteers enter data on-line through a NYSFOLA-hosted web page (https://www.cslapdata.org/index.php).

Sample processing and preservation methods

Chlorophyll *a*, (true) color and cyanotoxins are field filtered in open water CSLAP samples, although cyanotoxins are analyzed from raw water samples when collected from concentrated shoreline blooms in both CSLAP and the LCI, and in all open water LCI samples. Soluble nutrients and chlorophyll *a* are field filtered in LCI samples. Filtrations are conducted using Nalgene polysulfonate filter apparatus and hand-operated vacuum pumps with 0.45 cellulose nitrate (for all CSLAP filtrations and LCI filtering for soluble nutrients) or glass fiber (for LCI chlorophyll *a*) filters, consistent with the approved laboratory methodology for these indicators. Filters are placed in labeled vials, and chlorophyll vials are wrapped in aluminum foil to prevent additional algae growth. LCI nutrient and metals bottles are pre-preserved with sulfuric and nitric acid, respectively, by the laboratory. All bottles are pre-labeled prior to shipping.

All CSLAP samples except the raw water sample used for unextracted chlorophyll *a* measurements at SUNY ESF and cyanotoxins (field filter or raw water sample) are frozen overnight for next day shipping. LCI samples are placed in coolers with ice immediately after processing and kept in ice-filled coolers until shipping.

All samples are accompanied by Request for Analysis/Chain of Custody forms signed by the samplers and laboratory staff receiving the sampling bottles sent by the samplers.

Sample shipping

Pre-paid shipping labels are provided to all CSLAP samplers. Open water CSLAP sample bottles and filter vials are shipped to Upstate Freshwater Institute with ice packs in styrofoam coolers with all field forms, Shoreline bloom samples from CSLAP or LCI samplers are shipped as whole water samples with ice packs and coolers directly to SUNY ESF. LCI samples are either shipped or hand delivered to ALS laboratory in Rochester.

Analytical methods

The field indicators measured through CSLAP, LCI or HABs programs are measured through standard limnological methods as governed by DEC SOP 203-14 (Lake Monitoring Standard Operating Procedures); those with a laboratory equivalent are measured using methods approved by USEPA, Standard Methods, or some modification thereof. Those measured using field probes are analyzed as per the methodology outlined in the user manuals associated with the multiprobe electronic meters (Hydrolab or bbe Moldaenke). Each of the laboratory water quality indicators measured through CSLAP or the LCI are analyzed using accepted methodologies, as outlined in Table 4.1. Each of these laboratory analyses for which Environmental Laboratory Approval Program (ELAP) certification is available is analyzed using an ELAP approved method.

Table 4.1: Laboratory and other analytical method information for CSLAP and LCI parameters

Sampling Indicator	Program	Method	ELAP Certified?
Field Indicators			
Secchi disk transparency	CSLAP and LCI	SOP #203-14	NA
Water temperature	CSLAP	SM 2550B, thermometer	NA
Water temperature	LCI	SM 2550B, field probe	NA
pH	LCI	SM 4500H +B, field probe	NA
Specific conductance	LCI	SM 2510B, field probe	NA
Oxygen reduction potential	LCI	SM 2580B, field probe	NA
Chlorophyll a- unextracted	LCI	Hydrolab, 2014	NA
Phycocyanin- unextracted	LCI	Hydrolab, 2014	NA
Lake perception	CSLAP and LCI	SOP #203-14	NA
Laboratory indicators			
Total phosphorus	CSLAP and LCI	SM 18-20 4500-P E	Yes
Nitrate+Nitrite - NOx	CSLAP and LCI	USEPA 353.2 Rev 2.0	Yes
Ammonia- NH4	CSLAP and LCI	USEPA 350.1 Rev 2.0	Yes
Total nitrogen- TN	CSLAP and LCI	SM 20 4500-N C	Yes
Chlorophyll a- extracted	CSLAP and LCI	USEPA 445.0 Rev. 1.2	NA
pH	CSLAP	SM 18-20 4500 H+ B	NA
Specific conductance	CSLAP	SM 18-20 2510 B	NA
True color	CSLAP and LCI	SM 18-20 2120 B	Yes
Calcium	CSLAP and LCI	USEPA 200.7	Yes
Chloride	CSLAP and LCI	SM 4500-Cl-97, -11	Yes
Chlorophyll a- unextracted	CSLAP, LCI and HAB	bbe Moldaenke, 2014	NA
Bluegreen chlorophyll a unextracted	CSLAP, LCI and HAB	bbe Moldaenke, 2014	NA
Microcystin-LR	CSLAP, LCI and HAB	USEPA 544- LCMS	NA
Anatoxin-a	CSLAP, LCI and HAB	USEPA 545 – LCMS/MS	NA
Cylindrospermopsin	CSLAP, LCI and HAB	USEPA 545 – LCMS/MS	NA

ELAP Certified? = certified through the Environmental Laboratory Approval Program as per 40 CFR Part 136
SM = Standard Methods
USEPA = EPA approved methods
SOP = (DEC) Standard Operating Procedure
NA = ELAP certificate not available for this indicator

Quality Control

Several quality control measures have been instituted in the field and/or laboratory through these monitoring programs. These include the following:

- Training and procedure checks- as described above, a number of training techniques are used to assure sampling data accuracy. Each of these techniques involve feedback mechanisms- routine checks by CSLAP and LCI program staff, review of field and laboratory procedures to verify training techniques, sampler feedback, and periodic review of instructions
- Field measures- field duplicates and blanks are routinely collected through the LCI to evaluate a number of quality control measures. As appropriate, this leads to changes in training, sampling techniques, equipment, renewable supplies, or other program elements to assure quality data
- Laboratory measures- the CSLAP and LCI laboratories routinely conduct quality checks and deploy a number of quality measures outlined in the program QAPPs, including enhanced staff training, data documentation, equipment calibration logs and checks, matrix duplicate and spike sampling, and laboratory control samples.
- Data review- laboratory staff and project managers review program data with to assure the collection, transport, analysis and reporting of high quality data in support of the NYSDEC program objectives and compliance with the approved QAPPs.

Chapter 5: Eutrophication

The term trophic refers to nutrition, and originates from the Greek word *trophikos*, or food. In an ecological setting, it refers to the relationships among different organisms in the food chain. In a lake setting, the food chain, or more properly the food web, is based on phytoplankton, or algae. The amount of algae produced in a lake dictates the production of other organisms; hence, algae are referred to as the primary producers. Lakes with large amounts of algae (and other plants and animals) and reduced water clarity are called *eutrophic*, literally “well-nourished”, and lakes with little biological production and very clear water are called *oligotrophic*, or “scant(ly) nourished.” Lakes with intermediate nourishment are called *mesotrophic*. *Eutrophication* is the process in which lakes become overly nourished, whether naturally or induced by human activities (cultural eutrophication).

These definitions are not synonymous with water quality conditions or an indication of supporting lake use—many eutrophic lakes are highly productive sports fisheries, and many oligotrophic lakes do not support aquatic life, often due to high lake acidity imparted by acid rain. However, most ecologists and lake users will agree that either extreme conditions or a significant change in the *trophic state* of a lake represents a problem, and higher trophic states result in not only reduced water clarity and higher algae levels, but also greater susceptibility to harmful algae blooms and dominance by invasive aquatic plants. In many waterbodies, the trophic status dictates both the support of designated uses and serves as a surrogate for water quality conditions.

Total phosphorus

Trophic status is driven primarily by phosphorus, since phosphorus usually limits the amount of algae growth in a lake. There are multiple forms of phosphorus, and the amount of soluble, “available” phosphorus often dictates additional growth of algae. However, the primary measure of phosphorus is referred to as “total” phosphorus, which measures all forms and states of phosphorus and is the basis for the regulatory framework for these nutrients. It is recorded as micrograms per liter, or parts per billion. Readings less than 10 parts per billion are generally indicative of *oligotrophic lakes*, and indicative a low susceptibility for excessive algae growth and harmful algae blooms. Readings above 20 parts per billion indicate an increasing susceptibility to blooms, and are typical of *eutrophic* lakes. Readings between these thresholds are generally typical of *mesotrophic* lakes. NYSDEC has also designated a TP threshold of 20 parts per billion as the state guidance value associated with poor aesthetic quality; a comparable threshold to protect against excessive (toxic) algae blooms and poor water clarity has not yet been adopted. NYSDEC is also working to update this guidance value to better reflect impacts to recreational uses, but it is likely that this guidance will take the form of a “response variable” (a response to this excessive eutrophication, such as chlorophyll *a*) rather than a “stressor” (such as phosphorus or nitrogen levels triggering this response).

More information about phosphorus, including analytical detection limits and sampling methods, can be found at (link to fact sheet).

Monitoring for Phosphorus

Phosphorus is one of the indicators measured in nearly all lake monitoring programs, including CSLAP and the LCI. In most lake studies, it is measured as total phosphorus, representing the sum of all dissolved and suspended forms. This is due in part to the frequently undetectable levels of many forms of dissolved phosphorus (owing to its rapid update by algae during the growing season), the long-standing statistical relationship between total phosphorus and many other water quality indicators, and the use of this form of phosphorus in other regulatory actions, from assessment to management.

Phosphorus samples (and all other CSLAP water samples) are collected from the surface with a Kemmerer bottle, while LCI samples are collected with a depth integrating PVC tube. Both devices grab samples from the upper waters of the lake, although the Kemmerer bottle can also grab samples at any depth.

Unless otherwise noted, phosphorus levels reported here are collected from a surface grab (1.5 meters below the surface) in CSLAP, or 2 meter depth integrated sample (from the surface to a 2 meter depth) in the LCI; results from these slightly different collection strategies have been demonstrated to be comparable. Samples are usually collected at the deepest portion of the lake, assumed to be the most representative measure of (total) phosphorus throughout most of the surface waters in the lake. In thermally stratified lakes- generally those greater than 6 meters deep- bottom grab samples are also collected from a depth of 1-2 meters from the lake bottom.

Statewide Phosphorus Distribution

Table 5.1 summarizes the average total phosphorus results from Mohawk Region lakes sampled in 2016 and between 2012 and 2016, along with data from other New York state lakes over the same period. These data are presented in Figure 5.1. This table also shows the percentage of waterbodies in each region that are characterized in each of the major trophic categories. Data from Table 5.1 come from CSLAP, the LCI, the Adirondack Lake Assessment Program (ALAP), the Adirondack Lake Survey Corporation (ALSC), and the Hobart William Smith Finger Lakes studies, although it does not include the New York City drinking water reservoirs. **Except where noted, averages in each of the tables and figures presented in this report, reflect only those data collected during the June 15 through September 15 “index” period**.

Table 5.1- Regional summary of surface TP readings for New York state lakes, 2012-2016

Region	Number of Lakes	Avg TP	% Oligotrophic	% Mesotrophic	% Eutrophic
NYS	**462**	**0.033**	**31%**	**33%**	**36%**
NYC-LI	24	0.132	8%	17%	75%
Lower Hudson	48	0.038	6%	30%	64%
Mid-Hudson	49	0.035	14%	35%	51%
Mohawk	25	0.036	0%	36%	64%
Eastern Adirondack	110	0.010	60%	38%	2%
Western Adirondack	84	0.012	64%	23%	13%
Central NY	52	0.021	17%	54%	29%
Finger Lakes	34	0.075	6%	26%	68%
Western NY	29	0.057	3%	24%	72%

Average TP reported as mg/l
Oligotrophic = < 0.010 mg/l TP; Mesotrophic = 0.010-0.020 mg/l TP; Eutrophic = > 0.020 mg/l TP

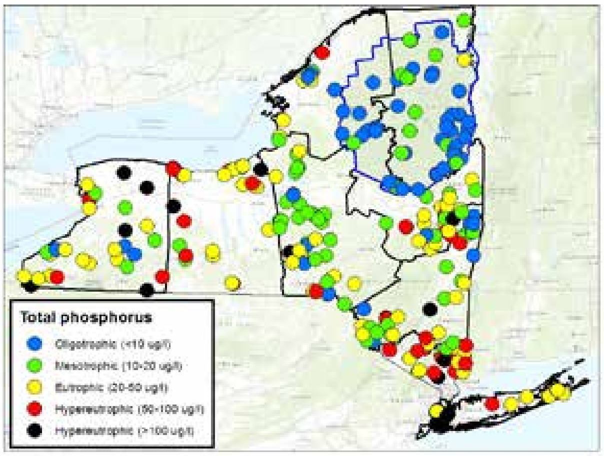


Figure 5.1: TP distribution in CSLAP and LCI lakes, 2012-2016

Figure 5.1 shows the distribution of total phosphorus readings in New York state, as presented in Table 5.1, The data presented in these figures represent average values for lakes sampled in CSLAP and the LCI since 2012.

Table 5.1 shows that phosphorus concentrations are lowest in the Adirondack region, resulting in substantially higher percentages of oligotrophic lakes and lower percentages of eutrophic lakes. Many eutrophic lakes are found in the New York City-Long Island, Lower Hudson, Finger Lakes and Western New York regions. It should be noted that the Finger Lakes region includes several of the very large Finger Lakes, but the Table 5.1 data from this region is dominated by much smaller, eutrophic lakes. The data in Table 5.1 and distribution in Figure 1 also reflect both the distribution of lakes overall in the state- higher concentrations in the Adirondacks, mid-Hudson and downstate region, and lower concentrations in other regions of the state- and the relative distribution of lakes sampled by DEC (through CSLAP and the LCI) in the last five years, with many lakes sampled in Central and Western New York (relative to the number of lakes in the region), and few sampled in the Finger Lakes region, the Catskills, and Long Island region. While there were many lakes sampled in these regions, and in the Adirondacks, over the last few decades, many of these lakes were not sampled by DEC in the last few years.

Mohawk region phosphorus distribution

Figure 5.2 shows the distribution of phosphorus readings for CSLAP and LCI lakes sampled within the Mohawk Region since 2012. Table 5.2 provides the average values and other descriptive information for these lakes. Figures 5.3 and 5.4 show the relationship between phosphorus and two other trophic indicators (chlorophyll *a*, a measure of algae levels, and water clarity, as measured with a Secchi disk) in the Mohawk Region and in New York state.

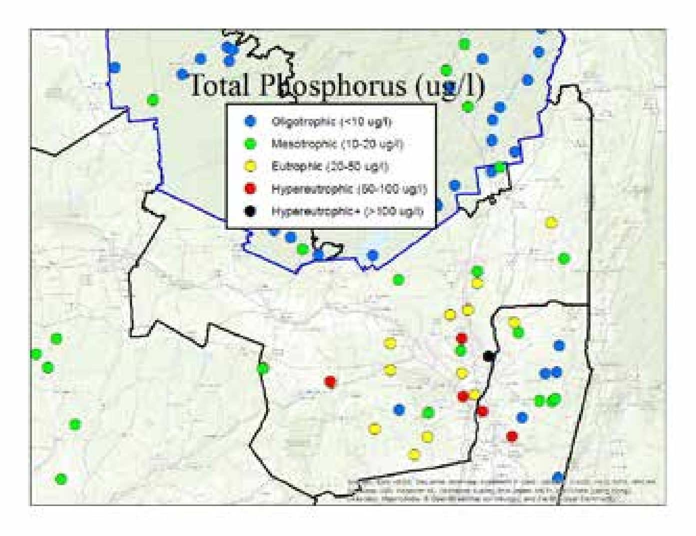


Figure 5.2: TP distribution in Mohawk region CSLAP and LCI lakes, 2012-2016

Table 5.2: Mohawk region TP 2016 data for CSLAP and LCI lakes compared to 2012-16 averages

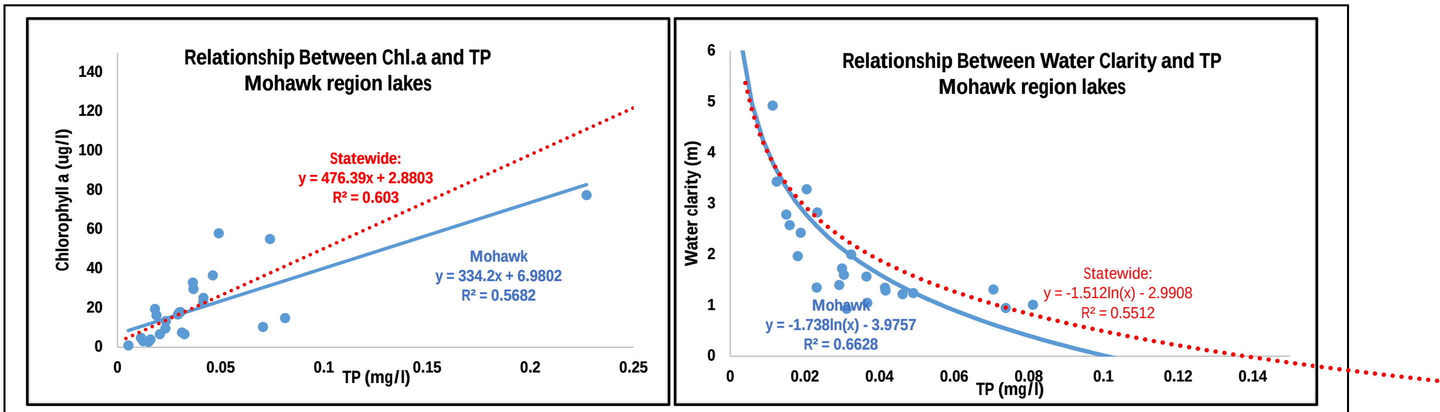
Lake Name	**Program**	**Average 2016**	**Average 2012-16**	**Trophic Condition 2012-16**	**% Above DEC Std 2012-16**	**Trend?***
All NYS Lakes		*0.024*	*0.033*		*37%*	
Mohawk Region- All Lakes		*0.027*	*0.035*		*62%*	
Ann Lee Pond	LCI		0.031	Eutrophic	88%	
Ballston Lake	CSLAP	0.033	0.037	Eutrophic	93%	↑↑
Ballston Lake- wide waters	CSLAP		0.046	Eutrophic	100%	no
Basic Creek Reservoir	LCI		0.037	Eutrophic	100%	
Buckingham Lake	CSLAP		0.081	Eutrophic	100%	
Central Bridge Reservoir-Lower	LCI		0.023	Eutrophic	33%	
Central Bridge Reservoir-Upper	LCI		0.074	Eutrophic	100%	
Cossayuna Lake	CSLAP	0.019	0.023	Eutrophic	57%	↓
Duane Lake	CSLAP	0.042	0.042	Eutrophic	97%	no
Engleville Pond - Lower	LCI		0.030	Eutrophic	60%	
Engleville Pond - Upper	LCI		0.015	Mesotrophic	11%	
Galway Lake	CSLAP	0.009	0.013	Mesotrophic	11%	no

Lake Name	**Program**	**Average 2016**	**Average 2012-16**	**Trophic Condition 2012-16**	**% Above DEC Std 2012-16**	**Trend?***
Lake Lauderdale	LCI		0.011	Mesotrophic	0%	
Lake Lonely	LCI		0.019	Mesotrophic	20%	
Lawson Lake	LCI		0.049	Eutrophic	100%	
Mariaville Lake	CSLAP	0.045	0.042	Eutrophic	95%	no
Murphy Pond	LCI		0.071	Eutrophic	75%	
Round Lake-S	LCI		0.031	Eutrophic	100%	
Saratoga Lake	CSLAP	0.017	0.021	Eutrophic	32%	no
Stony Creek Reservoir	LCI		0.018	Mesotrophic	33%	
Sugarloaf Pond	LCI		0.227	Eutrophic	100%	
Tivoli Lake	LCI		0.032	Eutrophic	100%	
Vly Creek Reservoir	LCI		0.016	Mesotrophic	0%	
Warners Lake	LCI		0.005	Oligotrophic	0%	
Woods Pond	*LCI*		0.029	Eutrophic	100%	

+ DEC Std = 20 ug/l (DEC assessment criteria for protecting aesthetic uses)

* trends indicated only for lakes with at least five years of data and regression correlation >0.33 and P value <0.05

Trend code: ↑↑ = significant increase; ↑ = increase; ↓ = decrease; ↓↓= significant decrease



Figures 5.3 and 5.4: TP-Chl a and TP-Secchi disk relationship in NYS and Mohawk Region CSLAP and LCI lakes, 2012-2016

Figure 5.2 shows that productivity ranges (lower to higher phosphorus levels) are found throughout the region, with the highest of the readings generally in the southern lakes. As in most regions of New York state, the lower productivity lakes are deeper. There are few lakes sampled in the western portion of the region, although this (the Montgomery County and areas along the Mohawk River) area has fewer lakes than in other parts of the region. Figures 5.3 and 5.4 show similar relationships between phosphorus and chlorophyll *a*¸and between phosphorus and Secchi disk transparency readings, in the Mohawk Region and throughout the state. This relationship shows that increasing water clarity and decreasing algae levels requires a decrease in phosphorus levels.

Discussion

Table 5.2 shows that most of the lakes in the region are best characterized as mesotrophic to eutrophic, and many of these consistently demonstrate phosphorus readings above the state guidance value (= 20 ppb) to protect aesthetic quality and recreational conditions. Most of these lakes have not demonstrated any long-term changes in phosphorus readings, although this relative stability in part reflects limited datasets (fewer than 5-10 years of data, a timeframe in which long-term changes may be small relative to in-season variability). Phosphorus readings in Ballston Lake have increased, and TP levels have decreased in Cossayuna Lake, although these lakes do not appear to be indicative of larger regional patterns. Nutrient loading patterns to each of these “changing” lakes should be evaluated to determine if changes in these nutrient levels are associated with manageable watershed changes.

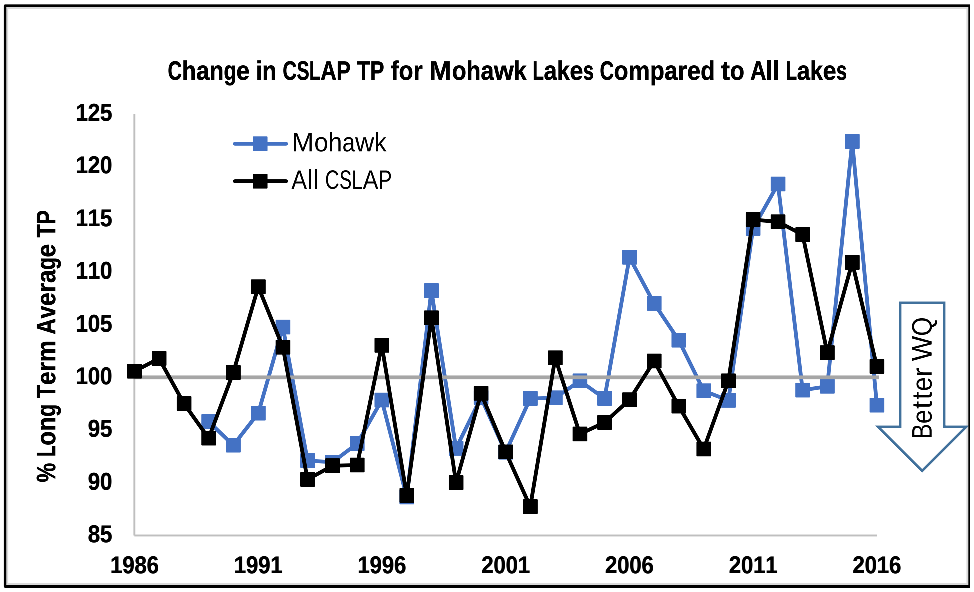


Figure 5.5: Long term change in TP levels in the Mohawk Region relative to all CSLAP lakes, 1986-2016

Most of these lakes exhibited slightly lower phosphorus readings in 2016 than in the previous four years, as seen in Table 5.2. This is also apparent in Figure 5.5, which shows the change in phosphorus concentrations over time in all CSLAP lakes and in the Mohawk (CSLAP) region lakes. The horizontal line corresponds to the long-term average for each lake. Each annual data point in Figure 5 corresponds to the relative TP values for all lakes sampled in that year relative to the long-term average for that lake. Readings above the line correspond to TP levels that are, on average, higher than normal in that year, while readings below the line are indicative of lakes with lower than normal TP readings. These data show lower phosphorus readings in the typical New York state and Mohawk Region lake in 2016 than in 2014 or 2015, but the 2016 readings were probably close to the long-term average for these lakes. These data also suggest that phosphorus readings have generally increased in New York state and Mohawk region lakes since the early 1990s, although perhaps not over the last thirty years. Some of this change may have been associated with drought conditions in much of the state in 2016, but the 2016 readings were not significantly different than those in other recent years with much more normal weather patterns.

Chlorophyll a

What most people refer to as “algae” is actually a highly diverse group of photosynthetic microscopic organisms referred to broadly as “phytoplankton” that include floating, suspended, and benthic forms. The broader term also includes photosynthesizing cyanobacteria that were once referred to as blue-green algae, but generally does not include macroalgae more frequently (and mistakenly) considered to be “weeds”. The amount of phytoplankton, or the biomass, in a lake or pond can appear to be dominated by any of these forms, but suspended phytoplankton usually represents the majority of the biomass, and thus serves as the base for the overall aquatic food chain. Except where noted, in the report the term “algae” will be used to describe all forms of suspended phytoplankton except cyanobacteria; they will be referenced as either cyanobacteria or blue-green algae.

As with phosphorus, trophic status can be assessed by measurements of suspended phytoplankton. This can be achieved in a number of ways, such as cell count, but is most frequently quantified by the measurement of chlorophyll *a*, a photosynthetic pigment found in all freshwater phytoplankton, including cyanobacteria. Chlorophyll *a* readings less than 2 parts per billion (or micrograms per liter) are generally indicative of *oligotrophic lakes*. Readings above 8 parts per billion indicate an increasing susceptibility to blooms, and are typical of *eutrophic* lakes. Readings between these thresholds are generally typical of *mesotrophic* lakes. NY DEC has not formally adopted a target threshold (water quality standard or guidance value) for lakes and ponds, but New York state research has identified a chlorophyll *a* threshold of 10 parts per billion above which reduced water clarity will likely create safety hazards for swimmers, open water and shoreline bloom formation will increase substantially, and aesthetic quality will be significantly degraded. Additional NYSDEC research indicates that lower chlorophyll *a* thresholds are associated with formation of disinfection by-products when this water is chlorinated in drinking water treatment to remove pathogens. Depending on the classification of the waterbody, governed by the expected extent of water treatment, these thresholds correspond to chlorophyll *a* levels of 4 to 6 parts per billion.

More information about chlorophyll *a*, including analytical detection and sampling methods, can be found at (link to fact sheet).

Monitoring for Chlorophyll a

Chlorophyll *a* is included in most lake monitoring programs, including CSLAP and the LCI, and increasingly is sampled as a flowing water indicator. In most lake studies, chlorophyll *a* is analyzed from a field filtered sample and subject to laboratory extraction of this pigment using several reagents. The resulting solution is measured either fluorometrically or spectrophotometrically in a laboratory. The results are reported as "total" chlorophyll *a*. Recent developments in field sampling equipment technology allow for field or laboratory measurements of unextracted chlorophyll pigments using fluorometry; this provides measurements of total and "fractional" chlorophyll *a*, with the latter quantified as chlorophyll fractions associated with cyanobacteria (*Cyanophyta*), green algae (*Chlorophyta*), diatoms (*Bacillariophyta*), golden brown algae (*Chryptophyta*), and other algae based on fluorescence peaks. These data, provided in support of the DEC harmful algae bloom (HAB) program coordinated in part through CSLAP and the LCI, are less accurate than extracted chlorophyll measurements, but provide useful screening information. These results are discussed later in this report.

Phytoplankton (algae) grow patchy throughout the lake, due to wind movement, buoyancy, and other factors. It is most accurately measured through depth integrated sampling. However, surface skim samples and grab samples can provide useful measures of algae content and may be more effective indicators of algae maxima or overall water quality conditions.

Unless otherwise noted, chlorophyll *a* levels reported here are collected from a surface grab (1.5 meters below the surface) in CSLAP, or 0-2 meter depth integrated sample in the LCI. Samples are usually collected at the deepest portion of the lake, assumed to be the most representative measure of (total) suspended phytoplankton throughout most of the surface waters in the lake. Deep samples are generally not analyzed for chlorophyll *a*, since algae growth below the thermocline (the depth range for these deeper samples) is usually minimal.

Statewide Distribution

Table 5.3 summarizes the average chlorophyll *a* results from Mohawk Region lakes sampled in 2016 and between 2012 and 2016, although this is also presented with data from other New York state lakes over the same period. These data are presented in Figure 5.6. This table also shows the percentage of waterbodies in each region that can be characterized in each of the major trophic categories. The source of data from Table 5.3 is described in the Phosphorus section above, on page 5.2.

Table 5.3- Regional summary of Chl.a readings for New York state lakes, 2012-2016

Region	Number of Lakes	Avg Chl.a	% Oligotrophic	% Mesotrophic	% Eutrophic
NYS	**462**	**16.6**	**14%**	**50%**	**36%**
NYC-LI	24	52.6	0%	42%	58%
Lower Hudson	48	24.0	2%	28%	70%
Mid Hudson	49	21.8	4%	49%	47%
Mohawk	25	17.0	4%	30%	65%
Eastern Adirondack	110	3.9	23%	72%	6%
Western Adirondack	84	6.5	27%	60%	13%
Central NY	52	10.2	10%	58%	33%
Finger Lakes	34	35.0	6%	18%	76%
Western NY	29	31.9	17%	14%	69%

Average Chlorophyll a reported as ug/l
Oligotrophic = < 2 ug/l Chl.a; Mesotrophic = 2-8 ug/l Chl.a; Eutrophic = > 8 ug/l Chl.a

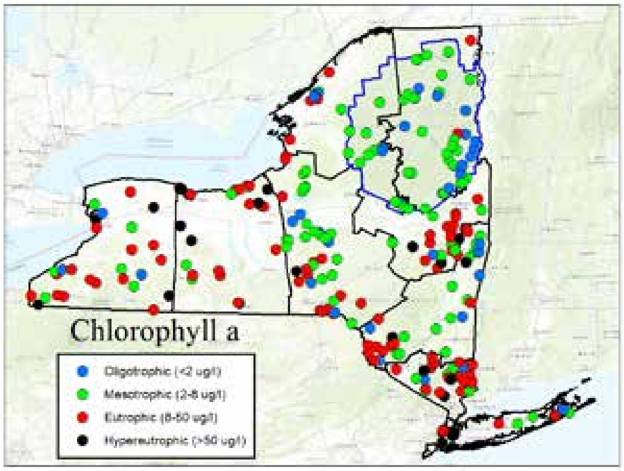


Figure 5.6: Chlorophyll *a* distribution in CSLAP and LCI Lakes, 2012-2016

Figure 5.6 shows the distribution of average chlorophyll *a* readings in New York state, as presented in Table 5.3, and Figure 5.7 shows the distribution within the Mohawk Region. Figures 5.8 and 5.9 show the relationship between chlorophyll *a* and two other trophic indicators (total phosphorus and water clarity, as measured with a Secchi disk) in the Mohawk Region and in New York state. The data presented in these figures represent average values for lakes sampled in CSLAP and the LCI since 2012.

Table 5.3 shows that chlorophyll *a* levels, like phosphorus concentrations presented earlier, are lowest in the Adirondack region, resulting in substantially higher percentages of oligotrophic lakes and lower percentages of eutrophic lakes. Algae levels are highest in the "outer" edges of the state- the New York City/Long Island region and in Western New York. The Finger Lakes region also appears to have high algae levels, but most of the 11 Finger Lakes (sampled through other programs) likely have substantially lower chlorophyll *a* readings than presented in Table 5.3.

Figure 5.6 shows low to moderate algae levels in the northern and central regions of the state, although (as will be seen in the HAB discussion) there are still many lakes in these regions with periodic to persistent HABs. It is presumed that algae levels are relatively low in the (unsampled) Catskill region, but the many unsampled small lakes and ponds in other regions may have higher algae levels.

Mohawk region distribution

Figure 5.7 shows the distribution of chlorophyll *a* readings in the Mohawk Region, with the average chlorophyll *a* levels and other descriptive information provided for individual Mohawk Region lakes in Table 5.4. Figures 5.8 and 5.9 show the relationship between chlorophyll *a* and two other trophic indicators (total phosphorus readings, and water clarity, as measured with a Secchi disk) in the Mohawk Region and in New York state.

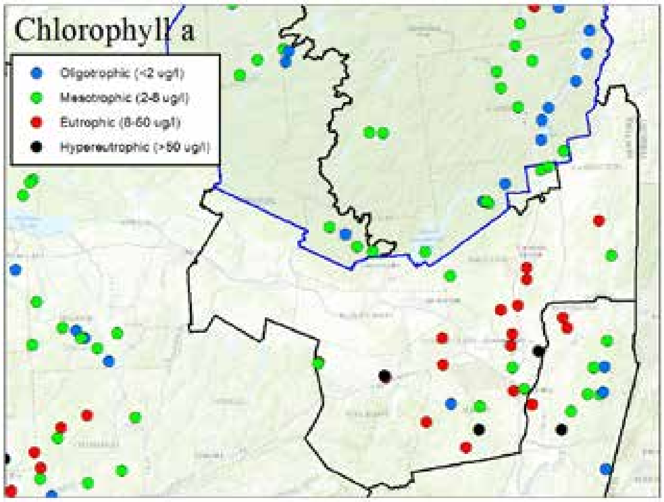


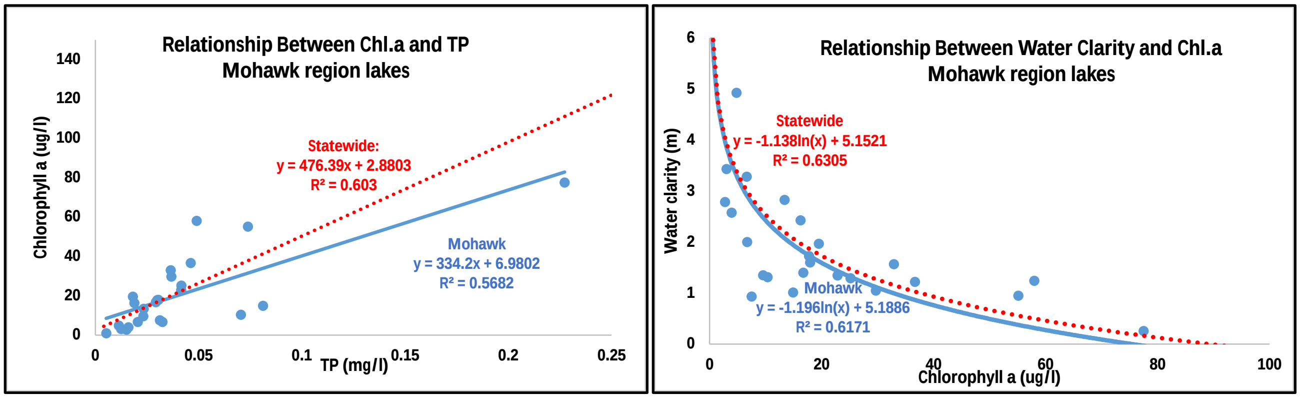
Figure 5.7: Chlorophyll *a* distribution in Mohawk region lakes, 2012-2016

The discrepancy in the number of lakes referenced in Table 5.3 and 5.4 is due to the large number of lakes sampled in other monitoring program (outside of CSLAP or the LCI). Some of the samples from these programs were not analyzed by ELAP certified laboratories, but since chlorophyll *a* is not (presently) an ELAP-certifiable water quality indicator, these results may be comparable across these monitoring programs. However, since the quality of these results cannot be verified through a DEC-approved QAPP, they are not highlighted in Table 5.4

Table 5.4: Mohawk region Chl.a 2016 data for CSLAP and LCI lakes compared to 2012-16 averages

Lake Name	Program	Average 2016	Average 2012-16	Trophic Condition 2012-16?	% Above DEC Std 2012-16	Trend?*
All NYS Lakes		*8.4*	*16.6*		*32%*	
Mohawk Region- All Lakes		*12.9*	*17.0*		*61%*	
Ann Lee Pond	LCI		7.5	Mesotrophic	13%	
Ballston Lake	CSLAP	15.9	32.9	Eutrophic	97%	no
Ballston Lake-s	CSLAP		36.7	Eutrophic	100%	no
Basic Creek Reservoir	LCI		29.7	Eutrophic	86%	
Buckingham Lake	CSLAP		14.9	Eutrophic	65%	
Central Bridge Reservoir-Lower	LCI		9.6	Eutrophic	67%	
Central Bridge Reservoir-Upper	LCI		55.1	Eutrophic	100%	
Cossayuna Lake	CSLAP	10.7	13.4	Eutrophic	64%	↓↓
Duane Lake	CSLAP	26.4	25.2	Eutrophic	100%	no
Engleville Pond - Lower	LCI		17.8	Eutrophic	60%	
Engleville Pond - Upper	LCI		2.8	Mesotrophic	0%	
Galway Lake	CSLAP	1.9	3.0	Mesotrophic	0%	↓
Lake Lauderdale	LCI		4.8	Mesotrophic	25%	
Lake Lonely	LCI		16.3	Eutrophic	50%	
Lawson Lake	LCI		58.0	Eutrophic	100%	
Mariaville Lake	CSLAP	18.9	22.8	Eutrophic	79%	no
Murphy Pond	LCI		10.4	Eutrophic	60%	
Round Lake-S	LCI		17.9	Eutrophic	75%	
Saratoga Lake	CSLAP	3.6	6.6	Mesotrophic	29%	↓
Stony Creek Reservoir	LCI		19.5	Eutrophic	67%	
Sugarloaf Pond	LCI		77.5	Eutrophic	100%	
Tivoli Lake	LCI		6.7	Mesotrophic	0%	
Vly Creek Reservoir	LCI		3.9	Mesotrophic	0%	
Warners Lake	LCI		0.9	Oligotrophic	0%	
Woods Pond	LCI		16.7	Eutrophic	50%	

* trends indicated only for lakes with at least five years of data and regression correlation >0.33 and P value <0.05
Trend code: ↑↑ = significant increase; ↑ = increase; ↓ = decrease; ↓↓= significant decrease
+ DEC Std = 10 ug/l (DEC assessment criteria for protecting recreational uses)



Figures 5.8 and 5.9: Chl a-TP and Secchi disk-Chl.a relationship in NYS and Mohawk Region lakes, 2012-2016

Figure 5.10 shows the change in chlorophyll *a* levels over time in all CSLAP lakes and in the Lower Hudson (CSLAP) region lakes. The horizontal line corresponds to the long-term average for each lake. Each annual data point in Figure 5.10 corresponds to the relative chlorophyll *a* values for all lakes sampled in that year relative to the long-term average for that lake. Readings above the line correspond to chlorophyll *a* levels that are, on average, higher than normal in that year, while readings below the line are indicative of lakes with lower than normal chlorophyll *a* readings. The horizontal line corresponds to the long-term average for each lake.

Discussion

Table 5.4 shows that most of the lakes in this region are best characterized as mesotrophic to eutrophic, and many of these consistently demonstrate chlorophyll *a* readings above the present DEC chlorophyll *a* assessment criteria established to minimize the formation of algae blooms and unsafe swimming conditions. A wide range of productivity is scattered in the lakes throughout the region (Figure 5.7), with no clear geographic pattern apparent. The lakes with the highest chlorophyll *a* levels correspond to the lakes with the highest phosphorus readings.

Most of these lakes have not demonstrated any long-term changes in chlorophyll *a* readings, although, as with phosphorus, this relative stability in part reflects temporally limited datasets. Only three lakes with sufficient long-term data to evaluate trends have exhibited statistically significant changes, and these do not point to any clear regional patterns. It may, however, be indicative of the large variability in algae densities within each sampling season and from year to year (as well as periodic active management of algae in some of these lakes). The decrease in algae levels in Cossayuna Lake is consistent with the drop in phosphorus readings, but the decrease in algae levels in Galway Lake and Saratoga Lake was not associated with a decrease in phosphorus levels in either lake. The rise in phosphorus levels in Ballston Lake did not result in a statistically significant increase in algae levels. This suggests that these changes may be the result of natural variability, although water quality changes in each of these lakes should continue to be evaluated.

Most of these lakes exhibited slightly lower chlorophyll *a* readings in 2016 than in the previous four years, as seen in Table 5.4. This is also apparent in Figure 5.10, which shows a drop in chlorophyll *a* levels over time in all CSLAP lakes and in the Lower Hudson (CSLAP) region lakes, particularly since the early 1990s. These data show lower chlorophyll *a* readings in the typical New York state and Mohawk Region lake in 2016 than in 2014 or 2015, and 2016 readings were lower than the long-term average for these lakes. As noted earlier, these datasets also suggest that phosphorus readings have generally increased in New York state and Mohawk region lakes since the early 1990s, even though chlorophyll *a* levels may have decreased over this period. It is not known if this discrepancy indicates that both indicators (which are usually closely aligned) are experiencing normal variability, or if this reflects a shift from green algae and diatoms toward cyanobacteria, which may result in heavy patchy growth or denser concentrations along the shoreline than in the open water (where these samples are collected).

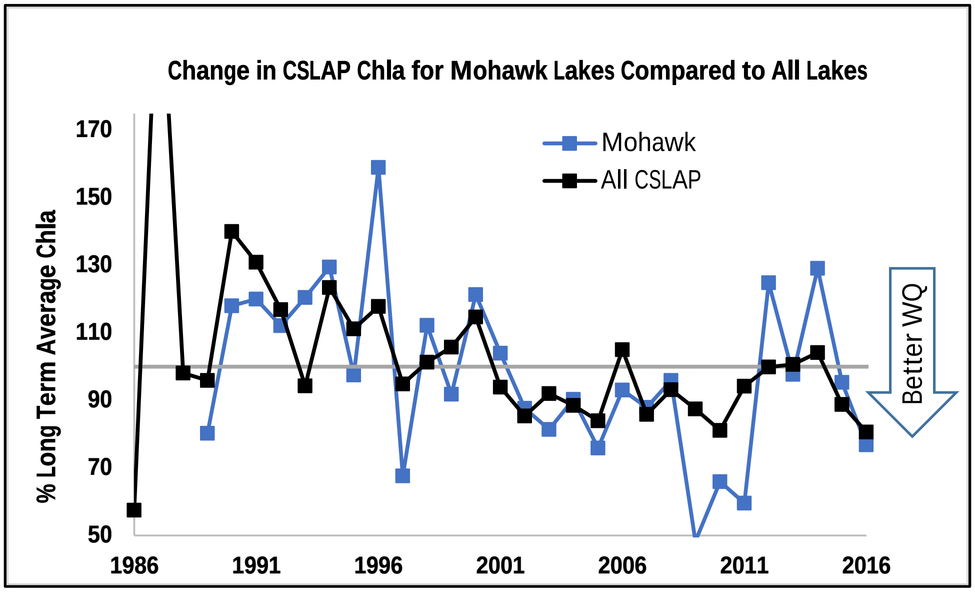


Figure 5.10: Long term change in Chl.a levels in the Mohawk region relative to all CSLAP lakes

Water clarity

The transparency of the water- “how clear is it?”- is one of the fundamental measures of water quality, due to its relative simplicity and relevance for both citizen science and professional monitoring programs, the relationship between water clarity and other limnological indicators, and the connection between water transparency and public use. Water transparency, also referred to as water clarity, is closely connected to the amount of suspended and dissolved material in the water. The former is comprised of both phytoplankton and suspended particles, and the latter relates to brownish color imparted by dissolved organic matter. In most deep lakes, water clarity is very closely related to phytoplankton, while in shallower lakes, water clarity is influenced by algae, suspended sediment, and natural brownness. If one or more of these factors are measured, the influence of the other factors can be deduced.

As with phosphorus and chlorophyll *a*, trophic status can be assessed by measurements of water clarity. Water clarity readings greater than about 5 meters (just over 16 feet) are generally indicative of *oligotrophic lakes*. Readings below 2 meters (just over 6 ½ feet) indicate an increasing susceptibility to blooms, and are typical of *eutrophic* lakes. Readings between these thresholds are generally typical of *mesotrophic* lakes. NYSDEC has not formally adopted a target water clarity threshold (water quality standard or guidance value) for lakes and ponds, although the state Department of Health will not site a new swimming beach unless water clarity exceeds 4 feet (or about 1.2 meters). This threshold is derived from the need for sufficient water transparency for lifeguards to see submerged swimmers, and for those swimmers to see submerged debris. The state Office of Parks, Recreation and Historic Preservation uses this guideline as an operational condition for keeping a beach open. NYSDEC research and trophic categories relate these water clarity thresholds to corresponding levels of nutrients (phosphorus) and algae (chlorophyll *a*).

More information about water clarity, including analytical detection and sampling methods, can be found at (link to fact sheet).

Monitoring for Water Clarity

Water transparency (clarity) measurements are included in nearly all lake monitoring programs, including CSLAP and the LCI. Water clarity is measured with the use of a Secchi disk, a 20 centimeter quartered black and white disk attached to a measured line. The disk is lowered from the shady size of the boat until it disappears from sight. This depth is recorded to the nearest 0.1 meter. The disk is then lowered further, and then slowly brought back to the lake surface. The depth at which the disk first reappears in sight is also recorded. The Secchi disk transparency is considered the average of these two readings. When the disk is still visible from the surface while resting on the lake bottom, the actual water transparency cannot be determined (although this truncated depth is recorded with a qualifier).

Water clarity can also be estimated with the use of turbidity tubes, some of which have small Secchi disk markings on the bottom of the tube. This can provide estimates of water clarity when the disk cannot be lowered vertically, such as in a rapidly flowing river. However, most tubes are of insufficient depth to accurately record water clarity in shallow lakes where lowered disks are visible on the lake bottom

Unless otherwise noted, Secchi disk transparency readings are recorded to the nearest 0.1 meter.

Statewide Distribution

Table 5.5 summarizes the average Secchi disk transparency results from Mohawk Region lakes sampled in 2016 and between 2012 and 2016, although this is also presented with data from other New York state lakes over the same period. These data are presented in Figure 5.11. This table also shows the percentage of waterbodies in each region that can be characterized in each of the major trophic categories. The source of data from Table 5.5 is the same as used in Table 5.1 and 5.3, as described in the Phosphorus section above, on page 5.2.

Table 5.5- Regional summary of water clarity readings for New York state lakes, 2012-2016

Region	Number of Lakes	Avg Water Clarity	% Oligotrophic	% Mesotrophic	% Eutrophic
NYS	**462**	**2.9**	**13%**	**50%**	**37%**
NYC-LI	24	1.3	0%	20%	80%
Lower Hudson	48	2.3	7%	45%	48%
Mid Hudson	49	2.4	7%	41%	52%
Mohawk	25	2.0	0%	39%	61%
Eastern Adirondack	110	4.0	22%	70%	8%
Western Adirondack	84	3.5	24%	51%	25%
Central NY	52	3.3	12%	56%	32%
Finger Lakes	34	1.9	3%	39%	58%
Western NY	29	1.7	0%	36%	64%

Average water clarity measured as Secchi disk transparency and reported as meters
Oligotrophic = >5 meters; Mesotrophic = 2-5 meters; Eutrophic = <2 meters

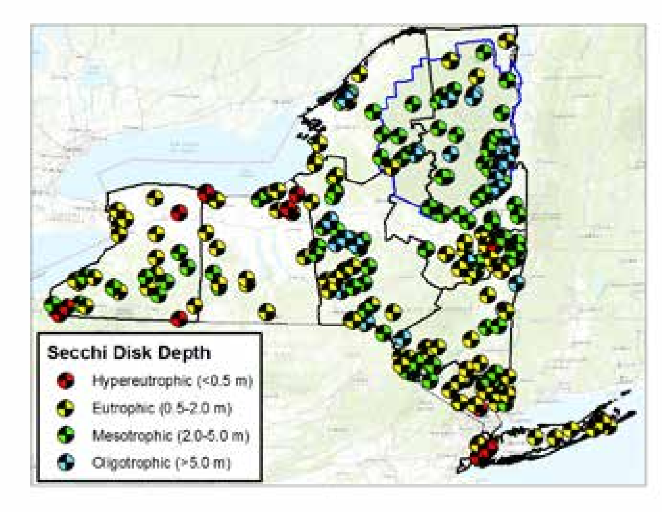


Figure 5.11: Water clarity distribution in CSLAP and LCI lakes, 2012-2016

Figure 5.11 shows the distribution of average water clarity readings in New York state, as presented in Table 5.5, and Figure 5.12 shows the distribution within the Mohawk Region. Figures 5.13 and 5.14 show the relationship between water clarity and two other trophic indicators (total phosphorus and chlorophyll *a*, as described earlier in this chapter) in the Mohawk Region and in New York state. The data presented in these figures represent average values for lakes sampled in CSLAP and the LCI since 2012.

Table 5.5 shows that water clarity readings are highest in the Adirondack region, consistent with lower nutrient and algae levels in the region. As with these other trophic indicators, this results in substantially higher percentages of oligotrophic lakes and lower percentages of eutrophic lakes in the Adirondacks. Water clarity is also lowest in the same regions where nutrient and algae levels are highest- the New York City/Long Island region and in Western New York. The Finger Lakes region also appears to have low water clarity, but most of the 11 Finger Lakes (sampled through other programs) likely have substantially higher Secchi disk transparency than is presented in Table 5.5. It is also presumed that water clarity is relatively high in the (unsampled) Catskill region and other deep NYS lakes, but the many unsampled small lakes and ponds in other regions may have lower water clarity. It is in these smaller, shallower lakes in which there may be some discrepancy between the nutrient and algae "findings" and water clarity readings. In these lakes, water transparency might be limited by lake depth, so these readings may not accurately represent water quality conditions in these lakes.

Mohawk Region Water Clarity Distribution

Figure 5.12 shows the distribution of water clarity readings in the Mohawk Region, with the average Secchi disk transparency readings and other descriptive information provided for individual Mohawk Region lakes in Table 5.6. Figures 5.13 and 5.14 show the relationship between Secchi disk transparency and two other trophic indicators (total phosphorus and chlorophyll *a* readings) in the Mohawk Region and in New York state.

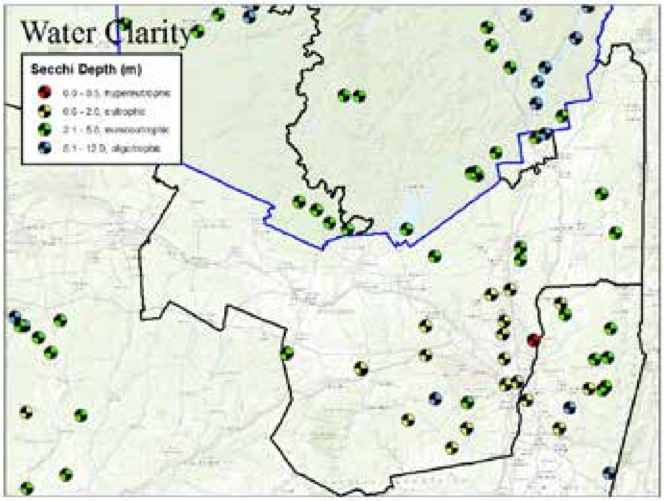


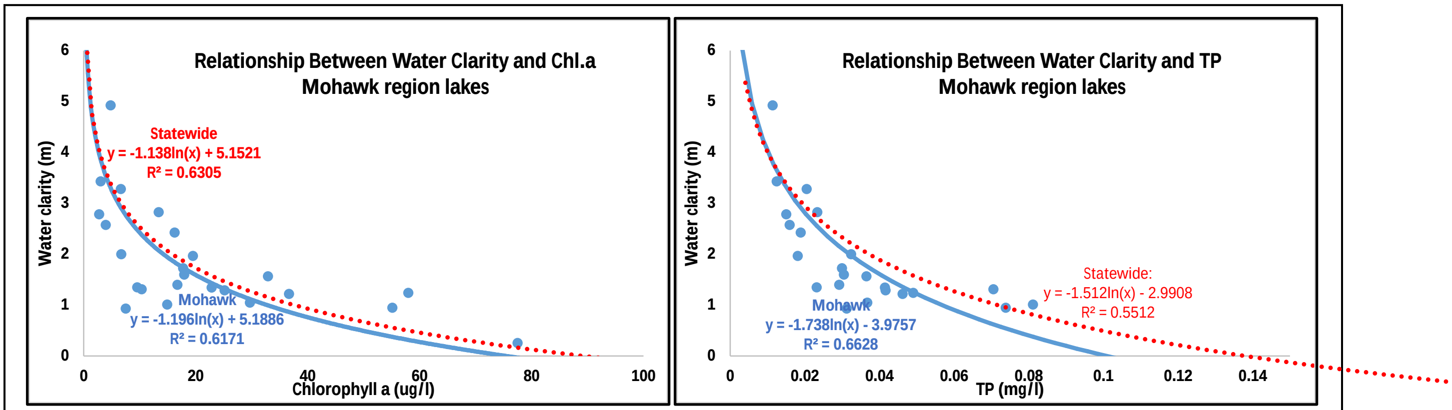
Figure 5.12: Water clarity distribution in Mohawk region lakes

As with chlorophyll *a*, many of the lakes are included in Table 5.5 but not in Table 5.6 due to the additional lakes with water clarity readings collected in other professional, academic, and citizen science programs. The individual lake data from these non-DEC programs could be highlighted in Table 5.6, since Secchi disk transparency readings do not require specialized equipment and has been standardized in all monitoring programs. However, to maintain consistency with the approach outlined in Tables 5.2 and 5.4, in which individual lake data summaries are limited to those from programs with approved QAPPs and ELAP certified labs, this ancillary Secchi disk transparency data is not presented in Table 5.6.

Table 5.6: Mohawk region water clarity 2016 data for CSLAP and LCI lakes compared to 2012-16 averages

Lake Name	**Program**	**Average 2016**	**Average 2012-16**	**Trophic Condition 2012-16?**	**% Below DEC Std 2012-16**	**Trend?***
All NYS Lakes		*3.3*	*2.9*		*20%*	
Mohawk Region- All Lakes		*2.5*	*2.1*		*20%*	
Ann Lee Pond	LCI		0.9	Eutrophic	100%	
Ballston Lake	CSLAP	2.0	1.6	Eutrophic	28%	↓
Ballston Lake-s	CSLAP		1.2	Eutrophic	55%	no
Basic Creek Reservoir	LCI		1.1	Eutrophic	83%	
Buckingham Lake	CSLAP		1.0	Eutrophic	56%	
Central Bridge Reservoir-Lower	LCI		1.4	Eutrophic	50%	
Central Bridge Reservoir-Upper	LCI		1.0	Eutrophic	75%	
Cossayuna Lake	CSLAP	3.3	2.8	Mesotrophic	7%	↑↑
Duane Lake	CSLAP	1.0	1.3	Eutrophic	39%	↓
Engleville Pond - Lower	LCI		1.7	Eutrophic	40%	
Engleville Pond - Upper	LCI		2.8	Mesotrophic	0%	
Galway Lake	CSLAP	3.8	3.4	Mesotrophic	0%	no
Lake Lauderdale	LCI		4.9	Mesotrophic	0%	
Lake Lonely	LCI		2.4	Mesotrophic	0%	
Lawson Lake	LCI		1.2	Eutrophic	50%	
Mariaville Lake	CSLAP	1.2	1.3	Eutrophic	37%	no
Murphy Pond	LCI		1.3	Eutrophic	40%	
Round Lake-S	LCI		1.6	Eutrophic	25%	
Saratoga Lake	CSLAP	3.3	3.3	Mesotrophic	0%	no
Stony Creek Reservoir	LCI		2.0	Eutrophic	0%	
Sugarloaf Pond	LCI		0.3	Eutrophic	100%	
Tivoli Lake	LCI		2.0	Mesotrophic	0%	
Vly Creek Reservoir	LCI		2.6	Mesotrophic	0%	
Warners Lake	LCI		8.1	Oligotrophic	0%	
Woods Pond	LCI		1.4	Eutrophic	20%	

* trends indicated only for lakes with at least five years of data and regression correlation >0.33 and P value <0.05
Trend code: ↑↑ = significant increase; ↑ = increase; ↓ = decrease; ↓↓= significant decrease
+ DEC Std = 10 ug/l (DEC assessment criteria for protecting recreational uses)



Figures 5.13 and 5.14: Chl a-Secchi disk and TP-Secchi disk relationship in NYS and Mohawk Region lakes, 2012-2016

Figure 5.15 shows the change in water clarity readings over time in all CSLAP lakes and in the Lower Hudson (CSLAP) region lakes. The horizontal line corresponds to the long-term average for each lake. Each annual data point in Figure 5 corresponds to the relative Secchi disk transparency readings for all lakes sampled in that year relative to the long-term average for that lake. Readings above the line correspond to Secchi disk transparency readings that are, on average, higher than normal in that year, while readings below the line are indicative of lakes with lower than normal water clarity readings.

Discussion

Table 5.6 shows that, using water clarity readings as a trophic measure, Mohawk Region lakes are typically identified as eutrophic or mesotrophic. This is confirmed in Figure 5.12, which shows a scattering of high and lower productivity lakes (corresponding to low and higher water clarity, respectively) throughout the region. This roughly corresponds to the distribution of chlorophyll *a* readings within the region.

Few of these lakes have water clarity regularly below the 4 foot threshold associated with unsafe swimming conditions, although some of these lakes do actively support swimming. For most of these lakes, reduced water clarity is associated with excessive nutrient and algae levels. Some of these lakes have exhibited long-term changes in water clarity- the rise in water clarity in Cossayuna Lake has been consistent with a drop in nutrient and algae levels, and the lower water clarity in Ballston Lake has corresponded to an increase in phosphorus readings). The lower water clarity in Duane Lake did not result from an increase in algae levels, although changes in both of these indicators may be related to other factors. It is not yet known how many of these lakes with water clarity trends have been subject to changes in lake management actions- increasing or decreasing use of algacides, for example.

Water clarity readings in 2016 were, on average, higher than those readings in the last five years in the Mohawk Region and in New York state, as seen in Table 5.6, although both regional and statewide differences may be due in part to different waterbodies sampled in each year. In addition, when sampled lakes are compared to themselves, water clarity readings appear to have increased over the last four years in the typical lake in both the Mohawk Region and New York state. This is apparent in Figure 5.15, which shows the change in water clarity readings over time in all CSLAP lakes and in the Lower Hudson (CSLAP) region lakes. The horizontal line corresponds to the long-term average for each lake. Each annual data point in Figure 5.15 corresponds to the relative Secchi disk transparency values for all lakes sampled in that year relative to the long-term average for that lake. Readings above the line correspond to water clarity levels that are, on average, higher than normal in that year, while readings below the line are indicative of lakes with lower than normal clarity readings. The 2016 readings, while higher than in the last few years, were probably close to the long-term average for these lakes. In the Mohawk Region and in New York state, water clarity appear to have been variable over time.

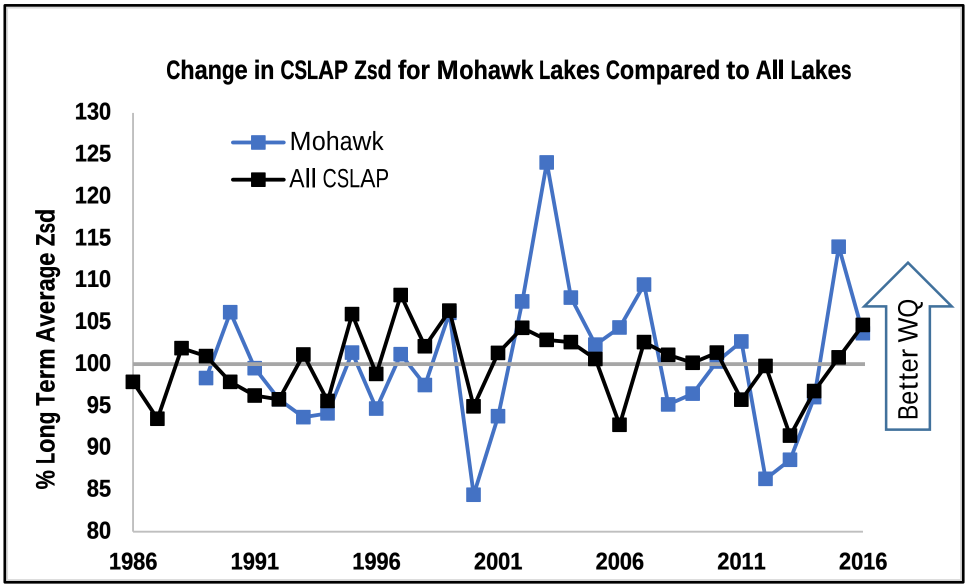


Figure 5.15: Long term change in water clarity levels in the Mohawk Region relative to all CSLAP lakes

Trophic State indices:

The relationship among these indicators has been explored by limnologists—lake scientists—for many years. Dr. Robert Carlson from Kent State University developed an index that places each of these trophic indicators on the same (logarithmic) scale. This allows each of these indicators to be used to define the trophic state of any lake, and to compare these indicators in a way that might provide some additional insights about the algal dynamics in lakes.

The trophic state of lakes can be defined both functionally—by measuring the actual biological production (biomass) in the system—and operationally—by measuring a few key indicators related to lake biomass. The former approach can be logistically difficult and costly. The latter approach can exploit a simple measure of algae biomass—chlorophyll a—and the relationship between algae and both the nutrients that drive algae growth—primarily phosphorus—and the lake changes observed by high algae production—changes in water transparency

Operational approaches were used by Carlson to establish empirical relationships among these indicators. The equations used by Carlson to define the Trophic State Index (TSI) for a set of midwestern US lakes in the mid-1970s are as follows (ln = natural logarithm in all equations):

TSI (water clarity) = 60 – 14.41 x ln(Zsd), where Zsd = Secchi disk transparency in meters
TSI (phosphorus) = 14.42 x ln(TP) + 4.15, where TP = total phosphorus in µg/l
TSI (chlorophyll a) = 9.81 x ln(Chl.a) + 30.6, where Chl.a = chlorophyll a in µg/l

Carlson developed these trophic state indices so that TSI values in a range between 40 and 50 would correspond to mesotrophic conditions for each of these trophic indicators, with higher TSI values corresponding to eutrophic conditions, and lower TSI values attributed to oligotrophic conditions.

However, New York, along with EPA and some other states, has defined these trophic boundaries differently. The small difference between these stems from the desire in New York state to use simple intervals, the recognition that trophic categories represent a continuum rather than clear delineations, and the fact that the New York state boundary between mesotrophic and eutrophic lakes are closely matched.

Discrepancies in TSI values- water clarity, chlorophyll *a*, or phosphorus readings out of sync with the other indicators- may be due to a variety of factors related to lake depth, flow, or other limnological factors. It may also be due to active management or even errors in sample collection of analysis. It is anticipated that the latter errors will be minimized in larger datasets, but single year deviations may prompt further evaluation.

A comparison of the New York and Carlson approaches are shown in Table 5.7, showing the TSI's corresponding to the eutrophic-mesotrophic boundaries, and the mesotrophic-oligotrophic boundaries, are similar.

Table 5.7: TSI ranges for New York state trophic categories

Indicator	Eutrophic		Mesotrophic		Oligotrophic	
	Carlson	NYS	Carlson	NYS	Carlson	NYS
Phosphorus	<40	<37	40-50	37-47	>50	>47
Chlorophyll a	<40	<37	40-50	37-51	>50	>51
Secchi disk transparency	<40	<37	40-50	37-50	>50	>50

Although the transitional TSI values for the New York state trophic categories may not be easy to remember—this was one of the reasons that 40 and 50 were chosen by Carlson for transitional values—the corresponding values for each of these water quality indicators are easily remembered integers (10 and 20 µg/l for phosphorus, 2 and 5 meters for water clarity, and 2 and 8 µg/l for chlorophyll a). More importantly, the transitional water quality values between mesotrophy and eutrophy are closely aligned in New York state lakes, and at least at present correspond to the state phosphorus guidance value. This is demonstrated in Table 5.8, which shows the percentage of CSLAP and LCI lakes sampled from 2012 to 2016 exhibiting eutrophic conditions (with TSI values less than 37).

Table 5.8- Regional summary of eutrophic Lakes (TSI < 37) for New York state, 2012-2016

Region	Number of Lakes	% Eutrophic TP	% Eutrophic Chl.a	% Eutrophic Secchi
NYS	**462**	**36%**	**36%**	**37%**
NYC-LI	24	75%	58%	80%
Lower Hudson	48	64%	70%	48%
Mid Hudson	49	51%	47%	52%
Mohawk	25	64%	65%	61%
Eastern Adirondack	110	2%	6%	8%
Western Adirondack	84	13%	13%	25%
Central NY	52	29%	33%	32%
Finger Lakes	34	68%	76%	58%
Western NY	29	72%	69%	64%

Eutrophic defined as TP > 0.020 mg/l, Chl.a > 8 µg/l, and Secchi disk transparency < 2 meters

The relationship among these indicators is very close in the Mohawk, Central, Mid-Hudson and Western NY regions, and is nearly identical overall in New York state, but less closely aligned in other regions. The discrepancy in some regions is due to dominance of shallow lakes (which can affect measured water clarity and dominant forms of phytoplankton), dystrophic lakes, and the patchiness and high variability in chlorophyll *a* readings in some lakes.

Table 5.9 shows the TSI calculations for each of the trophic indicators in each region, as determined by the average of the TSI values. This table also shows the percentage of lakes in each region for which each of the TSI calculations are within 10 points ("consistent TSI"), and the trophic indicator(s) in each lake that deviates from the other TSI indicators, referred to here as the "outliers". Overall TSI values are lowest for the Adirondack and Central regions, corresponding to lower lake productivity, while the highest TSIs are associated with the Downstate regions. The average TSI values for each of the trophic indicators are similar in each region—meaning that TSI calculations for water clarity (Zsd), total phosphorus (TP) and chlorophyll a (Chl.a) are similar—and the percentage of lakes in which the TSI values for each indicator are within 10 points ranges from 44% (Western Adirondacks region) to 81% (Central region). The most frequent outlier- the trophic indicator that is least consistent with the other trophic indicators- is total phosphorus. This may be due to the influence of other factors, nitrogen, lake residence time, temperature, competition from filamentous algae and macrophytes- on suspended algae and water clarity. Water clarity is a trophic outlier in the New York City-Long Island region, perhaps due to the influence of water depth (and the large number of very shallow lakes in this region) on measured water clarity. Chlorophyll a is a less representative trophic indicator in several regions, although never frequently than 10% of the time. This may be due to patchy algae growth or the natural variability in this water quality indicator.

Table 5.9: TSI assessments in New York state lakes, 2012-16

Region	# Lakes	TSI-TP	TSI-Chl	TSI-Zsd	% Similar TSI	%TP Outlier	%Chl Outlier	%Zsd Outlier	% Multiple Outliers
NYS	**452**	**45**	**49**	**48**	**66%**	**12%**	**5%**	**4%**	**14%**
NYC-LI	25	60	60	61	48%	24%	4%	12%	12%
Lower Hudson	44	54	57	51	77%	7%	2%	5%	9%
Mid-Hudson	44	50	53	50	70%	2%	9%	0%	18%
Mohawk	23	52	55	52	65%	4%	9%	0%	22%
Eastern Adks	105	36	42	41	70%	14%	0%	2%	13%
Western Adks	84	37	43	44	44%	23%	8%	7%	18%
Central	54	44	47	46	81%	7%	6%	2%	4%
Finger Lakes	38	57	58	55	68%	5%	8%	3%	16%
Western NY	34	55	53	55	71%	3%	9%	3%	15%

TSI-TP, -Chl, and -Zsd = Average TSI based on total phosphorus, chlorophyll *a*, and Secchi disk transparency
% Similar TSI = percentage of lakes with TSI-TP, TSI-Chl, and TSI-Zsd all within 10 points
% TP, Chl and Zsd outliers = percentage of lakes with TSI-TP,TSI-Chl, or TSI-Zsd > 10 points different than other TSIs
% Multiple Outliers = percentage of lakes with more than one TSI component (TP, Chl or Zsd) > 10 points different than each TSI

Other measures of eutrophication: Dissolved oxygen, and hypolimnetic pollutants

Eutrophication can trigger several ecological changes in lakes. One such change is an increasing variability in dissolved oxygen levels. In thermally stratified lakes- those lakes that are generally more than 6 meters (20 feet) deep- well defined layers are formed, with a layer of warmer water (in summer) overlaying a colder layer, with a thin transitional zone separating the layers (Figure 5.16). These layers are referred to as the *epilimnion, hypolimnion,* and *metalimnion*, respectively, with the depth of greatest thermal change within the *metalimnion* referred to as the *thermocline.* In the absence of biological activity, dissolved oxygen levels in the hypolimnion are higher than in the epilimnion, due to the greater solubility of oxygen in colder water. In some lakes, hypolimnetic oxygen levels may decrease naturally due to incomplete mixing of the water column during fall turnover. However, for many lakes, this natural process is exacerbated by bacterial breakdown of organic matter that rains into the hypolimnion during the summer. This organic matter can be comprised of phytoplankton (algae) and macrophytes (weeds) that can result from excessive eutrophication. This oxygen depletion often starts once thermal stratification sets up in the spring to early summer, and increases until this stratification breaks down in the fall (*turnover*), and can result in poorly oxygenated (*hypoxic*) and deoxygenated (*anoxic*) water at various depths in the hypolimnion. In extreme cases, hypoxia and anoxia can extend to the metalimnion and even the epilimnion, particularly in poorly stratified lakes or immediately after turnover when the hypolimnion is fully deoxygenated.

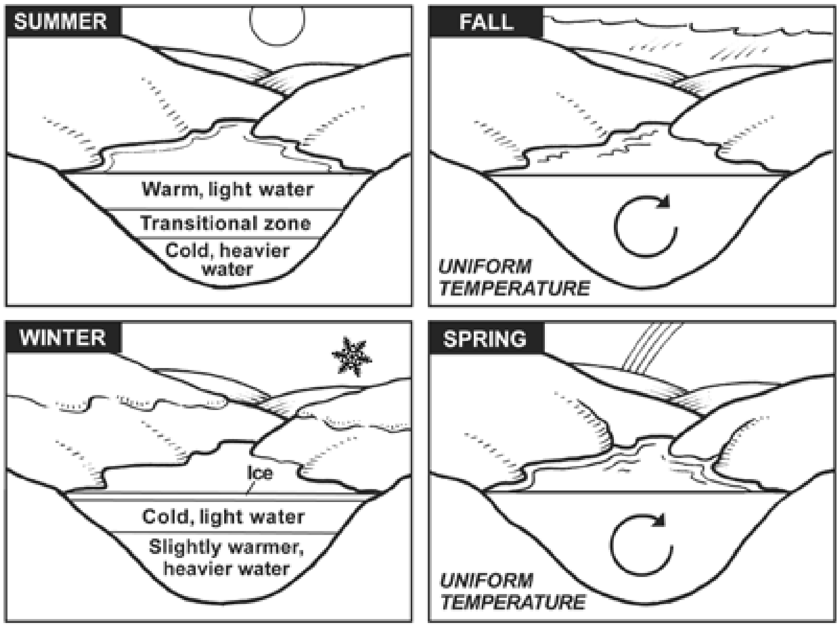


Figure 5.16: Stratification in lakes
(reproduced from Diet for a Small Lake)

Hypoxia and anoxia can have significant impacts on aquatic life, particularly those organisms dependent on both high oxygen and cold water conditions. The latter include salmonids- trout, salmon and other highly prized fish. In addition, an anoxic layer immediately above lake sediments can trigger *redox*- sensitive chemical reactions that result in conversion of sulfate to hydrogen sulfide (resulting in a rotten egg odor), several nitrogen reactions that lead to an increase in ammonia, and release of several pollutants from sediments, including phosphorus, iron, manganese, arsenic, and mercury. An increase in these pollutants can degrade drinking water quality, impact aquatic life, and can trigger the production of more algae growth, thereby perpetuating the cycle.

Dissolved oxygen is measured in milligrams per liter (or parts per million) units, usually to the nearest 0.1 milligrams per liter. New York state water quality standards for dissolved oxygen is above 4 mg/L for all surface waters at any time, 5 mg/l for trout waters (those classified as (T)), and 7 mg/l for trout spawning water (classified as (TS)). There are also minimum average daily values and allowances for “natural conditions”, and these conditions do not apply to the hypolimnion.

Monitoring for Oxygen

Dissolved oxygen is most accurately measured with “wet chemistry” tests that add reagents to water samples and quantify resulting color changes associated with chemical reactions due to exposure to oxygen. These tests are very time consuming and require water samples from each depth of interest. In recent years, dissolved oxygen is measured with the use of electronic meters that evaluate dissolved oxygen (as well as other electronic meter tests, such as temperature, conductivity, pH, turbidity, chlorophyll *a*, and oxygen-reduction potential, or ORP) using surrogate procedures. Test results are displayed on a handheld device and can be logged electronically for off-loading into electronic files. These meters are expensive and require regular calibration, limiting their use in citizen science programs.

Dissolved oxygen test kits can provide valuable information about the approximate oxygen levels at various depths in lakes, but the time to conduct these modified “wet chemistry” tests and the handling of the reagents in the field limit their use

Dissolved oxygen in the LCI is collected with these electronic meters as part of depth profiles, in which measurements are collected in one meter increments from surface to bottom. Except where noted, profiles were collected during each monthly sampling session. ORP can also be used to evaluate the duration of anoxia, since negative ORP levels may be associated with an extended duration of anoxic conditions, but these tests are not reliable with many electronic meters.

In CSLAP, direct dissolved oxygen measurements are not available. However, an “inferred” dissolved oxygen status can be determined by reviewing hypolimnetic phosphorus and ammonia data, since significantly elevated readings of these indicators, on the order of 10x those at the lake surface, are associated with anoxic conditions. These indicators are analyzed from hypolimnetic samples, collected from 1-2 meters off the lake bottom. Comparisons from one sampling session to another are difficult due to slight differences in sample depths- the exact distance from the lake bottom cannot be consistently determined at the exact time of sampling without disturbing the bottom or damaging the sensitive electronic meter. Small differences in these depths might result in significant expected differences between samples. However, these results can be consistently compared to surface samples to determine if anoxic conditions are likely.

Statewide Distribution

Table 5.10 summarizes the distribution of lakes sampled between 2012 and 2016 through the LCI and CSLAP as it relates to oxygen or inferred oxygen data. These data includes the depth category for each sampled lake and information about the extent of measured hypoxia and measured or inferred anoxia. The stratification category is based on depth information, rather than actual water temperature profiles, since these profiles are not available in most CSLAP lakes. These data show an apparent discrepancy between stratified lakes (defined by a depth measurement) and anoxia (defined by direct or inferred oxygen levels); in some basins, lakes shallower than 20 feet may periodically stratify and exhibit reduced oxygen levels or elevated deepwater nutrient readings. This may result in an apparent higher percentage of anoxic lakes than stratified lakes. However, these data suggest that outside of the Adirondack regions, most of the thermally stratified lakes exhibit at least some anoxia. Some of this may be natural, owing to lake

Table 5.10- Regional summary of dissolved oxygen Information for CSLAP and LCI lakes, 2012-2016

Region	% Stratified+	%Anoxic^	Avg Hypo NH4/ surf NH4	Avg Hypo TP /Surf TP
NYS	**59%**	**36%**	**8.4**	**2.9**
NYC-LI	25%	31%	8.6	0.6
Lower Hudson	39%	30%	35.5	6.7
Mid-Hudson	64%	39%	9.2	3.0
Mohawk	40%	64%	2.1	1.9
Eastern Adirondack	88%	20%	2.1	1.5
Western Adirondack	72%	20%	7.8	3.3
Central NY	64%	29%	7.9	3.1
Finger Lakes	59%	56%	16.8	3.4
Western NY	50%	50%	3.3	3.5

+ percentage of lakes greater than 6 meters (20 feet) deep, although some of these are weakly stratified

^ percentage of lakes with at least one measurement of < 1 mg/l dissolved oxygen or hypolimnetic to epilimnetic ratios of NH4 or TP > 10

Shallow vs. Deep:

Anoxia in lakes is usually a phenomena associated with hypolimnetic waters. However, anoxia can occur in shallower lakes that are weakly stratified or even unstratified. A "microlayer" of anoxic water overlying the sediment layer can trigger pollutant-release that results in periodic pulses of these pollutants into the water. However, neither CSLAP nor the LCI routinely sample shallow lakes for "deepwater" oxygen or pollutants, since these oxygen deficits are usually very short-lived and difficult to identify. These shallow lakes are not identified as having oxygen deficits, but some may have this problem.

morphometry or basin characteristics that inhibit complete or consistent lake mixing. However, absent sediment core sampling to hindcast the history of oxygen conditions in the bottom waters, the influence of cultural eutrophication or other recent lake stressors on hypolimnetic oxygen levels cannot be easily determined.

Highly elevated deepwater ammonia and phosphorus readings are common in many of these lakes, and in general, increases in deepwater ammonia appear to be synchronized with increases in deepwater phosphorus. The actual ratio of deep to surface ammonia and phosphorus may be highly dependent on sample depth relative to the lake bottom, since anoxia can increase exponentially toward the lake bottom. However, elevated ratios are likely confirmatory of anoxia. As with the frequency of measured or inferred anoxia, the surface-to-bottom ratios of ammonia and phosphorus are significantly higher in those regions with very high percentages of anoxic lakes.

As noted in Chapter 10, CSLAP and the LCI are not designed to measure actual impacts to the most oxygen-sensitive biota in the lake, including salmonids (trout and salmon) and some species *chironomids* (lake flies and midgets), or the dominance of *tubificids* (including sludge worms). Therefore, while oxygen deficits are common in CSLAP and LCI lakes (and by extension, most thermally stratified lakes in New York state), the actual impact to aquatic life is not clear. It is anticipated that additional New York state water quality data, such as fisheries composition and invertebrate data will be collected and combined with these water quality data to better assess aquatic life in these lakes.

Chapter 6: Harmful Algae Blooms (HABs)

Algae blooms have been observed and reported on New York state lakes for at least several centuries. Those blooms comprised of cyanobacteria, once called blue-green algae, have probably been around for at least that long, since these organisms are among the oldest on earth, dating back several billion years. However, these blooms have attracted significant interest around the world and in New York in recent years due to very high profile blooms in the Great Lakes, several Finger Lakes, and in at least hundreds of smaller lakes and ponds throughout the state.

What is a HAB?

Harmful algae blooms are dense concentrations of cyanobacteria (blue green algae) that can produce liver, nerve and dermal toxins, or other harmful substances. Exposure to blooms can result in health impacts through skin exposure, ingestion or inhalation.

NYSDEC and the state Department of Health began formally documenting cyanobacteria blooms through a Centers for Disease Control (CDC) grant in the late 2000s, and NYSDEC has established surveillance and monitoring partnerships with many partners in recent years. This includes a robust open water and shoreline bloom monitoring program through CSLAP, bloom sampling through the LCI, and surveillance and monitoring networks in several Finger Lakes and smaller lake communities in collaboration with the SUNY College of Environmental Sciences and Forestry (SUNY ESF). NYSDEC also established similar networks in New York City parks and Long Island lakes through a collaboration with SUNY Stony Brook. Beach closure information is reported through the local and state Department of Health, and public reports of blooms are received by both agencies.

What’s a Bloom?

These reports can take the form of visual observations, collected samples (and associated analytical results), digital pictures, beach operational decisions, and other data or information. Reports come into the NYSDEC each day, with the highest percentage of reports coming in mid- to late-week in late summer, when the largest number of lakes are surveyed and when potential HABs samples arrive at the partner laboratories.

Visual- cyanobacteria blooms usually look like spilled paint, pea soup, green streaks on the water surface, or large concentrations of green dots on or within the water column. They can also exhibit heavy green discoloration. In many cases, bloom reports don’t fit cleanly in one of these categories, but will share many visual characteristics.

Sampling results- when a bloom is suspected, samples are often collected and submitted to one of the laboratories cited above. This includes all suspected blooms at CSLAP or LCI lakes. Upon receipt at the laboratory, samples are run through a high end fluorometer (referred to as a fluoroprobe) and analyzed for total and fractional chlorophyll *a*, including measurements of cyanobacteria (blue green algae) chlorophyll *a* content. The chlorophyll pigment is not extracted from the cells, so this measurement is not as accurate as the extracted chlorophyll measurement described in Chapter 5. Samples with total chlorophyll *a* levels above 10 µg/l are also inspected (qualitatively) for the dominant algal taxa- the major algae or cyanobacteria organisms. All of these samples are also run for up to 26 different cyanobacteria toxins.

These reports are characterized by NYSDEC using the following categories, recognizing that the status of each report can change based on additional information:

Not a Bloom represents a low likelihood that a cyanobacteria bloom is present. The following criteria must be met: (1) in the absence of a sample, visual evidence is not consistent with a cyanobacteria bloom; samples show (2) blue green (BG) chlorophyll levels ≤ 25 µg/L; (3) a microscopic scan without dominance by cyanobacteria and bloom-like densities; or (4) only in absence of the previous criteria being met: microcystin ≤ 4 µg/L.

Suspicious Bloom fulfills either of the following criteria: (1) characterized by DEC HABs Program or DOH staff from surveillance reports or digital photographs from visual evidence of a bloom is likely to be cyanobacteria. In absence of digital photographs, a descriptive field report from professional staff or trained volunteer may indicate suspicious conditions; (2) staff from DOH or OPRHP close a regulated swimming beach due to the visual observation of a bloom.

Confirmed Bloom fulfills at least one of the following criteria: (1) BG chlorophyll *a* levels ≥ 25 µg/L; (2) microscopic confirmation that majority of sample is cyanobacteria and present in bloom-like densities; or (3) microcystin ≥ 4 µg/L but less than high toxin thresholds and accompanied by ancillary visual evidence of the presence or recent history of a bloom. These chlorophyll *a* thresholds are developed from the NYSDEC interpretation of the World Health Organization (WHO) thresholds between moderate and high probability of acute health effects.

Confirmed with High Toxins Bloom are confirmed blooms with laboratory analytical results meeting the following criteria: (1) microcystin ≥ 20 µg/L from shoreline bloom samples; (2) microcystin ≥ 10 µg/L from open water bloom samples; or (3) known risk of exposure to anatoxin or another cyanotoxins, based on consultation between DEC HABs Program or DOH staff. These thresholds also correspond to the WHO range of moderate to high probability of acute health effects. Anatoxin results will likely need to exceed 4 µg/L.

Bloom status designations form the basis of the NYSDEC HAB Notification program, in which Suspicious, Confirmed and Confirmed with High Toxin Blooms are cited in emails sent to samplers and NYSDEC and Department of Health staff in Albany and the counties corresponding to the bloom location. In addition, the NYSDEC HAB web page is updated every Friday afternoon with the most recent bloom status for these waterbodies. The cited information includes name and location of the waterbody (in tabular form and on a web-based New York state map), status date, extent of the bloom, the source of information, and any change in status since the last weekly web update.

Statewide HABs distribution

The New York state HABs distribution of HABs is provided in Figures 6.1 through 6.6, showing the 2012-16 cumulative summary of Suspicious, Confirmed and Confirmed with High Toxin Blooms from throughout New York state, and the annual distribution of blooms in each year. These maps show

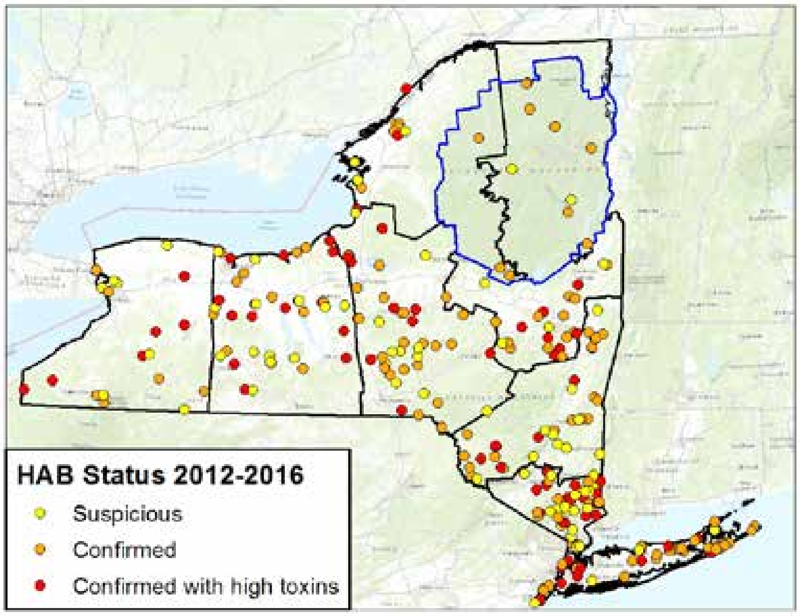


Figure 6.1: HABs reports in NYS lakes, 2012-2016

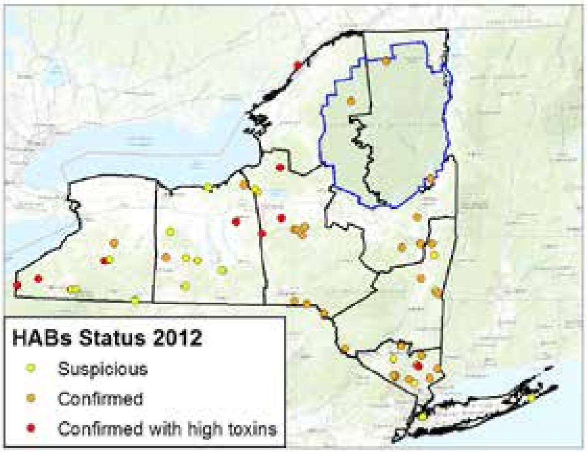


Figure 6.2: HABs reports in NYS lakes, 2012

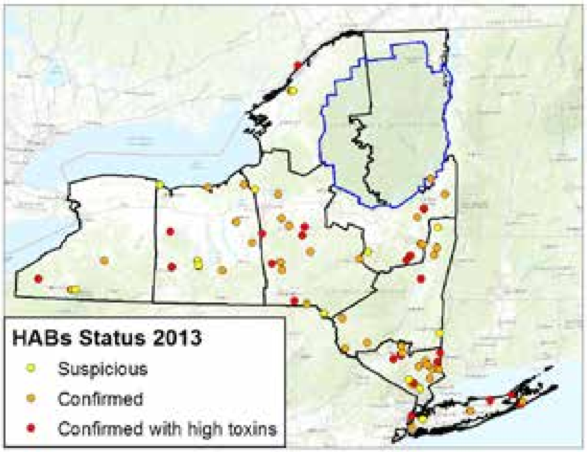


Figure 6.3: HABs reports in NYS lakes, 2013

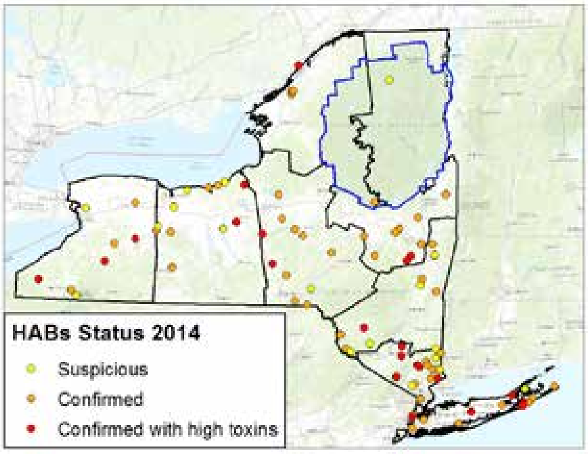


Figure 6.4: HABs reports in NYS lakes, 2014

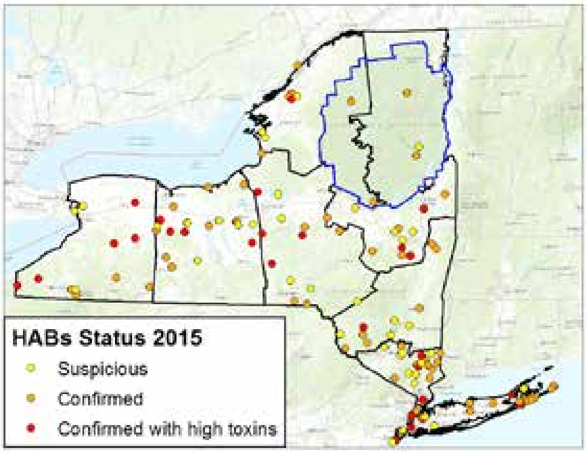


Figure 6.5: HABs reports in NYS lakes, 2015

the “peak” occurrence in each waterbody- Confirmed with High Toxin Blooms supersede Confirmed Blooms, which supersede Suspicious Blooms. Table 6.1 shows the number of waterbodies with Suspicious, Confirmed and Confirmed with High Toxin Blooms in each year. Figure 6.1 and Tables 6.2 through 6.6 demonstrate that the number of lakes with reported blooms has increased each year, and that the distribution of blooms throughout the state is extensive. A significant part of the increase in blooms can be attributed to increasing numbers of surveillance and monitoring partnerships and greater public attention to the issue.

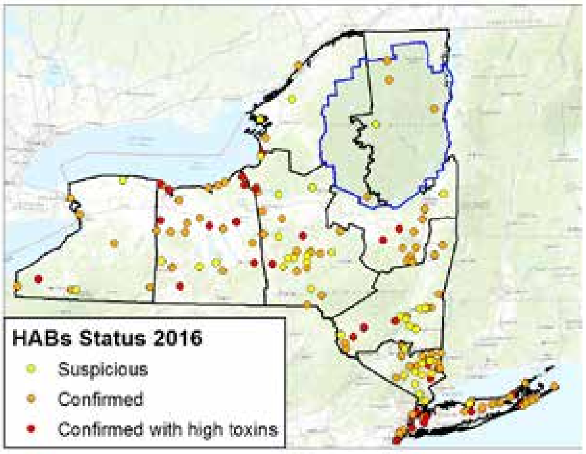


Figure 6.6: HABs reports in NYS lakes, 2016

Year	% Common CSLAP Lakes with HABs
2012	25%
2013	30%
2014	32%
2015	36%
2016	20%

Table 6.1: HABs in CSLAP lakes sampled each year since 2012

Although blooms recur in some lakes, and the absence of a bloom report does not necessarily mean the absence of any blooms, bloom reports in lakes sampled in each of the last five years increased from 2012 through 2015, but decreased in 2016, as shown in Table 6.1. This may have been in response to the drought conditions that were present in most of the state. However, since the number of lakes with reported blooms has increased each year, and different lakes are sampled each year, it is not yet known if the frequency of blooms is changing.

Bloom reports have increased in most regions of the state over the last five years, although blooms continue to be less frequent in the eastern and western Adirondack regions (particularly within the Adirondack Blue Line), due to lower nutrient levels in these lakes. Blooms are relatively less frequently reported in western New York, although this is due in part to fewer lakes in the region and a relatively low number of surveyed and sampled lakes. The large and increasing number of bloom reports in the New York City/Long Island region reflects the NYSDEC-NYC Parks-SUNY Stony Brook collaborative initiated since 2014.

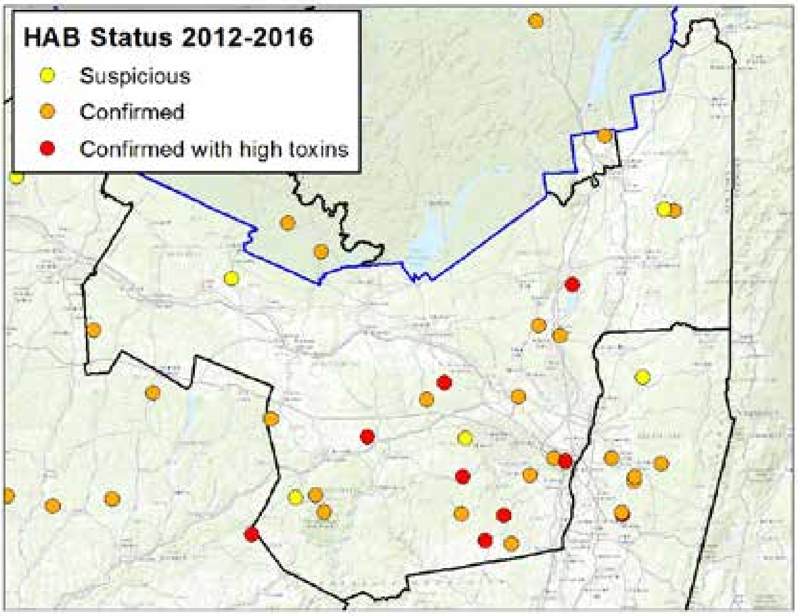


Figure 6.7: HABs reports in Mohawk region lakes, 2012-2016

Mohawk region HABs distribution

Figure 6.7 shows the distribution of lakes with suspicious, confirmed, and confirmed with high toxins reports since 2012 in this region. This includes CSLAP and LCI lakes, and other waterbodies with blooms reported by NYSDEC monitoring partners, the local Department of Health and the public. Information about open water and shoreline bloom reports from CSLAP and LCI lakes can be found in the individual lake reports later in this report, and detailed HAB reports from the more heavily surveyed lakes (by NYSDEC monitoring partners) can be found elsewhere (link).

The HABs distribution map in Figure 6.7 shows very few blooms reported in the western portion of the Mohawk region, particularly in the area near the Mohawk River. Blooms were more frequently reported in the southern portion of the region, particularly in Albany and Schoharie County, across each bloom status (suspicious, confirmed, and confirmed with high toxins blooms). This reflects a high percentage of CSLAP, and therefore more intensively sampled, lakes in this part of the region, but also reflects high nutrient and overall algae levels in these areas (see Chapter 5). While it is known that excessive nutrient levels, particularly phosphorus, can trigger the formation of algae blooms generally, and harmful algae blooms specifically, an increasing number of blooms have been documented on mesotrophic to oligotrophic lakes. For these lakes, localized nutrient sources, nitrogen to phosphorus ratios, nutrient fractions (dissolved or suspended), and seasonal nutrient inputs may be the proximate cause of these blooms.

However, other factors, including flow and stratification characteristics, wind concentration due to fetch length, food web interactions, and temperature or flash runoff increases from climate change may play an important role in bloom formation and toxin production. The data- water quality, biological condition, morphometry, and physical characteristics- from these lakes and from lakes with little to no evidence of blooms continues to be closely evaluated by the NYSDEC to gain a greater understanding of the causes of blooms.

Table 6.2 lists each of the waterbodies within the Mohawk region reporting suspicious, confirmed or confirmed with high toxins since 2012. **It should be assumed that harmful algae blooms may occur on any waterbody, particularly those identified as *mesotrophic* to *eutrophic* in Chapter 5. Any lake resident, visitor, or recreational user should follow the advice provided by the NYSDEC and the NYSDOH:**

- Avoid contact with any surface scums or heavily discolored water
- If exposed to the bloom, rinse with clean water, and seek medical assistance if experiencing nausea, vomiting, rashes, or difficulty breathing
- Report all health symptoms and exposure information to the local health department
- Report bloom information to the NYSDEC at HABsInfo@dec.ny.gov.

Table 6.2: Mohawk region documented HABs, 2012-2016

Lake	County	2012	2013	2014	2015	2016	Source
Alcove Reservoir	Albany	NS	NS	NS	NS	C	City Albany
Ann Lee Pond	Albany	NS	NR	NS	NS	NS	LCI
Ballston Lake	Saratoga	C	C	C	NS	NS	CSLAP
Basic Creek Reservoir	Albany	NS	HT	HT	NS	C	City Albany
Bozenkill Private Pond	Albany	NS	NS	NS	S	NS	Public
Buckingham Lake	Albany	C	C	C	NS	NS	CSLAP
Central Bridge Lower Reservoir	Schoharie	NS	NS	NS	NS	NR	LCI
Central Bridge Upper Reservoir	Schoharie	NS	NS	NS	NS	HT	LCI
Cossayuna Lake	Washington	NS	C	C	C	NS	CSLAP
Duane Lake	Schenectady	NS	NS	C	S	NS	CSLAP
Engleville Pond 1	Schoharie	NS	NS	C	NS	NS	LCI
Engleville Pond 2	Schoharie	NS	NS	NR	NS	NS	LCI
Galway Lake	Saratoga	NR	NR	NR	NR	NR	CSLAP
Iroquois Lake	Schenectady	NS	NS	NS	S	C	NYSDEC
Kyser Lake	Herkimer	NS	NS	NS	S	NS	Public
Lake Lauderdale	Washington	NR	NS	NS	NS	NS	LCI
Lake Lonely	Saratoga	NR	NS	NS	NS	NS	LCI
Lawsons Lake	Albany	NS	HT	HT	HT	C	LCI

Lake	County	2012	2013	2014	2015	2016	Source
Looking Glass Lake	Schoharie	NS	NS	C	NS	NS	LCI
Mallet Pond	Schoharie	NS	NS	NS	C	NS	LCI
Mariaville Lake	Schenectady	NS	NS	C	C	HT	CSLAP
Murphy Pond	Saratoga	NS	NS	NS	NS	NR	LCI
Onderdonk Lake	Albany	NS	NS	NS	C	NS	Public
Round Lake	Saratoga	NR	NS	NS	NS	C	Public
Saratoga Lake	Saratoga	NS	HT	NS	HT	C	CSLAP
Stony Creek Reservoir	Saratoga	NS	NS	NS	NR	NS	LCI
Sugarloaf Pond	Saratoga	NS	NS	NS	NS	NR	LCI
Summit Lake	Schoharie	NS	S	NS	NS	NS	Public
Summit Lake	Washington	NS	NS	NS	NS	S	CSLAP
Unnamed Pond (Slingerlands)	Albany	NS	NS	NS	NS	C	Public
Vly Creek Reservoir	Albany	NS	NS	NS	NS	NR	LCI
Warners Lake	Albany	C	NS	NS	HT	C	Public
Washington Park Lake	Albany	NS	C	NS	NS	NS	NYSDEC

S = suspicious HAB; C = confirmed HAB; HT = confirmed with high toxins HAB; NR = none reported; NS = no surveillance

Why are blooms occurring in New York state lakes?

As demonstrated in Figures 6.1 through 6.7 and in Table 6.1, harmful algal blooms occur in many waterbodies throughout New York. Widespread or lakewide blooms are detected through routine monitoring in CSLAP or the LCI- biweekly CSLAP samples are analyzed for cyanobacteria, and LCI lakes are sampled for open water blooms when apparent bloom conditions are observed during routine sampling. Shoreline blooms are far more common than open water blooms in lakes. These blooms- either originating near the shoreline or concentrated by wind or water movement along the lake shore- may be reported by lake residents or visitors. Some of the bloom reports cited in Table 6.1 come from public reports, observations of lake residents provided to CSLAP samplers, or shoreline blooms observed by happenstance during routine (open water) sampling. However, ephemeral and localized shoreline blooms are far more likely to be observed during routine surveillance- visual inspection of the shoreline for blooms, Bloom reports in some lakes (or in some years) are primarily a function of vigilant surveillance- blooms are observed and reported when surveyors look for blooms, particularly when this surveillance includes large portions of the shoreline. For some of the waterbodies in Table 6.1, blooms may have been present in each year since 2012, but were not reported or observed due to the lack of complete surveillance (and some lakes were not sampled each year).

However, some lakes do not experience cyanobacteria blooms. The frequency, duration, and intensity of blooms can be influenced by many factors. HABs research over the last few decades has documented several factors that trigger blooms, although it is likely that the reasons for blooms on any particular lake are unique to that lake. Some of the factors that appear to affect bloom formation include elevated algae levels, elevated nutrient levels, food web changes (zebra and quagga mussels), and lake geometry. Other factors, such as temperature, wind, and light, have not yet been assessed or can't yet be evaluated with the data collected in these programs.

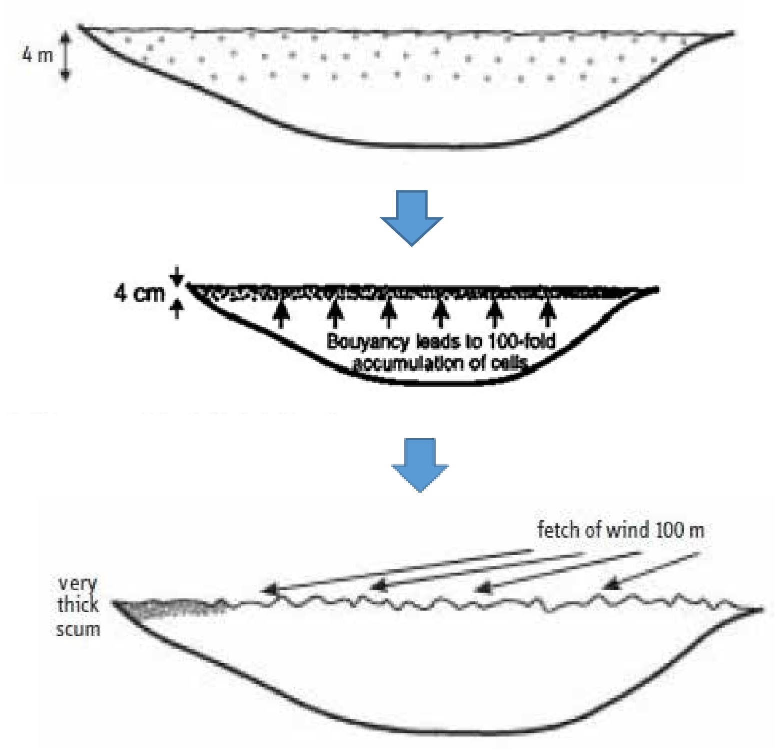


Figure 6.8: HAB formation in lakes (Chorus and Bertram, 1999)

Elevated algae levels

A strong relationship between shoreline bloom formation and open water algae levels, as measured by chlorophyll *a*, would be expected if these blooms originated from lesser amounts of algae in the open water concentrating in the upper few centimeters of the lake (due to cyanobacteria buoyancy) and then further concentrating by flow or wind or wave action along the windward shoreline. This phenomenon was described by Chorus and Bertram (1999) in the World Health Organization recreational guidance (Figure 6.8).

The CSLAP and LCI 2012-2016 datasets were analyzed to explore the relationship between shoreline HABs and several lake indicators. Each lake "year" was identified as either reporting a (shoreline) bloom or not reporting a bloom; Table 6.1 summarizes whether blooms were reported in each CSLAP or LCI lake in this basin. These includes "reports" based on unextracted chlorophyll levels in open water or shoreline samples, or credible visual reports. The annual average readings for several water quality indicators was compared to this "binary" choice of bloom occurrence- bloom present or absent. Some lakes with blooms did not have consistently reported blooms each year, even if blooms were actually present (but not observed or sampled), and the shoreline blooms in some of these lakes may have been very small and/or highly ephemeral. However, Figure 6.9 shows that the frequency of shoreline blooms increases as open water algae levels (extracted chlorophyll *a*) increase. More than half of all lakes with open water chlorophyll *a* levels above 10-15 µg/l report shoreline blooms. However, it is likely that blooms are even more common in these lakes, since open water chlorophyll *a* levels above 25-30 µg/l should result in shoreline blooms given that these conditions, even if not further concentrated along the shoreline, fit the criteria of a bloom. The lower-than-expected cyanobacteria bloom frequency in Figure 6.9 may be the result of several factors, including:

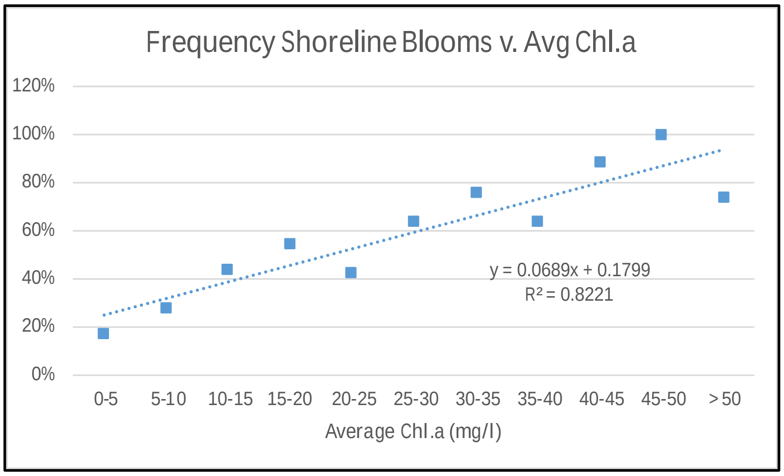


Figure 6.9: % frequency shoreline blooms v. open water chlorophyll a in CSLAP and LCI lakes, 2012-2016

- incomplete bloom reporting (including instances in which "greenish water" associated with elevated (> 30 µg/l) chlorophyll *a* levels may not be reported as a bloom);
- the presence of other (non-cyanobacteria) taxa in the chlorophyll measurements shown in Figure 6.9 (X axis);
- differences between unextracted chlorophyll (part of the basis for a "reported" bloom, the Y axis in Figure 6.9) and extracted chlorophyll (the basis for average chlorophyll readings, the X axis in Figure 6.9).

Elevated nutrient levels

The relationship between phosphorus and algae has been well established, going back to at least the pioneering 1970s work by David Schindler in the Canadian Experimental Lakes Area. This research, confirmed in many studies in the following decades throughout the world, formed the basis for the foundational principle of lake management linking phosphorus limitation with algae control. In many lakes, phosphorus serves as the primary limiting factor controlling algae growth during the summer growing season- increasing phosphorus, particularly soluble phosphorus, will increase algae levels. This relationship may be even stronger for lakes dominated by several cyanobacteria taxa that are capable of “fixing” atmospheric nitrogen (thereby providing a steady source of this nutrient).

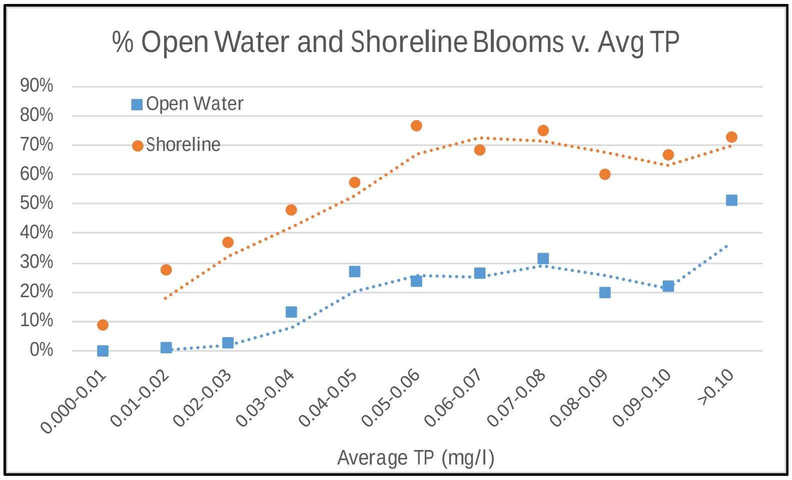


Figure 6.10: % frequency open water and shoreline blooms v. open water TP levels in CSLAP and LCI lakes, 2012-2016

Figure 6.10 shows that the frequency of open water and shoreline cyanobacteria blooms increases as open water total phosphorus (TP) readings increase. Open water blooms are essentially non-existent when open water phosphorus levels are less than 30 µg/l (=0.030 mg/l), but steadily increase when TP rises from 30-50 µg/l (and above 100 µg/l). The relationship between open water cyanobacteria bloom frequency and phosphorus levels may flatten out between 50 and 100 µg/l due to dominance by other forms of algae. Shoreline cyanobacteria blooms, however, occur in nearly 30% of the lakes even at TP levels < 20 µg/l, and steadily increase until TP levels reach approximately 60 µg/l. At elevated phosphorus levels, cyanobacteria blooms occur in nearly ¾ of all lakes.

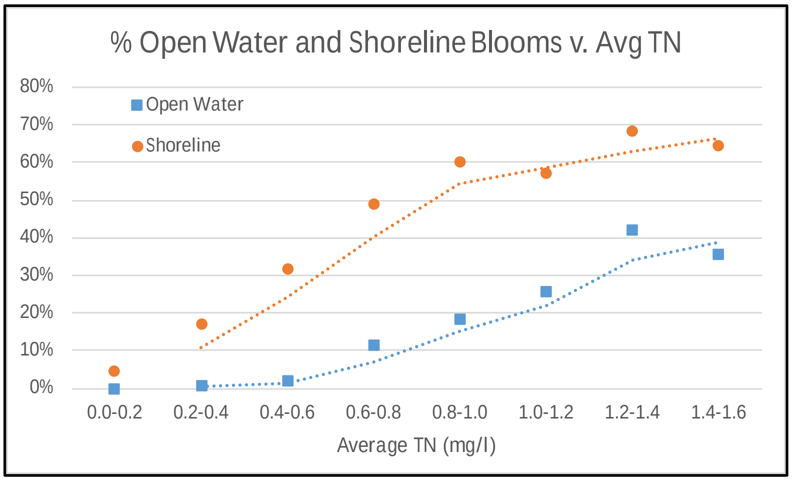
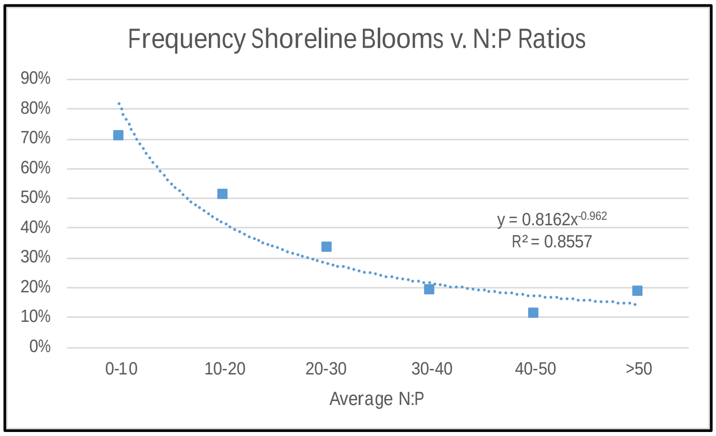


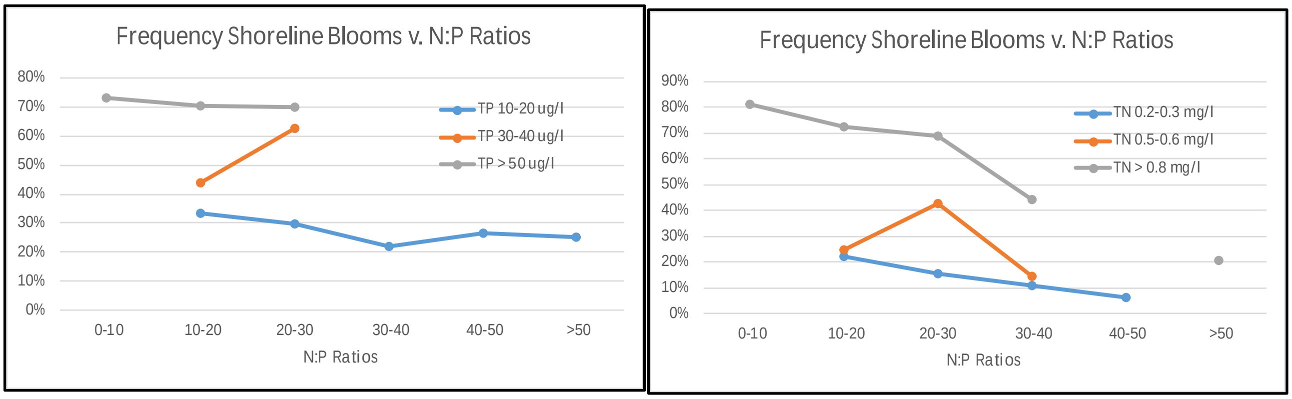
Figure 6.11: % frequency open water and shoreline blooms v. open water TN levels in CSLAP and LCI lakes, 2012-2016

A similar relationship exists between open water and shoreline blooms and total nitrogen (TN) levels, as shown in Figure 6.11. As with TP, open water blooms are mostly non-existent with TN levels less than 0.6 mg/l, but steadily increase at higher TN levels. Shoreline blooms are apparent at lower open water TN levels, and steadily increase as TN levels rise. This appears to contradict the primacy of phosphorus in triggering cyanobacteria blooms. However, nitrogen may play a role in cyanobacteria bloom formation in some lakes dominated by cyanobacteria that cannot fix atmospheric nitrogen (and therefore require a steady source of nitrogen in the water). In addition, many lakes with elevated TP also have elevated TN levels.



Figures 6.12: % frequency shoreline blooms v. N:P ratios in CSLAP and LCI lakes, 2012-2016

A further evaluation of the relative role of nitrogen and phosphorus in cyanobacteria bloom formation can be conducted by looking at bloom formation at fixed N or P levels, while evaluating nitrogen to phosphorus ratios. Figure 6.12 shows that the frequency of shoreline bloom occurrence is generally highest when N:P ratios are low- when N is low or TP is high- and decreases as N:P ratios increase, consistent with findings reported throughout the scientific literature. To determine whether this relationship is more dependent on N or P, Figures 6.13 and 6.14 evaluate the change in bloom occurrence over three fixed ranges of P and N- low, moderate, and high- as N:P ratios change. These figures are limited by the lack of data at the extreme ranges- for example, there are few to no lakes with high N:P ratios and high P. However, these figures generally show that the frequency of shoreline blooms does not change significantly as N levels increase within defined ranges of P, but that the frequency of blooms does decrease with decreasing P levels within defined ranges of N. This suggests that P plays a stronger role in the frequency of bloom occurrences in NYS lakes.



Figures 6.13 and 6.14: % frequency shoreline blooms v. N:P ratios over range of TP and TN in CSLAP and LCI lakes, 2012-2016

Zebra or quagga mussels

Dreissenid mussels (zebra and quagga mussels) can significantly alter the biological condition of lakes. For example, while dreissenids will filter phytoplankton out of the water column, thereby increasing water clarity, they selectively remove green algae, diatoms, and other algae, leaving cyanobacteria at relatively higher concentrations in the lake. This also results in less competition for nutrients, further exacerbating cyanobacteria growth. The extent of zebra and quagga mussel colonization in New York state lakes is not fully known, although Chapter 8 shows an extensive dataset of known zebra and quagga mussel infestations in New York state.

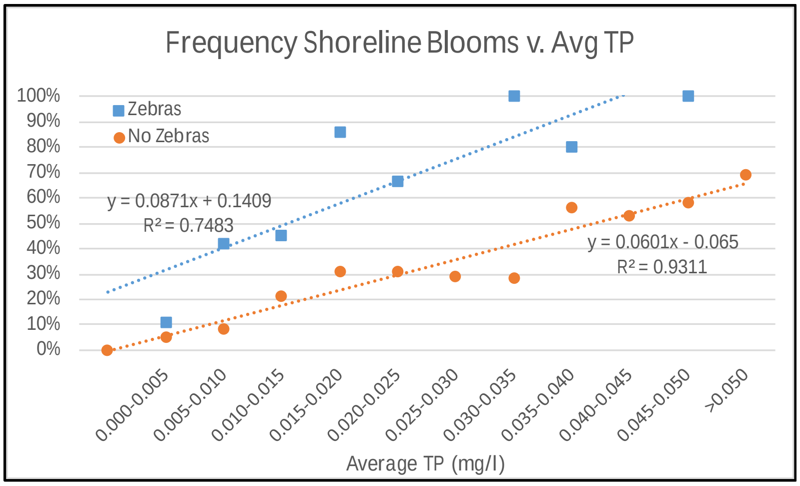


Figure 6.15: % frequency shoreline blooms v. average open water TP levels in lakes with and without zebra mussels in CSLAP and LCI lakes, 2012-2016

Figure 6.15 shows that the frequency of shoreline blooms in lakes with zebra (and quagga) mussels is consistently higher than in lakes without evidence of zebra mussels (referred to in Figure 6.15 as “Zebras” and “No Zebras”, respectively). The increase in shoreline bloom frequency- the slope of the lines in Figure 6.15- is also higher in lakes with zebra and quagga mussels, indicating a higher susceptibility to nutrient inputs.

Lake Geometry: Depth and Fetch length

The physical configuration of some lakes renders them susceptible to blooms. The factors that may contribute to blooms include lake size, retention time (the amount of time water is stored in a lake), and the shape of the lake. These and other factors continue to be evaluated as contributors to bloom formation, although these physical factors can generally not be manipulated to reduce the susceptibility to blooms.

Lake Depth categories:

Shallow- lakes that are less than about 20 feet (6 meters) deep, defined thermal layers (*epilimnion, metalimnion, hypolimnion*) are not established. In the absence of strong density gradients associated with these thermal layers, the entire water column can be well-mixed (although a very small anoxic layer may exist immediately above the sediment layer)

Polymictic- lakes that are about 20-50 feet (6-15 meters) deep, in which thermal layers are often weakly established. Lake mixing periods can occur during storms or high wind events, alternating with periods of thermal stratification and nutrient release from bottom sediments

Deep- lakes that are deeper than 50 feet (15 meters) form strong thermal stratification layers that remain intact throughout the growing season. Deepwater nutrients generally don't migrate to the water surface until fall turnover

Two physical favors that may influence blooms include lake depth and fetch length. Several lakes exhibiting cyanobacteria blooms despite relatively low nutrient levels appear to be *polymictic*, based on water depth (although thermal profiles are not available on many of these lakes). In polymictic lakes, phosphorus levels may build up above the sediment-water interface, near the lake bottom, due to phosphorus release from sediments under anoxic conditions (see Chapter 7). During mixing events, these nutrients can migrate to the lake surface and trigger algae growth, In addition, several cyanobacteria taxa can migrate to the bottom waters in both polymictic and shallow lakes and extract these nutrients.

Figure 6.16 shows a higher frequency of cyanobacteria blooms in polymictic and deep lakes than in shallow lakes. Bloom frequency is low at all three types of lakes at low nutrient levels, slightly higher in polymictic lakes at TP levels between 10 and 20 µg/l, but then consistently higher in polymictic and deep lakes at higher phosphorus levels. The relatively low frequency of cyanobacteria blooms in shallow lakes may be due to the competition from

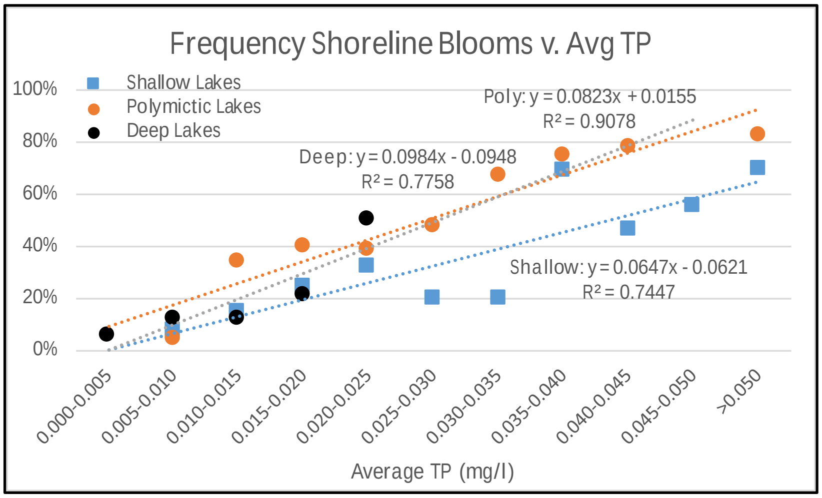


Figure 6.16: % frequency shoreline blooms v. open water TP levels in shallow, polymictic, and deep lakes in CSLAP and LCI lakes, 2012-2016

rooted aquatic plants (weeds), high turbidity more commonly found in shallow lakes, and especially predominance from other algal types, including benthic and floating filamentous algae.

Fetch length is the distance over water across which wind can blow unabated. The maximum fetch length can be calculated by measuring the longest straight-line distance from one shoreline to another. This may not necessarily represent the longest effective fetch length exhibited at any time, but it does represent the distance over which algae can concentrate and pile up along a shoreline. The maximum fetch length is usually longer on large lakes, but the ratio of maximum fetch length to shoreline length may indicate a higher susceptibility to bloom concentration.

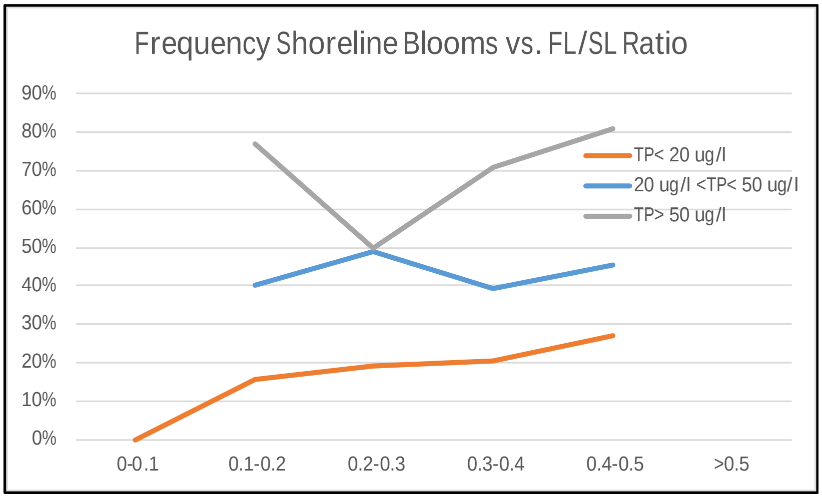


Figure 6.17: CSLAP and LCI lakes % frequency shoreline blooms v. Fetch Length to Shoreline Length Ratio (FL/SL) over range of open water TP levels, 2012-2016

Figure 6.17 shows the relationship between shoreline bloom frequency and the ratio of maximum fetch length (FL) to shoreline length (SL) over a range of open water TP levels. These data indicate that bloom frequency increases as the FL/SL ratio increases for lakes with relatively low open water phosphorus readings, but that the relationship is not as well defined for higher TP levels. This suggests that the physical configuration of the lake may play a role in triggering shoreline blooms in waterbodies with relatively low nutrient levels.

Toxins v. Nutrients

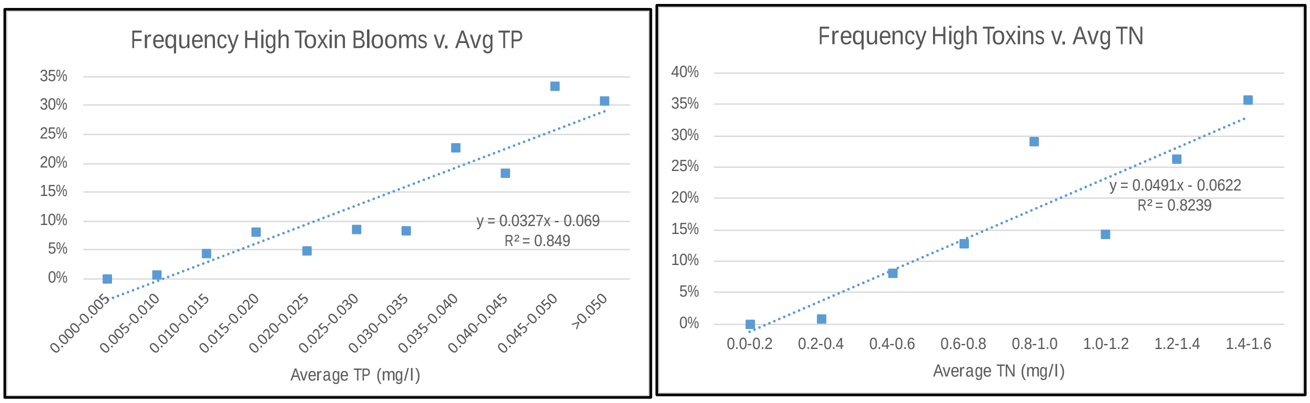
Each of the shoreline and open water HABs samples submitted to SUNY ESF are analyzed for up to 26 different algal toxins. These include several congeners of microcystin (a liver toxin that is likely the most common cyanotoxin in New York waterbodies) and anatoxin (a neuro toxin), as well as cylindrospermopsin (a liver toxin) and BMAA (β-Methylamino-L-alanine, a neurotoxin that may be associated with several neurological disorders). To date, neither cylindrospermopsin nor BMAA have been detected in any New York state lake samples.

USEPA has developed draft guidance values for (total) microcystins for protection of treated drinking water and recreational uses. In 2015, EPA issued a 10-day drinking water health advisory of 0.3 µg/l for children (less than six years old), and 1.6 µg/l for older children (>6 years of age) and adults. This advisory was intended to apply to treated drinking water, not “raw” lake water. Draft human health recreational ambient water quality criteria for microcystin released by USEPA in 2016 suggest a swimming advisory threshold of 4 µg/l, not to be exceeded on any day or more than 10% of days per recreation season. As noted earlier, NYSDEC previously adopted a “high toxin” threshold of 20 µg/l. Neither USEPA nor NYSDEC has adopted guidance values for anatoxin, although readings above 4 µg/l were closely evaluated by NYSDEC and NYSDOH to determine if any additional advisories are warranted.

The NYSDEC HABs Program outreach and overall bloom messaging is built off the presence of cyanobacteria blooms, not elevated toxin levels. Although high toxins represent an elevated known health risk, the absence of elevated toxin levels does not necessarily represent a lower risk, for the following reasons:

(1) There are more than 100 cyanotoxins or variants, most of which do not have accepted analytical tests. These toxins may be present in samples with low levels of “known” toxins
(2) Cyanotoxin testing results represent a single point in time and space. Higher readings may be present in other parts of the bloom or sometime after the sample was collected
(3) Although the available analytical cyanotoxin tests represent the most up-to-date science, there may be some uncertainty in the laboratory results
(4) At least one cyanotoxin- anatoxin- degrades very rapidly and may not be accurately measured in the laboratory given available collection, preservation, and transport methods
(5) Cyanobacteria blooms can produce lipopolysaccharides and other non-toxin substances that can create dermal reactions or represent other health risks
(6) Not all conditions with visual evidence of blooms can be sampled, and therefore toxin levels are not known

However, although the presence of cyanobacteria blooms is considered a risk even if cyanotoxins levels are undetectable, toxin levels continue to be closely evaluated through CSLAP, LCI and other HAB surveillance and monitoring programs in New York state. The NYS HABs dataset, among the most extensive in the world, can provide some insights about cyanotoxin dynamics in a variety of lake settings.



Figures 6.18 and 6.19: CSLAP and LCI lakes % frequency high toxin blooms v. open water TP and TN, 2012-2016

Figures 6.18 and 6.19 show that the frequency of high toxin (total microcystin > 20 ug/l, above the NYSDEC “high toxin” threshold described earlier) blooms increases with increasing open water TP and TN. The frequency of these blooms increases significantly as TP levels exceed 0.035 mg/l (= 35 ug/l), but increases steadily as TN levels rise. Recent research indicates a potential relationship between nitrogen enrichment and toxin levels- these datasets will continue to be evaluated to determine if these relationships are present in New York state lakes. This will include a detailed evaluation of differences in lakes dominated by N-fixing taxa (those dominated by *Anabaena* and other taxa that fix atmospheric nitrogen) and those dominated by taxa that do not fix atmospheric nitrogen (such as *Microcystis*). Preliminary results, shown in Figures 6.20 and 6.21, indicate that the relationship between frequency of high toxin production and nutrient levels does not change significantly when one of the nutrients (TN or TP) is limited, although there are only small amounts of data in some of these data ranges. However, the role of N or P in high toxin production at any specific lake may be significantly different than demonstrated in these figures, and may warrant more detailed evaluation of the taxa producing the toxins in these lakes.

Toxins v. Cyanobacteria Quantities

Although cyanobacteria are present in nearly all waterbodies in at least small quantities, and may produce non-detectable levels of these toxins, one of the primary concerns for harmful algae blooms is the production of harmful quantities of these toxins within blooms. As noted earlier, bloom quantities are defined by NYSDEC as cyanobacteria (blue green algae) levels above a threshold that indicates an increased risk for exposure, defined as 25 µg/l blue green chlorophyll *a* using fluorometry (or visual evidence of a bloom). Although the production of toxins is not necessary for a cyanobacteria bloom to be considered harmful, toxin production does represent a known elevated risk. It is expected that bloom quantities of cyanobacteria are necessary for elevated levels of toxin production.

Tables 6.3 and 6.4 show the % frequency of exceeding several toxin (*Microcystin,* or MC) thresholds at varying levels of fluoroprobe (FP) blue green chlorophyll *a* levels in the open water and shoreline, respectively, based on thousands of New York state CSLAP, LCI, and HABs program samples. The 0.3 µg/l threshold corresponds to the 2016 USEPA draft health advisory guidance for treated drinking water. The 4 µg/l threshold corresponds to the 2017 USEPA draft recreational guidance. The 20 and 2000 µg/l values were established by the World Health Organization as the boundaries between lower and upper boundaries of high risk for acute health effects (and the 20 µg/l value corresponds to the "high toxins" threshold for the NYSDEC HABs program). The blue green chlorophyll *a* ranges are somewhat more arbitrary, but in general correspond to the entire range between relative absence of cyanobacteria and thick bloom scums.

Table 6.3: Open water FP BG vs. % samples w/ Microcystin exceeding specific thresholds

	BG Chl.a < 1	BG Chl.a <10	BG Chl.a <25	BG Chl.a 25-50	BG Chl.a 50-100	BG Chl.a 100-1000	BG Chl.a > 1000
% MC < 0.3 μg/l	96%	94%	93%	76%	81%	100%	
% MC > 0.3 μg/l	4%	6%	7%	24%	19%	0%	
% MC > 4 μg/l	0%	0%	0%	8%	0%	0%	
% MC > 20 μg/l	0%	0%	0%	3%	0%	0%	
% MC > 2000 μg/l	0%	0%	0%	0%	0%	0%	
Number samples	2928	3872	4088	93	21	2	0

Table 6.4: Shoreline FP BG vs. % samples w/ Microcystin exceeding specific thresholds

	BG Chl.a < 1	BG Chl.a <10	BG Chl.a <25	BG Chl.a 25-50	BG Chl.a 50-100	BG Chl.a 100-1000	BG Chl.a > 1000
% MC < 0.3 μg/l	97%	93%	90%	69%	64%	44%	39%
% MC > 0.3 μg/l	3%	7%	10%	31%	36%	56%	61%
% MC > 4 μg/l	0%	2%	4%	18%	19%	41%	50%
% MC > 20 μg/l	0%	0%	0%	10%	11%	28%	38%
% MC > 2000 μg/l	0%	0%	0%	0%	0%	0%	3%
Number samples	431	754	893	98	98	232	313

These results can be summarized as follows:

1. These data represent a very large dataset- more than 10,000 samples collected over a five year period
2. The "error" rate in toxin measurements- measuring detectable toxins in the absence of any cyanobacteria (blue green chlorophyll *a*) appears to be 3-4%, and none of these samples demonstrated toxin levels above the USEPA draft recreational guidance value (= 4 µg/l microcystin).
3. A similarly small percentage of samples show blue green chlorophyll levels below the DEC HAB threshold (= 25 µg/l BG Chl.a) with toxin levels above the USEPA recreational guidance value; all of these were measured in shoreline samples.

4. Few (just over 100) open water blooms were documented, and only a small percentage of these demonstrated high toxin levels. None of these indicated dense algal scums (above 1000 µg/l BG Chl.a)
5. In the range of BG Chl.a levels just above the DEC HABs threshold, corresponding to BG Chl.a of 25-50 µg/l), the frequency of detectable toxins increases significantly in both open water and shoreline samples, and the frequency of “high toxin” levels (above 20 µg/l microcystin) also increases. In fact, these represent the lower boundary of high toxin conditions, suggesting that this bloom threshold (=25 µg/l BG Chl.a) adequately represents an elevated risk criteria.
6. Very high toxin blooms- above 2000 µg/l microcystin- appear to be limited to the thick scums associated with BG Chl.a above 1000 µg/l. However, high toxin levels- above 20 µg/l microcystin- can frequently be associated with BG Chl.a levels exceeding 100 µg/l.
7. Detectable levels of anatoxin- not reported here- are very uncommon in New York state lakes. Only about 1% of all samples had anatoxin levels above 1 µg/l, and most of these were less than the 4 µg/l value that has prompted further evaluation by NYSDEC and its partners. USEPA has not developed any guidelines for interpreting anatoxin data.

Chapter 7: Other Water Quality Indicators

Lake eutrophication is the primary stressor on the most heavily used New York state lakes, those at moderate to lower elevation and supporting residential development and uses. Eutrophication and related lake problems are the strongest influence for most of the lakes sampled through CSLAP and the LCI. However, other water quality indicators are measured through these programs, and these ancillary indicators may provide important information about some sampled lakes. These include the laboratory analyses cited in the green box to the right.

These indicators can be evaluated to identify the environmental setting for these lakes, since most of these indicators are strongly affected by geology and soil characteristics, but in some cases these analyses provide important insights about water quality conditions that might affect lake uses. The most important of these indicators are described below.

CSLAP indicators: water clarity, total phosphorus, chlorophyll *a,* nitrogen (total, nitrate + nitrite, and ammonia), pH, conductivity, color, calcium, chloride, and temperature

LCI indicators: nitrogen (total, nitrate + nitrite, and ammonia), alkalinity, total organic carbon, silica, cations and anions (calcium, chloride, iron, manganese, arsenic, and sulfate in some years), and depth profiles for temperature, dissolved oxygen, pH, conductivity, and oxygen reduction potential.

Nitrogen:

Several forms of nitrogen are included in most water quality monitoring programs, and CSLAP and the LCI are no exception. These forms include nitrate + nitrite (NOx), ammonia (NH4) and total nitrogen (TN).

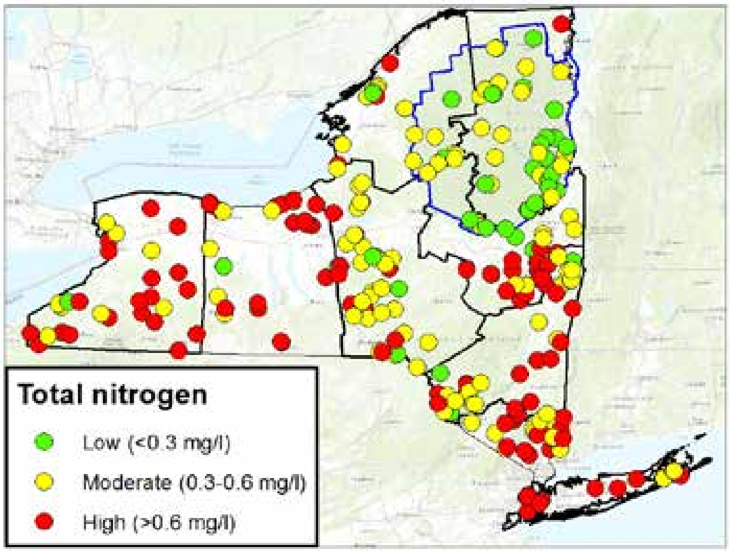


Figure 7.1: TN distribution in CSLAP and LCI lakes, 2012-16

Nitrate (NO_3) is the form of nitrogen most readily available for biological uptake, including uptake by algae. It is more easily detected as NOx, or nitrate + nitrite. Nitrite (NO_2) is rarely found in surface waters, and can be created as an intermediate step in denitrification, the conversion of nitrate into nitrogen gas in the absence of oxygen. Nitrate can be a limiting nutrient for some forms of green algae and may be an important nutrient in some regions of the state, such as Long Island. Nitrate can be an important component of wastewater, stormwater, fertilizers, and soil erosion. Therefore, it can be an indirect surrogate for pollutant loading to lakes, although elevated nitrate readings may be natural in some parts of the state. Nitrite can be toxic to aquatic life, though it readily converts to nitrate (or other forms of nitrogen) in the presence of oxygen. NO_x has been measured through CSLAP and LCI for the duration of these programs.

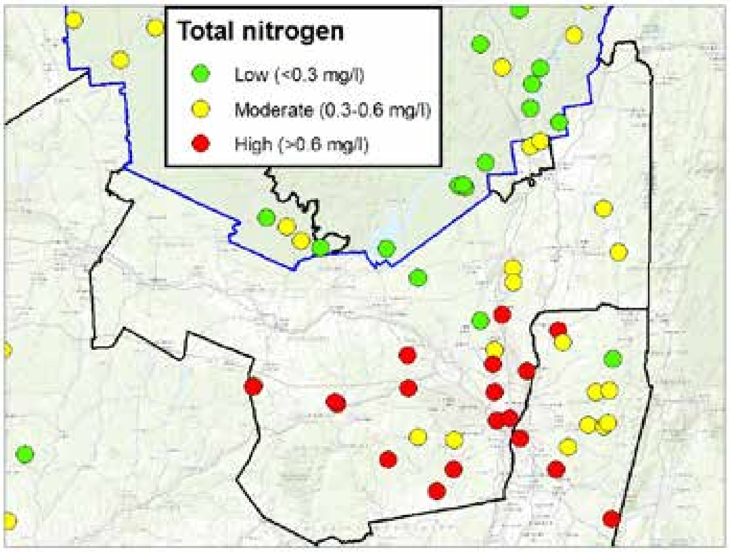


Figure 7.2: TN distribution in CSLAP and LCI lakes in the Mohawk region, 2012-16

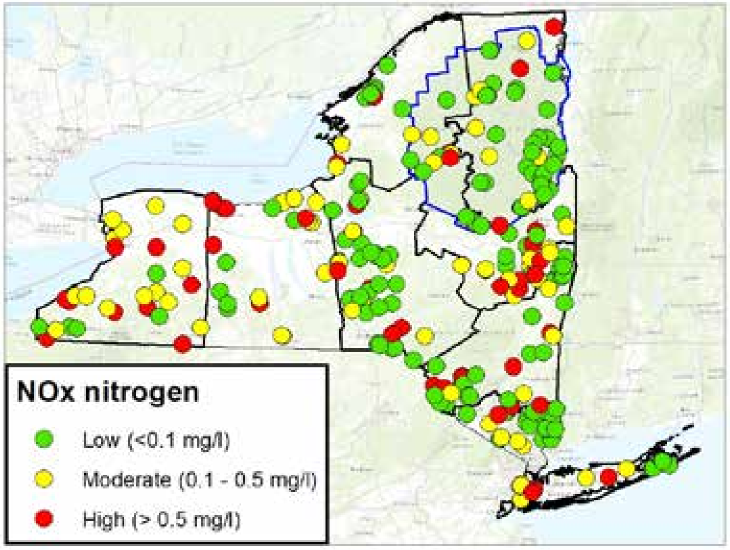


Figure 7.3: NOx distribution in CSLAP and LCI lakes, 2012-16

Ammonia is a micronutrient produced from nitrogen gas by nitrogen fixation and through the degradation of organic matter, found in wastewater, and generated through several biological processes. It is toxic to aquatic organisms and (to a much lesser extent) humans at concentrations occasionally found in lake water, particularly at high pH or in the absence of oxygen (such as occasionally found in the bottom waters of productive lakes). High ammonia readings may also be a sign of other forms of pollution and indicate persistent problems with deoxygenated water. Deepwater ammonia results are summarized in Chapter 5. Ammonia has been analyzed in LCI samples for several decades, but only through CSLAP since 2002.

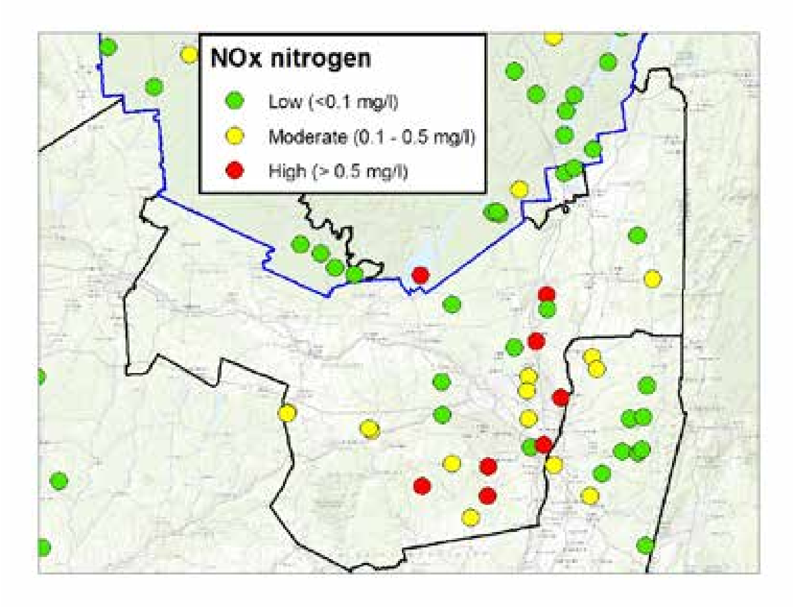


Figure 7.4: NOx distribution in CSLAP and LCI lakes in the Mohawk region, 2012-16

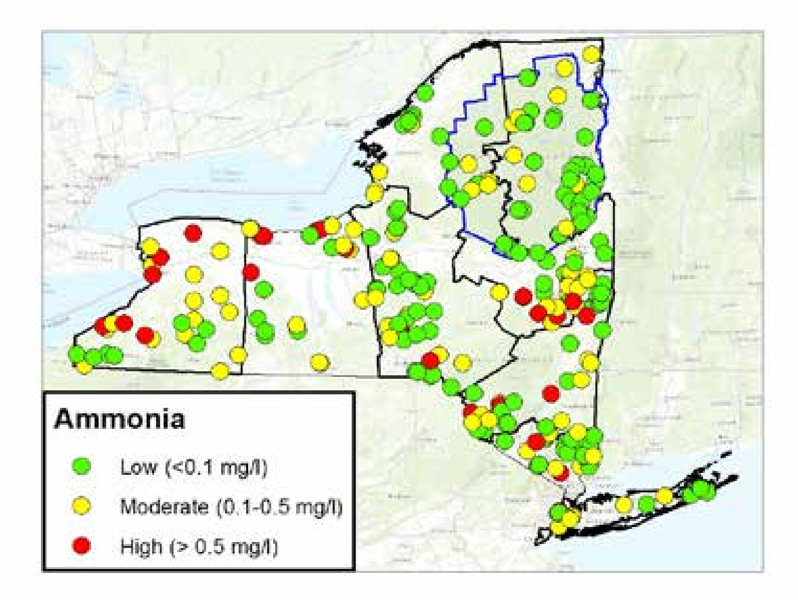


Figure 7.5: NH4 distribution in CSLAP and LCI lakes, 2012-16

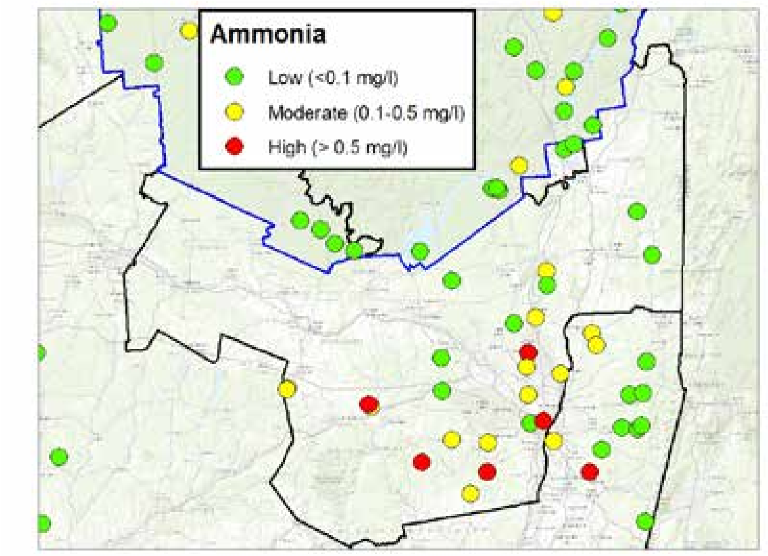


Figure 7.6: NH4 distribution in CSLAP and LCI lakes in the Mohawk region, 2012-16

Total nitrogen is the sum of all component forms of nitrogen—NOx + total Kjeldahl nitrogen (or TKN, which is equal to total ammonia + organic nitrogen). It can also be computed as an independent laboratory analysis, without first analyzing the nitrogen components. It has been analyzed in CSLAP samples since 2002, and computed through component evaluation of LCI samples at least periodically since the 1980s.

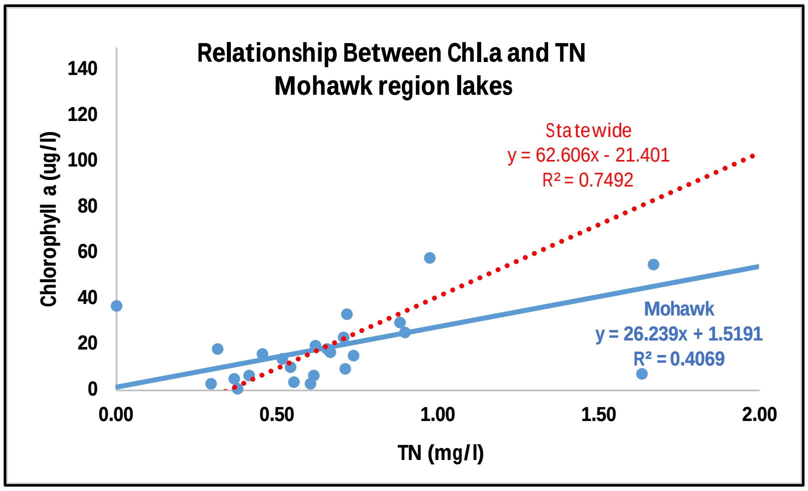


Figure 7.7: Relationship between Total Nitrogen and Chl.a in New York state and the Mohawk region

The ratio between total nitrogen (TN) and total phosphorus, referred to as N:P ratios, may influence the extent and type of algae growth, and may have relevance for the production of both cyanobacteria biomass and cyanotoxins.

The role of nitrogen in cyanobacteria biomass and cyanotoxins has come under intensive study in recent years, although the empirical relationship between any specific nitrogen form and chlorophyll *a* is not as strong as the relationship between phosphorus and chlorophyll *a*. However, phytoplankton communities may be shifting more toward dominance by *Microcystis* and other cyanobacteria taxa that cannot fix atmospheric N_2 as (and therefore require nitrogen inputs to lakes). This shift may be altering the relationships among these water quality indicators, although many of the lake management actions targeting phosphorus inputs to lakes (such as stormwater management, erosion control, and other non-point source management actions) will also likely target nitrogen inputs. However, the specific role of nitrogen, phosphorus, and other bloom "triggers" at each lake may be specific to that lake, and not well understood in some of these lakes.

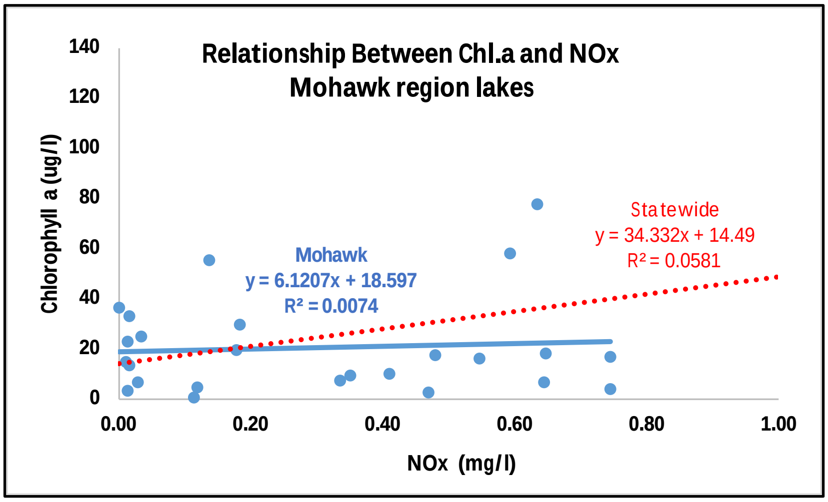


Figure 7.8: Relationship between NOx and Chl.a in New York state and the Mohawk region

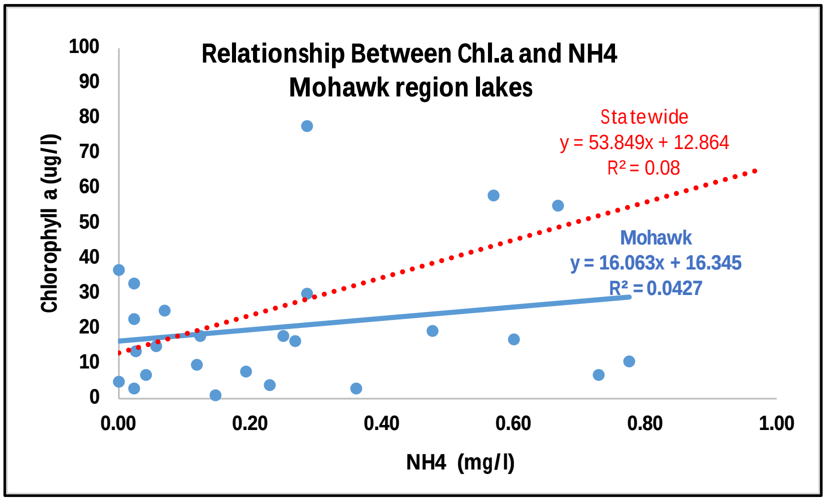


Figure 7.9: Relationship between NH4 and Chl.a in New York state and the Mohawk region

There are no water quality standards for total nitrogen, although in some lakes, TN levels above 0.6 milligrams per liter (mg/L) indicate eutrophic conditions. The state water quality standards for ammonia are 2 mg/L (although lower standards for pH dependent forms of ammonia are applied to trout waters), but this is very rarely reached in surface water samples. Elevated ammonia in bottom waters may be an indication of deoxygenation, often in response to excessive algae or other eutrophication measures. This is discussed further in Chapter 5. The NO_3 drinking water standard in New York is 10 mg/l; this is well above the readings found in New York state lakes. For both NO_x and ammonia, readings above 0.3 mg/l could be considered elevated.

Figures 7.1 through 7.6 show the distribution of average TN, ammonia (NH_4), and nitrate + nitrite (NO_x) in CSLAP and LCI lakes across New York and in the Mohawk region from 2012 to 2016. These figures show the highest total nitrogen readings in western, Finger Lakes, Mohawk, Hudson and New York City and Long Island regions, most often associated with elevated algae levels (since much of the nitrogen load in these lakes is found within algae cells). The lowest TN readings are in the Adirondack and Central regions. This generally corresponded to the patterns with NOx and ammonia, although the highest NOx readings were more scattered throughout the same regions. Elevated NH4 readings were mostly associated with western and Mohawk regions, with low ammonia readings found in most waterbodies. These regional patterns are mostly consistent with the statewide phosphorus patterns. This is not coincidental; many sources of phosphorus in lakes- runoff from nutrient-rich soils, wastewater, fertilizers, waterfowl- are also sources of nitrogen.

Within the Mohawk region, the highest TN, NO_x and NH_4 readings are found in the lakes in the southeastern part of the region, although there is limited data in some parts of the region. Given the relatively high algae levels in many of these lakes, it is likely that this reflects relatively low levels of available nitrogen, with most NO_x and NH_4 previously used for algae growth. This is also consistent with higher total nitrogen levels in this part of the region; high TN is associated with high algae levels. As noted in Figure 7.2, low TN limited to the northern and eastern lakes in this region.

Figures 7.7 through 7.9 show that there is a poor correlation between either NOx or ammonia and algae levels (chlorophyll *a*) in most New York state lakes, and in the Mohawk region. There is a strong relationship between total nitrogen and algae levels in New York state lakes, but a flatter and less significant relationship between these indicators in the Mohawk region lakes. It is possible that the relationship between TN and chlorophyll a is a redundant measure of nitrogen levels found within algae cells. The nitrogen to phosphorus ratios in most CSLAP lakes (discussed in Chapter 5) indicate that phosphorus is likely the limiting nutrient in most lakes. However, the relationship between nitrogen and other water quality indicators will continue to be explored as part of water quality assessment and management actions.

pH and alkalinity:

pH is the abbreviation for “powers of hydrogen”, and is a mathematical construct that characterizes the acidity of water on a simple scale. It is the negative logarithm of the hydrogen ion concentration, and is measured on a 14 point scale, from 0 (very highly acidic) to 14 (very highly basic). The effective scale for most waterbodies is 4 to 10, with 7 considered neutral (equal concentrations of hydrogen and hydroxide ions).

The survival of most aquatic organisms is strongly dependent on pH. Many aquatic organisms do not properly function in water with pH below 6.5 or above 8.5, corresponding to the state water quality standards. Aquatic life impacts from low pH are well understood. However, high pH from strongly alkaline inputs or algae blooms (drawing CO_2, a weakly acidic gas, out of the water through respiration) can also stress aquatic life. This sensitivity of aquatic organisms to pH also reflects the sensitivity of some chemical compounds to pH—the sensitivity of fish to low pH water is a function of aluminum compounds, which can clog gills once certain forms of aluminum predominate at lower pH values. Other compounds, such as ammonia, are more highly toxic at elevated pH. A long history of acid rain in the northeastern United States resulted in strong acidification (low pH) and loss of fish in many lakes in New York, pH continues to be too low in many small, high elevation lakes within the Adirondack Park and other highland areas in New York state. However, pH and alkalinity (a measure of the buffering capacity of lakes) levels in these vulnerable lakes have risen over the last two decades in response to federal and state Clean Air Act control measures reducing sulfate (SO_4) and NO_x emissions that result in acid deposition. Some of these lakes have seen the early signs of biological recovery, including increases in phytoplankton and zooplankton populations, and propagation of acid-sensitive fish. It is anticipated that these improvements will continue.

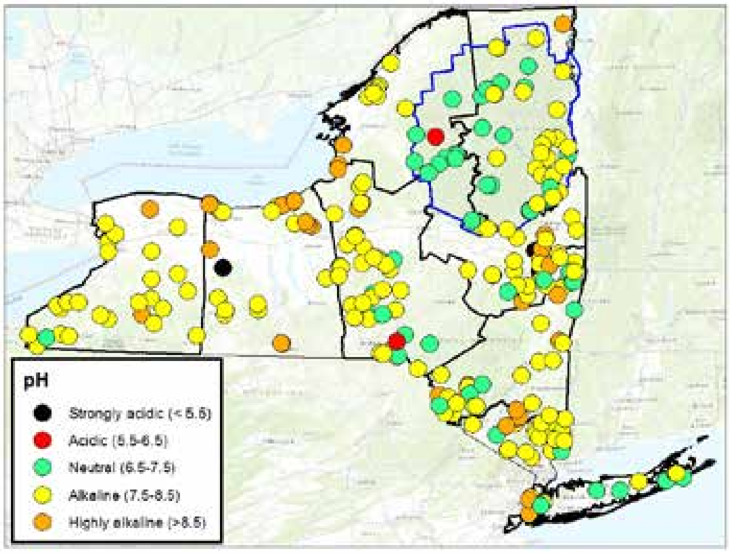


Figure 7.10: pH Distribution in CSLAP and LCI lakes, 2012-16

Nearly all CSLAP and LCI lakes are used by the public, through privately owned lakefront property and visitors to public waterbodies. These waterbodies are generally not found in areas that are sensitive to acidic deposition, due to underlying soils and geology that have sufficient buffering capacity and characteristics that support residential use. Therefore, although pH may play a role in susceptibility to HABs and AIS in some of these lakes, in general pH and alkalinity are not “primary” water quality indicators in these lakes.

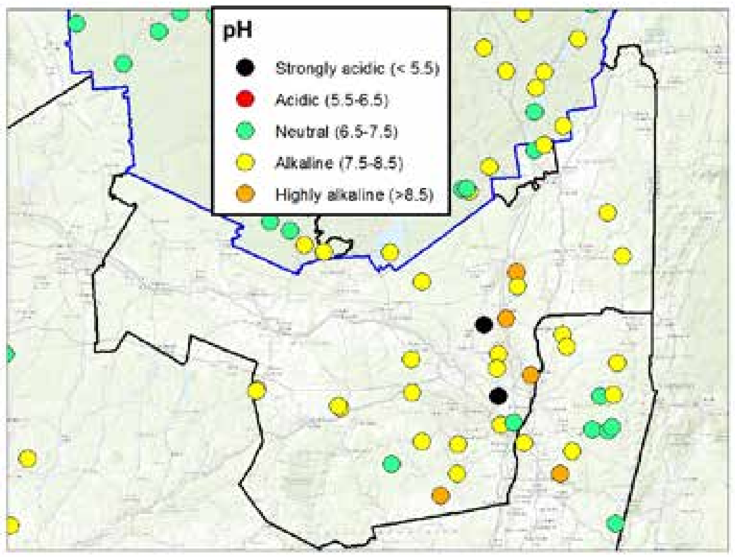


Figure 7.11: pH Distribution in CSLAP and LCI lakes in the Mohawk region, 2012-16

pH is a core water quality indicator in most sampling programs, and has been included in both CSLAP and the LCI since their inception. It is analyzed as a benchtop laboratory test in CSLAP, and over the two decades has been analyzed as a field test in the LCI using a multi-parameter electronic meter. The results from the CSLAP surface samples can be compared to the results from the average of the 1 meter and 2 meter depth profile measurement collected through the LCI.

Figures 7.10 and 7.11 shows the distribution of average pH readings in CSLAP and LCI lakes across New York and in the Mohawk region from 2012 to 2016. Despite the continuing (but decreasing) acidification of small, high elevation lakes in the Adirondack and Catskill region, the CSLAP and LCI dataset contains few acidic lakes. The Adirondack region and Long Island CSLAP and LCI lakes have a higher percentage of neutral lakes (defined as average pH between 6.5 and 7.5), with more alkaline lakes found throughout the state, including the eastern Adirondacks. Alkalinity data (collected in the LCI but not presented here) indicate high buffering capacity at nearly all of these sites, indicating a low vulnerability for future pH changes. Very high conductivity and alkalinity is found in the Finger Lakes and other lakes scattered throughout New York state, but many of these have not been sampled in CSLAP or the LCI in the last five years.

Within the Mohawk region, low pH is found in a few lakes, but most lakes have moderate to highly alkaline condition. These readings are consistent with moderate to high algae levels in some of these lakes. Some pH fluctuations (associated with periodic swings in algae growth) may also be common in these lakes.

A more detailed discussion of pH and acid neutralizing capacity (ANC) in vulnerable regions of New York state, including access to pH, ANC, and other water quality data, can be found in the annual Adirondack Lake Survey Corporation reports, at http://www.adirondacklakessurvey.org/.

Conductivity:

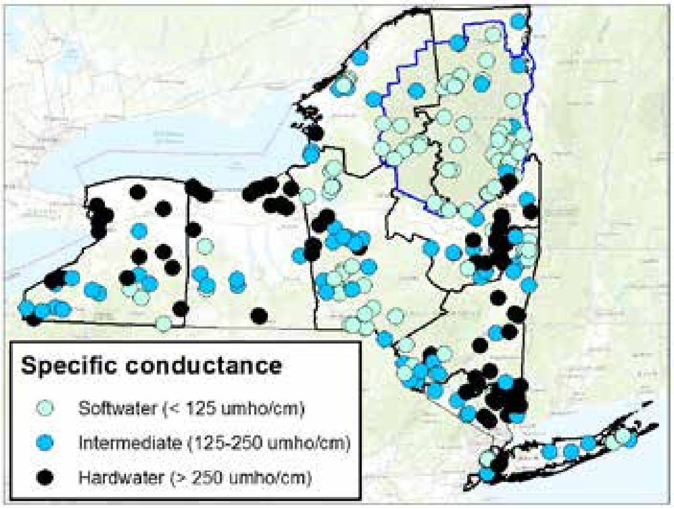


Figure 7.12: Specific conductance distribution in CSLAP and LCI lakes, 2012-2016

Conductivity, reported as specific conductance (and corrected to 25°C), measures the amount of current that can be carried through water (and “conduct” electricity). The current is carried by ions such as sodium, potassium, and calcium, so the conductivity is a rough measure of the number of these ions. It is also closely related to water hardness and alkalinity (buffering capacity), and is usually a characteristic of the geology of the basin surrounding the lake. However, while conductivity itself is not a strong indicator of water quality, changes in conductivity can indicate changes in pollutant inputs to lakes or can change biological habitat, and conductivity can change the way nutrients remain in the water.

It is measured in the laboratory through CSLAP, and in the field using an electronic meter in the LCI, reported as micromhos (or microsiemens) per centimeter, as described in the pH section. Figures 7.12 and 7.13 show the distribution of conductivity in CSLAP and LCI lakes in New York and the Mohawk region from 2012 to 2016. The lowest conductivity, softwater, lakes are found in the Adirondacks and in the Central region. The ALSC study of small, high elevation lakes also indicated very low conductivity lakes in the Adirondack and Catskill regions, rendering these lakes susceptible to small inputs of acid deposition. The highest conductivity readings are found along the southern and western edges of the state, particularly in the Lower Hudson, Western, and Mohawk regions. Extremely high conductivity is also found in the Finger Lakes, but as noted above, most of these were not sampled through CSLAP or the LCI in the last five years.

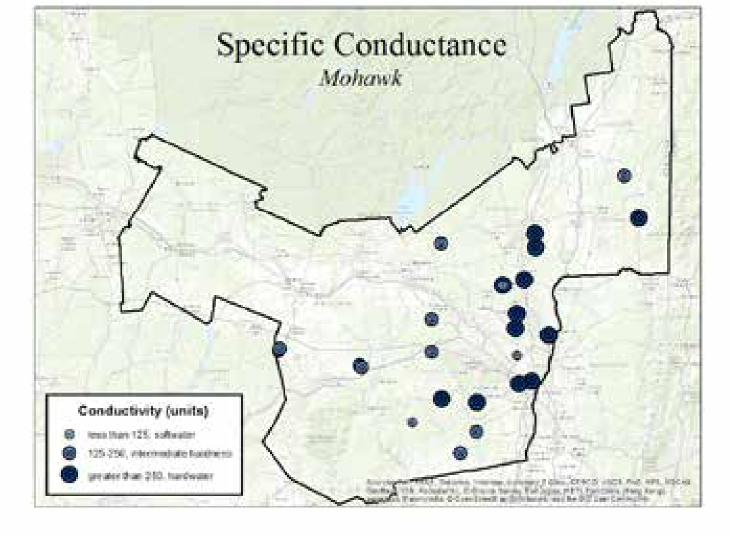


Figure 7.13: Specific conductance distribution in CSLAP and LCI lakes in the Mohawk region, 2012-2016

Figure 7.13 shows that higher conductivity readings, associate with hardwater, is found in lakes in the eastern portion of the Mohawk region. Softwater lakes are less common (or have not been monitored through these programs) in this region.

Table 7.1 shows the average conductivity for all New York state lakes (sampled over the last thirty years through a variety of programs), and those lakes sampled within the last five years. This table includes data from some brackish or salt intrusion lakes in Long Island prior to 2012 (significantly increasing the regional average), as well as the large number of ALSC lakes sampled in the Adirondack region. These data show that just under 25% of the CSLAP lakes have experienced an increase in conductivity in recent years, although this number is highly variable across the state. More than half of the Mohawk region lakes with more than five years of data have exhibited an increase in conductivity, compared to less than about 20% in any other region. It is not known if this reflects changes in runoff patterns (including changes in precipitation), land use changes, or biological interactions that result in more extensive ionic exchange in these lakes. These (apparent) changes in conductivity do not correspond to similar changes in any of the other water quality

Table 7.1- Regional summary of conductivity for all NYS lakes, and 2012-2016 sampled lakes

Region	# All Lakes	Cond All Lakes	# 12-16 Lakes	Cond 12-16 Lakes	% CSLAP Lakes ↑ Cond
NYS	**2488**	**83**	**486**	**121**	**23%**
NYC-LI	96	707	27	121	0%
Lower Hudson	149	219	48	282	60%
Mid-Hudson	176	138	49	135	20%
Mohawk	91	226	29	303	0%
Eastern Adirondacks	780	44	109	56	21%
Western Adirondacks	904	31	88	49	18%
Central NY	108	163	55	156	15%
Finger Lakes	75	273	42	257	0%
Western NY	109	247	38	245	14%

% ↑ Cond refers to the percentage of CSLAP lakes in each region showing a statistically significant increase in annual average over at least five years of sampling, defined as a regression coefficient (R^2) > 0.3 and a p-value < 0.05

indicators measured through CSLAP (although calcium and chloride data collections are not sufficiently extensive to determine if this pattern is apparent with individual ions). However, this long-term trend appears to be borne out by Figure 7.14 showing a mostly steady long-term increase in conductivity in CSLAP lakes in the Mohawk region since 1986 (with some mid-2000s deviations), particularly in the last three years (see the text around Figure 5.5 for a detailed explanation for how to interpret this figure).

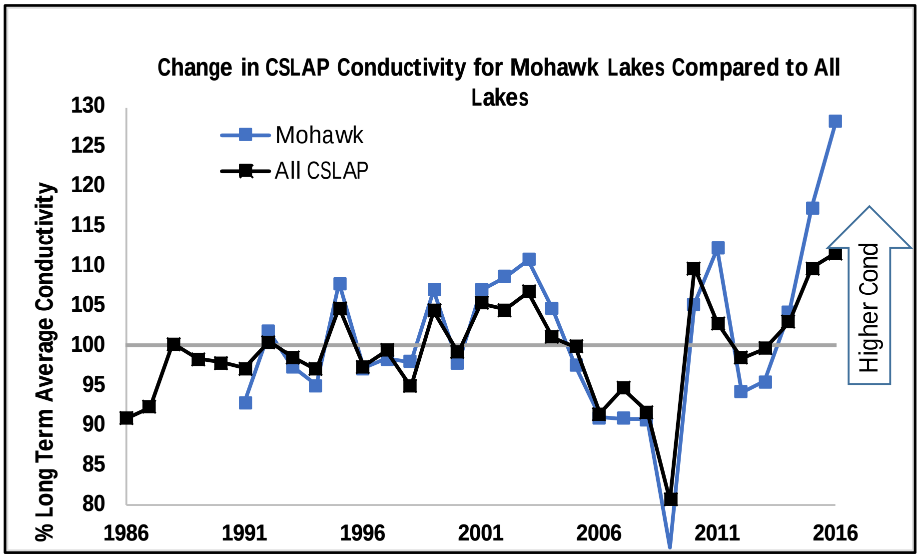


Figure 7.14: Long term change in conductivity levels in the Mohawk region relative to all CSLAP lakes, 1986-2016

Additional data analysis at individual lakes or on a statewide basis will help to determine if changes in conductivity are bellwethers for changes in other water quality indicators, particularly those related to eutrophication (nutrient levels) or aquatic life (calcium or chloride levels).

Color:

Water color is a surrogate for dissolved organic carbon, and is manifested in a brownness in the water associated with weak organic (tannic and fluvic) acids. These weak acids are derived from organic soils or heavily vegetated wetlands or littoral areas in the lake, and can result in slightly depressed pH. However, these are most apparent when elevated brownness limits the transparency of the water. When lakes have high levels of dissolved organic matter, they are often referred to as *dystrophic*, indicating that this conditions influences the evaluation of trophic state (since phosphorus readings, chlorophyll a values, and water clarity are not as balanced as in other *clear water*- or even greenish- lakes). Many of the small, high elevation, weakly to strongly acidified lakes in the western Adirondack region are highly colored, with a natural “tea” coloration. These lakes are not well represented in CSLAP or the LCI, since they are usually remote or have very limited public use. In fact, most CSLAP and LCI lakes are either not highly colored, or have color readings that do not appear to affect water clarity.

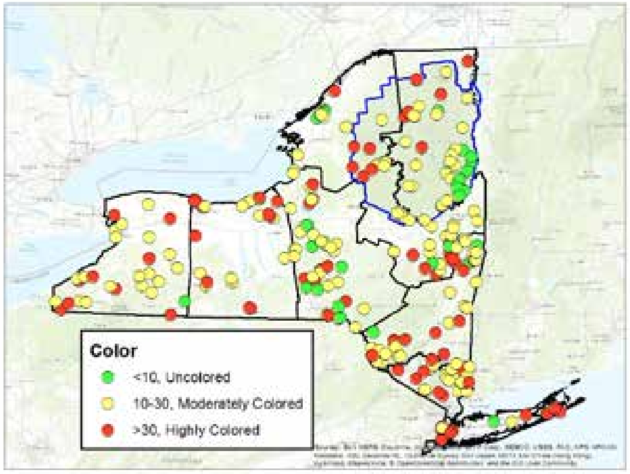


Figure 7.15: Color distribution in CSLAP and LCI lakes, 2012-2016

Strong water color is not strongly linked to public water quality perception, since dissolved color is often “natural” in many lakes. However, changes in color can indicate changes in runoff patterns to lakes, and may be considered a problem. High color can be negatively correlated to conductivity, since dissolved organic matter is often comprised of neutrally charged particles that do not carry current.

Color has been analyzed visually in CSLAP and LCI samples in the laboratory against known standards of platinum cobalt solution, measuring relative brownness of the water. The CSLAP samples are filtered in the field, and the LCI samples are filtered in the laboratory.

Figure 7.15 shows the distribution of color readings in CSLAP and LCI lakes from 2012 to 2016. The highest color readings are found in the western Adirondacks (associated with dystrophic, or tea colored lakes), and in other locations where color may be comprised of both algae or other “greenness” that might pass through filters, and the same natural brownness found in the western Adirondacks. The CSLAP and LCI results are somewhat different, with LCI color readings higher than those found in CSLAP lakes. There is some evidence that the differences in field processing, and the different laboratories, may yield inconsistent results. However, there is little evidence that color readings in many of the CSLAP or LCI lakes are high enough to adversely affect measured water transparency. Additional monitoring might be needed to determine if this apparently elevated water color affects other lake uses, including drinking water or aquatic life.

Calcium:

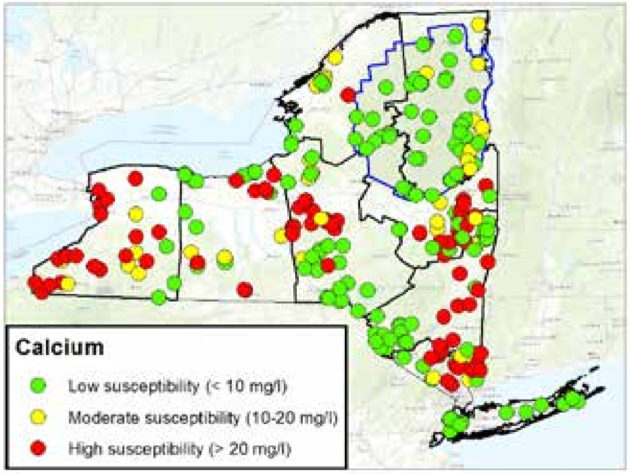


Figure 7.16: Calcium distribution in CSLAP and LCI lakes, 2012-2016

Calcium has been sampled through CSLAP since 2002, and periodically through the LCI. It is a trace metal closely associated with limestone geology and strongly buffered, alkaline lakes. It can be considered a surrogate for alkalinity, or buffering capacity—lakes with high calcium levels are generally immune to swings in pH due to acid rain or other acidic inputs to lakes. Calcium is also a micronutrient required by freshwater mussels to grow their shells, and calcium may be one of the most significant limiting factors to colonization by zebra mussels. It is fairly stable in most lake systems, so it is analyzed in only two samples per year, although calcium levels may vary significantly spatially within a lake, due to inputs from concrete, lime or limestone leaching. Open water calcium levels may be significantly lower than those measured near developed shorelines, thus underestimating the potential for “microhabitats” for zebra mussels.

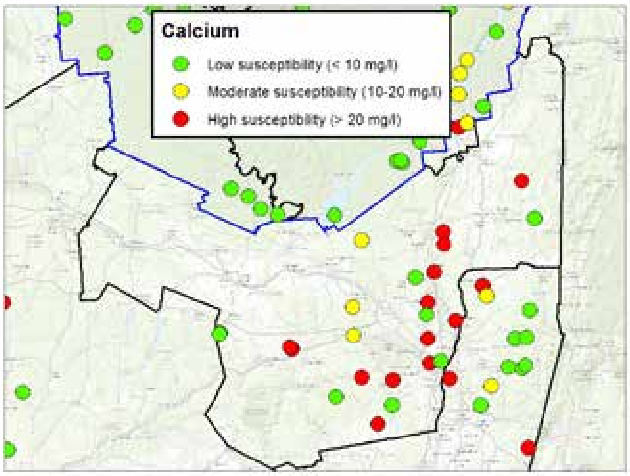


Figure 7.17: Calcium distribution in CSLAP and LCI lakes in the Mohawk region, 2012-2016

Figures 7.16 and 7.17 show the distribution of calcium readings in CSLAP and LCI lakes from 2012 to 2016; some of the LCI lakes were not analyzed for calcium within the last five years. These data show low calcium readings in many Adirondack lakes and in other softwater lakes; the lowest readings correlate well with the distribution of conductivity readings in Figures 7.4 and 7.15. These correspond to lakes with a low vulnerability to zebra mussel infestations, even if the veligers (the larval form of zebra mussels) enter the lake. However, some of these lakes may be susceptible to localized (probably small) zebra mussel populations on concrete walls, near the mouth of streams, and other nearshore sources of calcium.

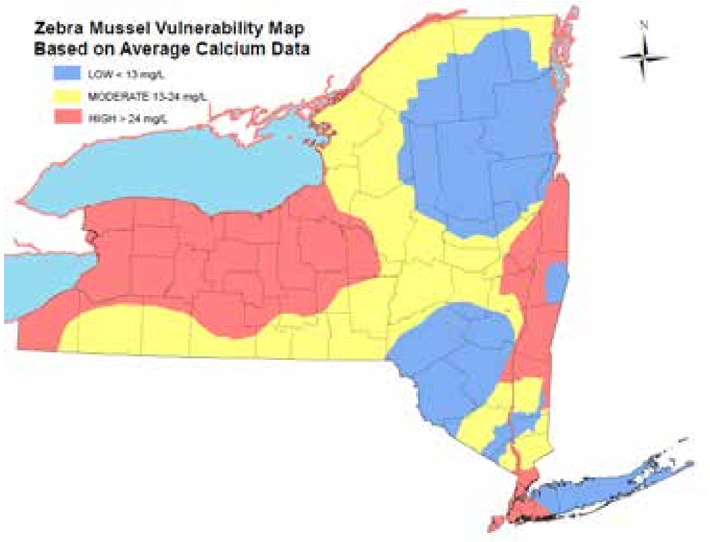


Figure 7.18: New York state zebra mussel vulnerability (DEC 2014)

Calcium levels are moderate to high in lakes in the Mohawk region, with the highest readings (and highest vulnerability for zebra mussels) found in lakes and ponds near the Hudson and Mohawk Rivers. To date, zebra mussels have not been reported in most of the lakes in the Mohawk region, although Figure 7.17 suggests that these lakes, particularly in the eastern part of the region, may be candidates for zebra mussel infestations.

The CSLAP and LCI data, along with other New York state data sources, was used to develop New York state zebra mussel vulnerability maps, shown in Figure 7.18. There remains some debate about the calcium thresholds separating high, moderate and low vulnerability, but these statewide maps identify the larger geographic regions that are most and least likely to have lakes with these invasive animals. The results in Figures 7.16 and 7.18 appear to be similar, although Figure 7.16 shows that there may be individual lakes with elevated calcium levels within regions associated with low calcium lakes. There is some discrepancy between these two statewide maps, due to some differences in defining the thresholds for zebra mussel susceptibility (due to recognition of localized calcium sources in some lakes with overall calcium levels that otherwise have a low vulnerability) and due to some recent calcium data collected since the map in Figure 7.18 was generated.

Chloride:

Chloride is a constituent of road deicing agents (road salt), intrusion from salt water, wastewater and other inputs to lakes. It can be highly corrosive to metal, and may adversely affect aquatic life. It has only been sampled through CSLAP since 2015 (and only twice per year- in early and late summer) and only periodically through the LCI over the last five years. Recent concerns about rising chloride levels in some Adirondack lakes has prompted the additional of chloride in monitoring programs.

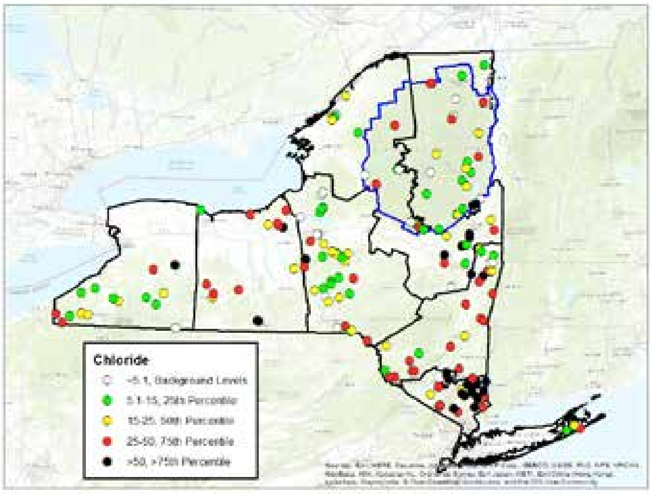


Figure 7.19: Chloride distribution in CSLAP and LCI lakes, 2012-2016

The New York state drinking water standard for chloride is 250 mg/l, values rarely measured in New York state lakes. No standards exist for protection of aquatic life, although this is an active area of research in the northeastern United States.

Figure 7.19 shows the distribution of chloride levels in New York state lakes sampled through CSLAP and the LCI since 2012. These data are divided by quartiles, with values below 5 mg/l approaching background levels for lakes. These readings show the highest chloride levels in the downstate region, corresponding to the highest population centers (and likely greater use of road salt due to extensive roadways and associated traffic). Lower chloride levels are scattered throughout the state. Additional biological data will need to be collected to determine the impact of road salt on aquatic life, and to identify thresholds associated with elevated risk for these biota.

Temperature:

Water temperature is the primary influence and measure of the thermal properties of a lake. Given the relative stability of water temperature readings, these readings are assumed to be representative of thermal conditions at the time of sampling.

Water temperature is an indicator of several important lake functions. Biological productivity is enhanced by rising temperature in the range found in most freshwater systems. Algae production generally increases as air and water temperatures increase, leading to higher oxygen demands when these algae die and are broken down by bacteria. In turn, as water temperatures increase, the amount of oxygen that can dissolve in water decreases, accelerating the biological stress on lake biota susceptible to low oxygen and high temperature conditions. Temperature changes also select for specific organisms, including introduced (warmer climate) aquatic invasive species (AIS) and some cyanobacteria. Rising air and water temperatures are also a response to global climate change, and can strongly influence the duration and intensity of ice cover, which in turn can influence growing seasons, water movement, and light transmission through the lake water column.

Temperature measurements are a fundamental part of all lake monitoring programs, and water temperature readings are often collected at the surface and at multiple depths. CSLAP samplers collect air temperatures, and water temperatures readings from surface and bottom samples, immediately after sample collection using a dial bimetal pocket thermometer. Electronic meters are used in the LCI to collect temperature profiles in one meter increments from the surface to the lake bottom.

With some exceptions, water temperature readings in New York state largely reflect a combination of latitude, elevation, and lake volume (particularly water depth). However, trends in water temperature readings at the surface and lake bottom are most likely to provide some indication of local climate and associated biological stress. However, the intra-annual variability in temperature is usually larger than the small annual differences from climate change.

Table 7.2: Regional changes in water temperatures in CSLAP lakes with longer datasets

Regions	%Lakes>10 yrs data with ↑ temp	%Lakes>10 yrs data with ↑↑ temp	%Lakes>20 yrs data with ↑ temp	%Lakes>20 yrs data with ↑↑ temp
NYS	**27% (29)**	**9% (10)**	**27% (10)**	**11% (4)**
NYC-LI	0% (0)	0% (0)	0% (0)	0% (0)
Lower Hudson	42% (5)	25% (3)	50% (2)	25% (1)
Mid-Hudson	36% (4)	18% (2)	33% (1)	33% (1)
Mohawk	50% (3)	0% (0)	50% (2)	0% (0)
Eastern Adirondack	13% (3)	4% (1)	0% (0)	0% (0)
Western Adirondack	25% (4)	6% (1)	17% (1)	17% (1)
Central NY	29% (7)	4% (1)	33% (3)	0% (0)
Finger Lakes	33% (2)	33% (2)	50% (1)	50% (1)
Western NY	14% (1)	0% (0)	0% (0)	0% (0)

↑ = moderately significant increase; ↑↑ = strongly significant increase
Number of lakes in each region listed in parentheses

Table 7.2 shows the percentage of CSLAP lakes sampled within the last five years in each region exhibiting weak and strong long-term trends in water temperatures. Only lakes sampled more than 10 years and more than 20 years are shown in the table. There are few lakes with long-term datasets in some of these regions, and in these regions, water temperature trends can’t be evaluated. However, on a statewide basis, and in some regions, the number of lakes exhibiting moderate to strong long-term increases over the last 10-20 years is significant. There does not appear to be stronger evidence of long-term temperature increases in the lakes with the larger (longer) datasets, although this may become apparent with more data. This does suggest that the rise in water temperature has been most significant in the last ten years.

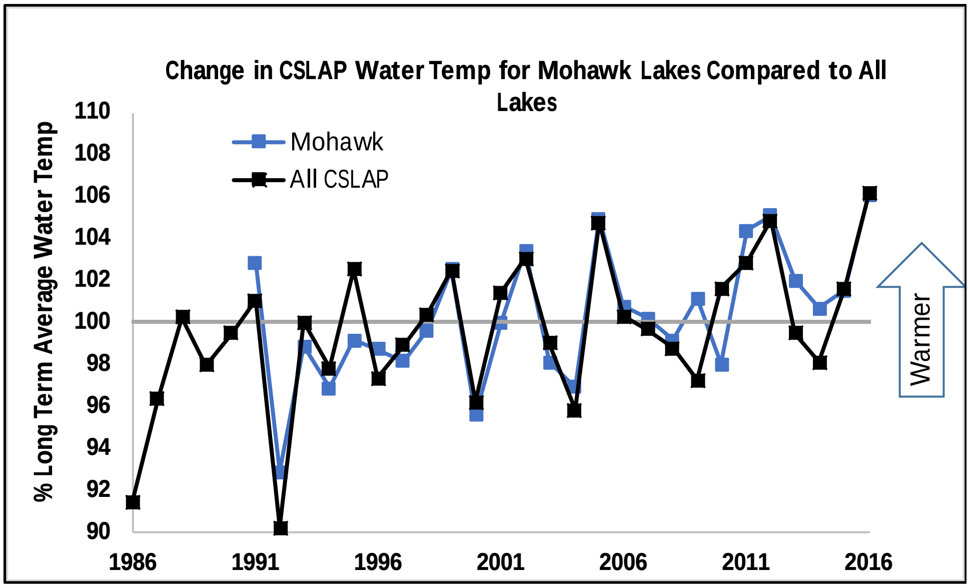


Figure 7.20: Long term change in water temperature in the Mohawk region relative to all CSLAP lakes, 1986-2016

Additional evidence of long-term increases in water temperate in New York state and in the Mohawk region is also found in Figure 7.20. This figure shows the comparison of average water temperatures in each CSLAP lake in each year compared to the long-term water temperatures for these lakes. Annual readings above 100 indicate higher than normal water temperatures for the typical lake sampled that year, while readings below 100 indicate lower temperatures. Figure 7.20 shows that water temperatures in statewide CSLAP lakes and Mohawk River basin lakes generally track each other, with variations from year to year. However, there appears to be an overall trend toward increasing water temperatures in the last thirty years, with higher than normal readings in each of the last few years. However, the readings in 2016 may have been close to the long-term average for the region.

The long-term change in water temperatures in New York state and CSLAP lakes will continue to be studied. This CSLAP data should be supplemented by ice in-ice off dates and consistent measurements of deepwater temperatures to document these potential impacts from local and global climate change.

Chapter 8: Aquatic Invasive Species (AIS)

The flora (plants) and fauna (animal) communities in lakes are a critically important component of aquatic ecosystems. Aquatic plants protect water quality and the use of lakes for drinking water, recreation, and other aquatic life by filtering pollutants, retaining sediment, providing oxygen, habitat, cover and food for fish, mammals and invertebrates, and other vital ecological functions. Removal of these plants can trigger ecological problems, whether due to intentional removal, ancillary measures that indirectly affect plant communities, or replacement by invasive species. The loss of native plant communities by discriminate or indiscriminate means represents a problem in many lakes, and may be an increasing consequence of eutrophication, sediment loading, climate change, and other water quality changes. However, the introduction of invasive species represents a significant threat to native plant communities and ecological health.

The timeline for the introduction of aquatic invasive species is not well understood, but dates at least to the introduction of water chestnut (*Trapa natans*) to Sanders Pond in the Mohawk River basin in the 1880s and Brazilian elodea (*Egeria densa*) in Long Island in the 1890s. The confluence of many waterbodies (between 7500 and 16,000 lakes, ponds, and reservoirs), extensive marine (Atlantic Ocean, Long Island Sound, and Hudson River) and Great Lakes (Lakes Ontario and Erie) ports, network of canals and highways, large population base, hundreds of public and private boat launches, and wide variety of aquatic habitats, creates a perfect storm for the migration of AIS into and within the state.

Monitoring for AIS

AIS monitoring is not a required component of CSLAP sampling. However, many CSLAP volunteers have surveyed their lake for aquatic plants generally, and AIS plants specifically, since the mid-1980s. For many years, a large percentage of AIS “hits” in New York state came from CSLAP volunteers, although this percentage has decreased in response to enhanced volunteer and professional surveillance throughout the state. CSLAP volunteers will collect voucher specimen or digital photos of suspicious plants or mussels and send them to NYSDEC for identification and documentation in iMapInvasives, the state AIS database. This survey work has been done by combinations of rake toss sampling, diver surveys, “Drop a Brick” programs, documentation of plant or mussel wash along the shorelines or near launches, and even casual observations. In 2016, NYSFOLA developed a “Shoreline Plant Protocol” to standardize and focus AIS surveillance efforts to those areas where AIS are likely to be observed- boat launches, public access points, weed beds, and other nearshore areas. Most AIS animal findings in iMap Invasives are not derived from CSLAP; aquatic animal surveying has been conducted by DEC Fisheries staff or other resource managers.

Statewide Distribution

Table 8.1 shows the number of reported waterbodies with the major invasive aquatic plants and animals as of 2016, the date of the first known reports of the organism in New York state, and a summary of their distribution within New York state. The introduction of invasive aquatic animals is better documented than for aquatic plants, although the initial sighting of the major aquatic plants can probably be pinned to a particular decade. Table 8.1 shows the widespread distribution of Eurasian watermilfoil, curly-leafed pondweed, water chestnut, and the common carp, with documented locations of each in excess of 100 waterbodies throughout New York. Some of these invasive species have only recent migrated into some parts of the state- Eurasian watermilfoil moving into Long Island and water chestnut moving westward, for example- and the habitat for these species may be limited by water chemistry, flow, depth, or other factors for several of these invaders. However, the widespread distribution of these AIS indicates a high susceptibility of most waterbodies to introduction from a variety of vectors, particularly boat traffic, hydrologic connections, and waterfowl spread. Figures 8.1 and 8.2 show the statewide distribution of the known AIS plants and animals, as well as a few of the individual major AIS species.

Table 8.1a: Most common AIS plants in New York state waterbodies

Type	Common Name	Scientific Name	# NY Sites	First NY Report	Summary of Distribution
Plant	Eurasian watermilfoil	*Myriophyllum spicatum*	414	1940s	Throughout state; less common Long Island, high elevation and acidic lakes
Plant	Curly-leafed pondweed	*Potamogeton crispus*	238	1890s	Similar distribution to EWM; may be underreported due to early summer dieoff
Plant	Water chestnut	*Trapa natans*	155	1882	Common along Hudson/ Mohawk/ Champlain corridor and rivers; moving west
Plant	Variable leaf watermilfoil	*Myriophyllum heterophyllum*	81	Native?	Scattered throughout eastern/southern part of state; tolerant of softwater acid conditions
Plant	Brittle naiad	*Najas minor*	60	1940s	Scattered; more common along Hudson corridor (pioneering locations)
Plant	Fanwort	*Cabomba caroliniana*	48	1940s	Mostly Long Island / southern NY; scattered elsewhere; soft and weakly acidic waters
Plant	European frog bit	*Hydrocharis morsus-ranae*	43	1982	Margins of state- St. Lawrence and Lake Champlain regions; little interior NY movement
Plant	Hydrilla	*Hydrilla verticillata*	25	2008	Most often found in Long Island, but scattered; major sites near Cayuga Lake, Erie Canal
Plant	Brazilian elodea	*Egeria densa*	17	1893	Most often found in Long Island; little migration north of Lower Hudson region

Table 8.1b: Most common AIS animals in New York state waterbodies

Type	Common Name	Scientific Name	# NY Sites	First NY Report	Summary of Distribution
Animal	Common carp	*Cyprinus carpio*	177	1830	Distributed throughout state
Animal	Zebra mussels	*Dreissena polymorpha*	94	1989	Primarily Great Lakes, Finger Lakes, and along the Mohawk / Hudson corridor; not found in softwater sites
Animal	Goldfish	*Carassius auratus*	50	1842	Throughout New York, but limited in the Adirondacks; most common central/western NY
Animal	Asian clam	*Corbicula fluminea*	45	1977	Scattered distribution throughout state, but limited distribution in the Adirondacks
Animal	Rudd	*Scardinius erythrophthalmus*	38	1897	Limited downstate distribution
Animal	Virile crayfish	*Orconectes virilis*	16	1928	Mostly SE Adirondacks and western NY
Animal	Quagga mussels	*Dreissena rostriformis bugensis*	8	1991	Mostly in western and central NY lakes, particularly in deeper water
Animal	Spiny water flea	*Bythotrephes longimanus*	8	1985	Great Lakes and adjacent waters; found in southeastern Adirondack region

Figure 8.1: AIS plants in NYS

Figure 8.2: AIS animals in NYS

Among the less common AIS, hydrilla and quagga mussels represent a particularly significant statewide threat due to their highly invasive nature, colonization of multiple (hydrilla) or novel (quagga mussels) environmental niches, and the extreme difficulty in managing rapid infestations associated with their introduction. These organisms have only been found in limited, and in the case of hydrilla, seemingly random, locations, but the risk of spread is very high for both.

Table 8.1 and Figures 8.1 and 8.2 indicate that AIS are widespread throughout New York, and the large percentage of unsurveyed lakes and rivers suggest that the actual AIS maps are probably more crowded, particularly in those portions of the state (such as the "Mid Hudson" and "Lower Hudson" regions) with a large number of interconnected waterbodies, large population bases with heavy usage patterns, ideal water chemistry for AIS (for most AIS, alkaline, turbid water), and longer growing seasons. Those sections of the state showing “holes” in the maps represent a combination of fewer waterbodies (the Finger Lakes region and western New York), limited survey information (the Catskills and portions of the mid Hudson region) and reduced susceptibility due to unfavorable (for AIS) water chemistry or limited access (the Adirondack region). However, as noted in Table 8.2 and Table 8.3, AIS plants and animals are common in each region in New York state, although the distribution of specific AIS differ from region to region.

Table 8.2: Regional distribution of AIS Plants

Region	**Number of Waterbodies (Lakes, Ponds, Streams,…) with**									
	Any AIS Plant	EWM	CLP	Water chestnut	VLM	Brittle naiad	Fanwort	EFB	Hydrilla	Brazilian elodea
NYC_LI	64	5	10	4	12	4	27	1	10	11
Lower Hudson	96	56	36	21	13	11	7	0	3	5
Mid Hudson	82	50	26	41	0	7	4	2	0	0
Mohawk	75	38	38	45	0	9	0	2	0	1
Eastern Adirondacks	83	60	17	4	16	7	4	8	0	0
Western Adirondacks	56	30	12	4	21	5	0	13	0	0
Central NY	69	55	27	9	7	4	3	5	2	0
Finger Lakes	83	65	34	19	6	7	0	9	7	0
Western NY	48	38	25	1	0	5	0	1	1	0

Data reflect waterbody occurrences documented in iMapInvasives
EWM = Eurasian watermilfoil; CLP = Curly leaf pondweed; VLM = Variable leaf watermilfoil; EFB = European frogbit

Regional Distribution- Mohawk Region

Several AIS species are common to the Mohawk Region, due to many lakes in proximity to several major road (New York State Thruway and the Adirondack Northway) and water (Hudson River, Mohawk River, Erie Canal) pathways, and habitat and water chemistry conditions favorable to AIS. The Mohawk Region was the first with water chestnut in New York state (and perhaps North America), and several other AIS migrated to the region many years ago. Each of the major AIS species in New York state can be found in this region, and any perceived limits to the distribution of these species within the region is likely due to incomplete local survey data.

Tables 8.2 and 8.3 show the regional distribution of the major New York state AIS plant and animal species. Invasive aquatic plants and animals are common within the region. The large number of waterbodies with AIS plants in the Mohawk region reflects the movement of water chestnut and “northern” species (Eurasian watermilfoil and curly leafed pondweed) throughout the region. Several AIS animals are found in the region,

Table 8.3: Regional distribution of AIS Animals

Region	Number of Waterbodies (Lakes, Ponds, Streams,…) with								
	Any AIS Animal	Common carp	Zebra mussels	Goldfish	Asian clam	Rudd	VCF	Quagga Mussels	SWF
NYC_LI	42	25	0	16	7	1	0	0	0
Lower Hudson	27	9	5	2	2	1	3	0	0
Mid Hudson	25	9	9	1	2	3	4	0	0
Mohawk	30	11	14	2	2	0	5	0	0
Eastern Adirondacks	16	4	4	1	1	2	1	0	4
Western Adirondacks	32	21	5	0	0	6	1	0	2
Central NY	59	31	16	3	15	2	1	0	0
Finger Lakes	63	36	27	15	12	7	0	6	1
Western NY	43	31	10	8	4	7	1	1	1

Data reflect waterbody occurrences documented in iMapInvasives and USGS databases
VCF = virile crayfish; SWF = spiny waterflea

particularly zebra mussels (most likely due to movement associated with the Mohawk or Hudson rivers). Virile crayfish are found in more lakes in this region than in any other region, although it is uncommon in all regions. It is not known if this reflects under reporting of animals, since the surveillance, monitoring and reporting of AIS animals is outside the purview of CSLAP and LCI monitoring. As more data are collected and reported to iMapInvasives, it is anticipated that ‘holes’ in these maps will fill with new AIS reports.

Table 8.4 shows the waterbodies within the Mohawk Region for which AIS have been documented. As in most parts of the state, AIS animal reports in the NYC-LI are dominated by invasive fish. Zebra mussels appear to be limited to the Hudson River or nearby waterbodies, despite the favorable water chemistry conditions in the region (see Figures 5.2 and 7.13).

Susceptible waterbodies

As noted in Figure 5.2 and Table 7.1, the typical lake in the Mohawk Region has moderate to elevated nutrient levels, moderate hardness, and alkaline water. These conditions typically support most of the AIS reported in New York state, whether transported from the more temperate climates to the south or the northern portions of the state. The proximity of most waterbodies in the region with no documented AIS to those with one or more AIS species indicates an overall high susceptibility to AIS infestations. At particular risk are those waterbodies with public or private boat launches, waterbodies hydrologically connected to other infested waterbodies, those along waterfowl flyways, and those near the Hudson or Mohawk Rivers or along the major travel corridors, particularly the New York State Thruway and the Adirondack Northway. Additional surveillance should be conducted throughout the region, with a particular focus on the western portion of the region (Schoharie, Fulton, Montgomery, and especially Herkimer and Otsego Counties), to determine if AIS are more widespread than reported through iMapInvasives or the USGS invasives database.

Table 8.4: Mohawk region waterbodies with documented AIS

Lake Name	County	AIS Plants	AIS Animals
Alcove Reservoir	Albany	Eurasian watermilfoil	
Ann Lee Pond	Albany	Eurasian watermilfoil, curly leafed pondweed, water chestnut	
Anthony Kill	Saratoga	water chestnut	common carp
Ballston Lake	Saratoga	Eurasian watermilfoil, water chestnut	zebra mussels
Barkley Pond	Washington	curly leafed pondweed, water chestnut	
Basic Creek Reservoir	Albany	Eurasian watermilfoil, curly leafed pondweed	virile crayfish
Batten Kill	Washington		zebra mussels
Beaver Pond (Five Rivers)	Albany	water chestnut	
Blatnick Pond	Schenectady	curly leafed pondweed, water chestnut	
Blenheim Gilboa Reservoir	Schoharie		common carp
Buckingham Pond	Albany	water chestnut	
Central Bridge Reservoir- Lower	Schoharie	curly leafed pondweed	
Central Bridge Reservoir- Upper	Schoharie	curly leafed pondweed, Eurasian watermilfoil, water chestnut	
Champlain Barge Canal	Washington	Eurasian watermilfoil, water chestnut	Asian clam, common carp
Collins Lake	Schenectady	curly leafed pondweed, Eurasian watermilfoil, water chestnut	
Cossayuna Lake	Washington	Eurasian watermilfoil, curly leafed pondweed, water chestnut, brittle naiad,	zebra mussels
Crystal Lake	Albany	Eurasian watermilfoil	
Duane Lake	Schenectady	curly leafed pondweed	
Duck Pond	Schenectady	Eurasian watermilfoil	
Engleville Pond - Lower	Schoharie	curly leafed pondweed	
Engleville Pond - Upper	Schoharie	curly leafed pondweed	
Erie Canal	Herkimer		zebra mussels
Erie Canal	Montgomery		zebra mussels, common carp
Fawn Lake	Albany	water chestnut	
Featherstonhaugh Lake	Schenectady	Eurasian watermilfoil	
Finch Marsh	Washington	water chestnut	
Fish Creek	Saratoga		common carp

Lake Name	County	AIS Plants	AIS Animals
Five Rivers ornamental pond	Albany	Brazilian elodea (may be extirpated)	
Franklinton Vlae Pond	Schoharie	curly leafed pondweed	
Fuller Pond	Schoharie	curly leafed pondweed, water chestnut	
Fulmer Creek	Herkimer		common carp
Galway Lake	Saratoga	Eurasian watermilfoil, water chestnut, brittle naiad	
Hedges Lake	Washington	Eurasian watermilfoil, curly leafed pondweed	zebra mussels
Helderberg Lake	Albany	curly leafed pondweed	
Heron Pond (Five Rivers)	Albany	water chestnut	
Hills Pond	Washington	brittle naiad, curly leafed pondweed	
Hoosic River	Washington		common carp
Hudson River	Albany	Eurasian watermilfoil, water chestnut	zebra mussels, Asian clam, common carp, goldfish
Hudson River	Saratoga	Eurasian watermilfoil, water chestnut	virile crayfish
Ida Lake	Saratoga	water chestnut	
Ilion Reservoir Number Three	Herkimer	curly leafed pondweed	
Iroquois Lake	Schenectady	brittle naiad, curly leafed pondweed, Eurasian watermilfoil, water chestnut,	virile crayfish
Kayaderosseras Creek, near Greenfield	Saratoga		virile crayfish
Kyser Lake	Herkimer	curly leafed pondweed	
Lake Lauderdale	Washington	Eurasian watermilfoil	
Lake Myosotis	Albany		rusty crayfish
Lawson Lake	Albany	curly leafed pondweed, water chestnut	
Little Round Lake	Saratoga	brittle naiad, Eurasian watermilfoil, water chestnut	
Littles Lake	Albany	curly leafed pondweed, Eurasian watermilfoil, water chestnut	
Lock 13 Pond (NYS Thruway)	Montgomery	brittle naiad	
Mariaville Lake	Schenectady	Eurasian watermilfoil	
Mayfield Lake	Fulton	Eurasian watermilfoil, curly leafed pondweed, brittle naiad	
Mohawk River	Schenectady	Eurasian watermilfoil, water chestnut	
Mohawk River	Albany	water chestnut	
Mohawk River	Herkimer		common carp
Mohawk River	Schenectady		zebra mussels, common carp
Moreau Lake	Saratoga	Eurasian watermilfoil	

Lake Name	County	AIS Plants	AIS Animals
Murphy Pond	Saratoga	Eurasian watermilfoil, curly leafed pondweed, water chestnut	
Onderdonk Lake	Albany	curly leafed pondweed	
Rensselaer Lake	Albany	brittle naiad, curly leafed pondweed, Eurasian watermilfoil, water chestnut,	
Round Lake	Saratoga	Eurasian watermilfoil, water chestnut, brittle naiad	
Sanford (Colonie Library) Pond	Albany	Eurasian watermilfoil, water chestnut	
Saratoga Lake	Saratoga	Eurasian watermilfoil, curly leafed pondweed, water chestnut	zebra mussels, common carp, goldfish
Schoharie Reservoir	Schoharie		rusty crayfish
Steinmetz Lake	Schenectady	curly leafed pondweed, Eurasian watermilfoil	
Stony Creek Reservoir	Saratoga	Eurasian watermilfoil, water chestnut	
Sugarloaf Pond	Saratoga	water chestnut	
Summit Lake	Washington	Eurasian watermilfoil, curly leafed pondweed	zebra mussels
SUNY Albany Pond	Albany	water chestnut	
Thompsons Lake	Albany	Eurasian watermilfoil, curly leafed pondweed	zebra mussels, rusty crayfish, virile crayfish
Tivoli Lake	Albany	curly leafed pondweed, water chestnut	
unnamed pond Rt 41	Schoharie	curly leafed pondweed, water chestnut	
Unnamed tributary to Mohawk River	Herkimer	curly leafed pondweed	
Van Patten's Pond	Saratoga	water chestnut	
Vly Creek Reservoir	Albany	curly leafed pondweed, water chestnut	
Warners Lake	Albany	Eurasian watermilfoil, curly leafed pondweed, water chestnut	zebra mussels
Watervliet Reservoir	Albany	curly leafed pondweed, Eurasian watermilfoil, water chestnut	
Weaver Lake	Herkimer	Eurasian watermilfoil, European frogbit	green sunfish
White Birch Pond	Albany	water chestnut	
Whitehall Launch, Champlain Barge Canal	Washington	Eurasian watermilfoil, European frogbit, water chestnut	
Wood Creek	Washington	water chestnut	
Wood Lake Apartments Ponds	Albany	water chestnut	
Woodland Lake	Saratoga	curly leafed pondweed	
Woodlawn Preserve Pond	Schenectady	curly leafed pondweed	
Woods Pond	Albany	water chestnut	

Lake Name	County	AIS Plants	AIS Animals
Young Lake	Herkimer	curly leafed pondweed, Eurasian watermilfoil	

Figures 8.1 through 8.11 show the geographic distribution of AIS plants and animals in the Mohawk Region. Eurasian watermilfoil and curly-leafed pondweed are found in many of the same lakes, well documented in the eastern and southern portion of the region. Water chestnut is common along the Hudson River corridor, and has been found in some waterbodies near and some portions of the Mohawk River. Other AIS plants are well distributed throughout the rest of the region, with hydrilla and other "southern" plants not common or even present in the region. Zebra mussels have likely been found throughout the Hudson River and Mohawk River in the region, but are only one marker is designated per county in Figure 8.10.

Figure 8.3: AIS plants in Mohawk

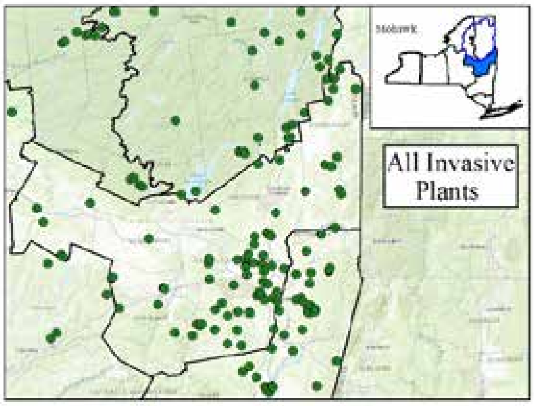


Figure 8.5: Water chestnut in Mohawk

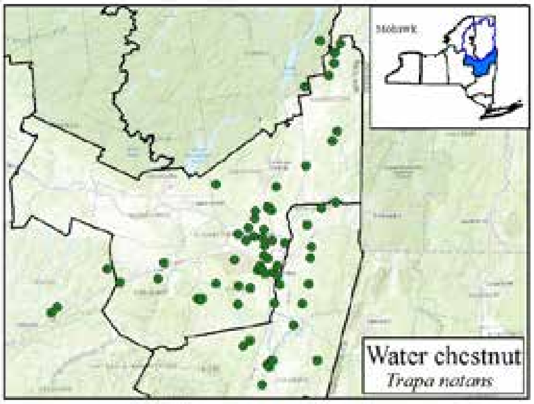


Figure 8.4: AIS animals in Mohawk

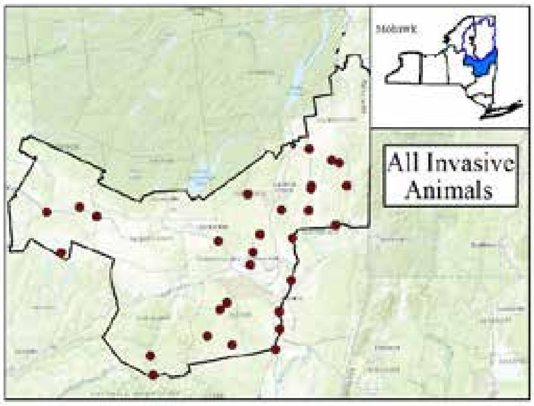


Figure 8.6: EWM in Mohawk

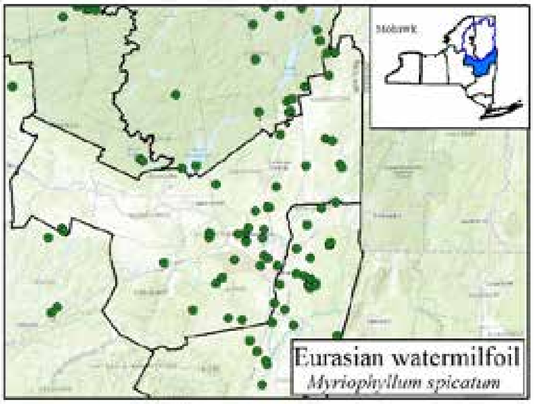


Figure 8.7: CLP in Mohawk

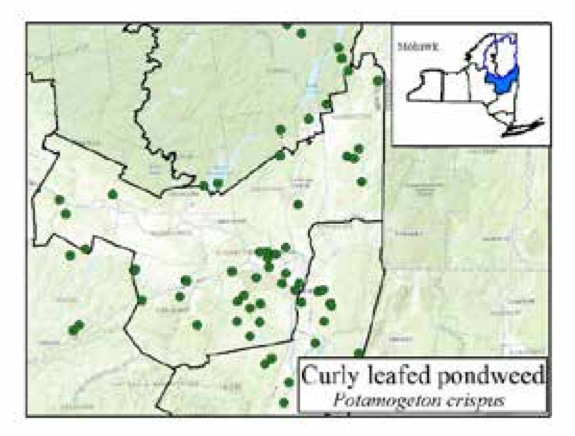


Figure 8.10: Zebra mussels in Mohawk

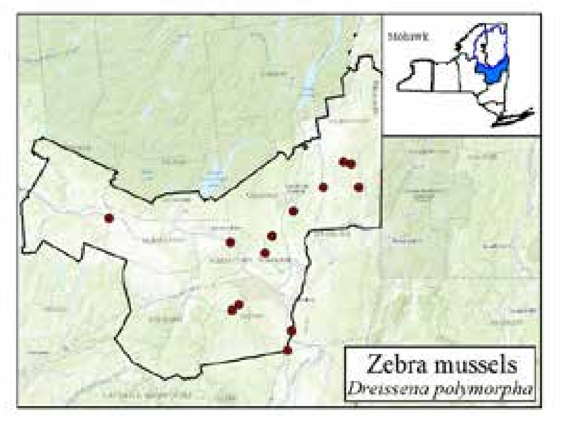


Figure 8.8: Brittle naiad in Mohawk

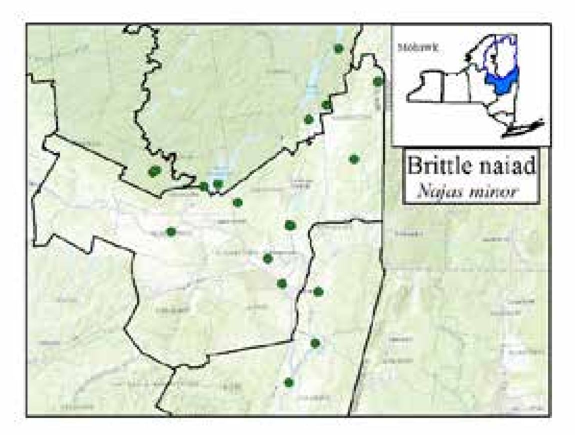


Figure 8.11: VCF in Mohawk

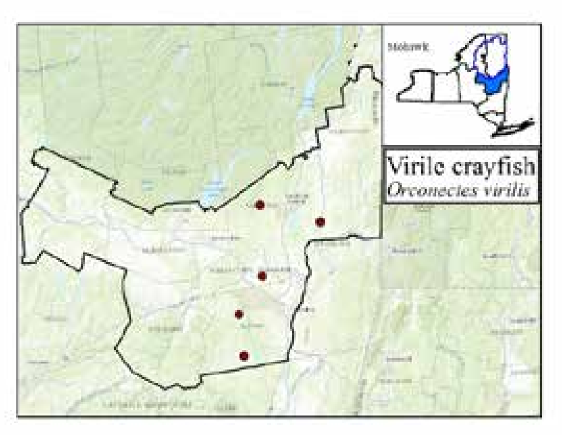
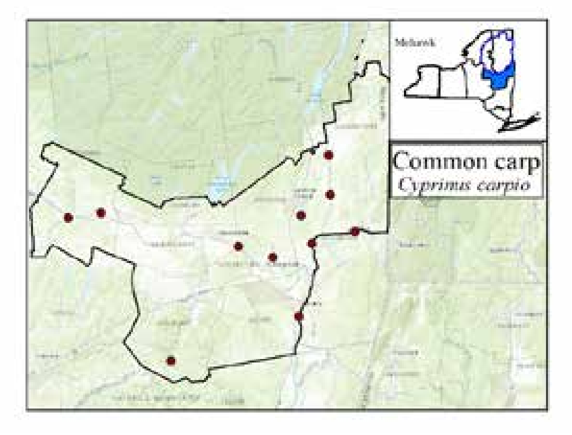


Figure 8.9: Common carp in Mohawk



Common carp is found in some lakes and ponds scattered throughout the county. Virile crayfish, more common than in other regions but still limited to only a few lakes, appears to be in waterbodies near the Hudson River.

It should be assumed that all waterbodies in the region may be susceptible to AIS that have not yet been observed or reported, including those AIS not yet found in New York. Any new AIS sightings should be reported to the DEC, with digital pictures of suspected AIS, at DOWinfo@dec.ny.gov. Additional information about AIS can be found on the DEC website at http://www.dec.ny.gov/animals/50121.html.

Chapter 9: Lake Perception

Public perception of lakes is a critical component of lake assessment and management. Public dissatisfaction with (or desire to protect) the condition of the lake is frequently a strong impetus for the development of management, protection, or restoration plans for a lake, and often informs the desire to fund and implement management actions. Perception of water quality and recreational conditions can also represent a composite view of recent observations of the lake, not just at the time of sampling, and may provide an additional measure of representative conditions. Well-designed perception surveys can identify spatial and temporal issues- shoreline blooms, local dense plant beds, recent turbidity events- that may be missed during even frequent routine open water sampling. Local monitors are familiar with “normal” conditions and can identify lake changes that may portend or anticipate larger problems. Lake perception is often closely linked to measurable water quality or lake indicators, affording the opportunity to gauge progress and success, and to conduct cost-benefit analyses of specific management activities. Standardized scales can provide opportunities for comparison from year to year and across regional and state boundaries, since most New England and Upper Midwestern states use the same standardized tool for assessing lake perception. Much of this information cannot be gathered in traditional water quality monitoring programs.

Lake perception through CSLAP and the LCI is evaluated via a 6 question survey. The first and third questions relate to the physical condition of the lake (how it looks) and the recreational condition of the lake, respectively. These are graded on a 5 point scale, ranging from most favorable (1) to least favorable (5). These survey questions are adopted from user perception surveys developed by the states of Vermont and Minnesota, as referenced above. The second question relates to the aquatic plant coverage in the lake, ranging from not visible (1) to densely covering the entire lake surface (5). The samplers are instructed to evaluate a representative shoreline site that is not explicitly managed. The fourth question asks survey respondents to identify which factor(s) adversely affect recreational assessments, choosing from a menu of options.

The surveys are completed during each sampling session prior to data or sample collection, to minimize bias. These first four questions have been included in CSLAP perception surveys since 1992, and have been completed by LCI (professional) monitors over the last five years.

Two additional questions were added to the survey form since 2008. These reference health and safety issues, asking for information about any specific health or safety reports or observations at the time of sampling (question 5) and since the last survey (question 6), also chosen from specific options. These include algal blooms, taste and odor, swimmers itch, waterborne illness, and fish kills.

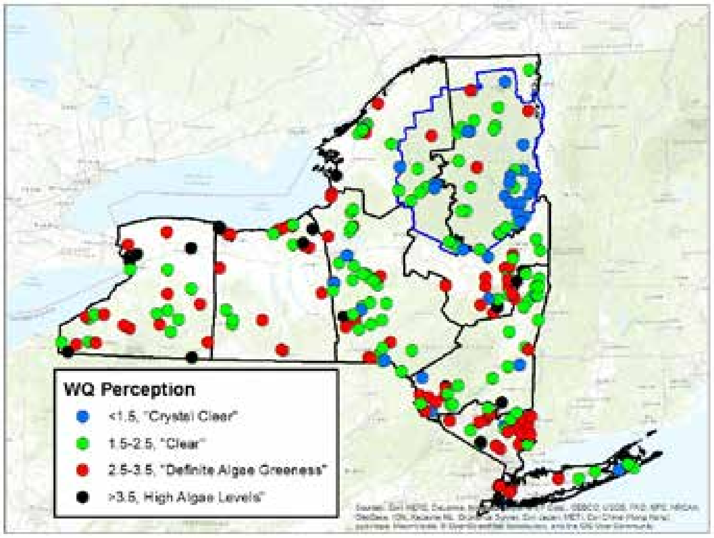


Figure 9.1: Water quality perception in CSLAP and LCI lakes, 2012-2016

Figure 9.1 shows that water quality perception is most favorable in the eastern Adirondack region, and the western portion of the Central region, eastern portion of Long Island, and northern portion of the Mohawk region. These assessments are less favorable in the eastern portion of the Mohawk region and in the New York City region. This statewide map would largely overlap with the water clarity distribution in CSLAP and LCI lakes shown in Figure 5.11, and the algae (chlorophyll *a*) distribution shown in Figure 5.6.

Figure 9.2 shows that water quality perception is variable across the Mohawk region, but as with the statewide maps, Figure 9.2 largely reflects the regional variability in water clarity and algae levels shown in Chapter 5. There is no clear geographic pattern within the region.

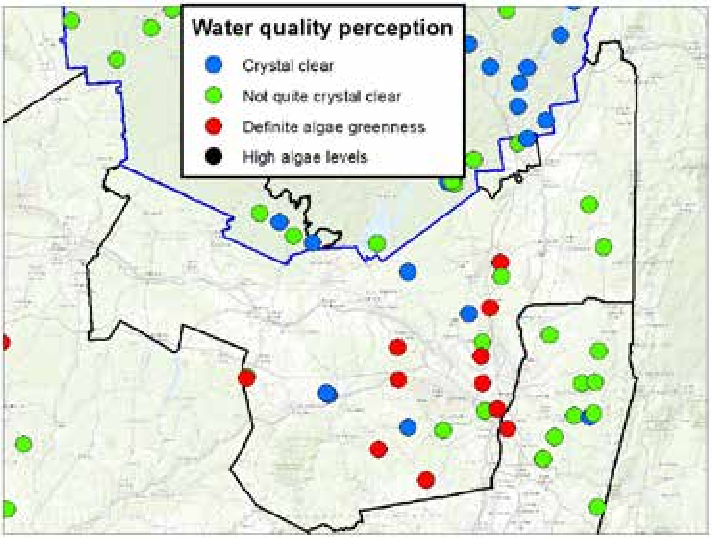


Figure 9.2: Water quality perception in CSLAP and LCI lakes in the Mohawk region, 2012-2016

The relationship between water quality perception and water clarity is shown in Figure 9.3, and between perception in algae (chlorophyll a) in Figure 9.4. These figures suggest that more than half of the variability in water quality perception can be attributed to Secchi disk transparency and chlorophyll *a* levels in the CSLAP and LCI lakes. Some of this variability can be attributed to other factors that influence water quality perception, including water color, lake depth (which limits the measured water clarity), the presence of macrophytes (weeds) and other phytoplankton, including benthic and floating filamentous algae not captured in the chlorophyll *a* measurements, and perceived or measured changes in water clarity.

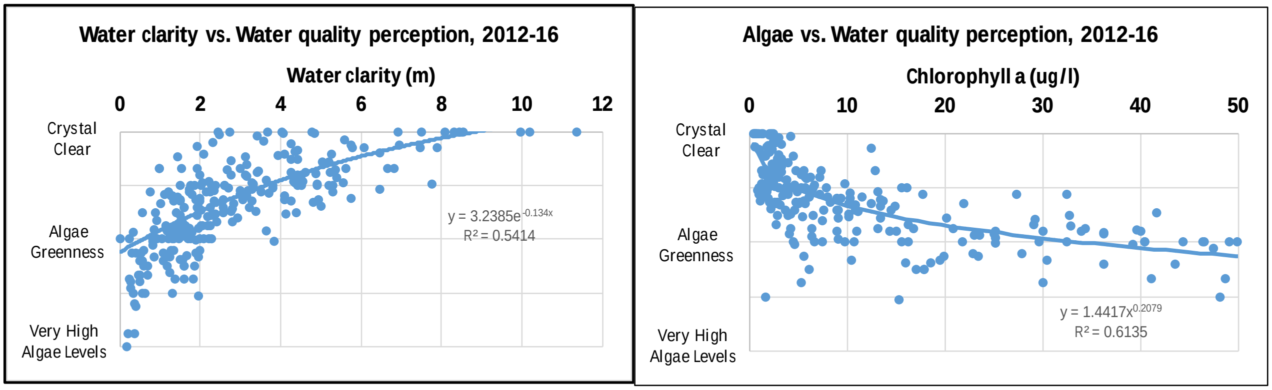


Figure 9.3 and 9.4: Water quality perception compared to Secchi disk transparency and chlorophyll *a* in CSLAP and LCI lakes, 2012-2016

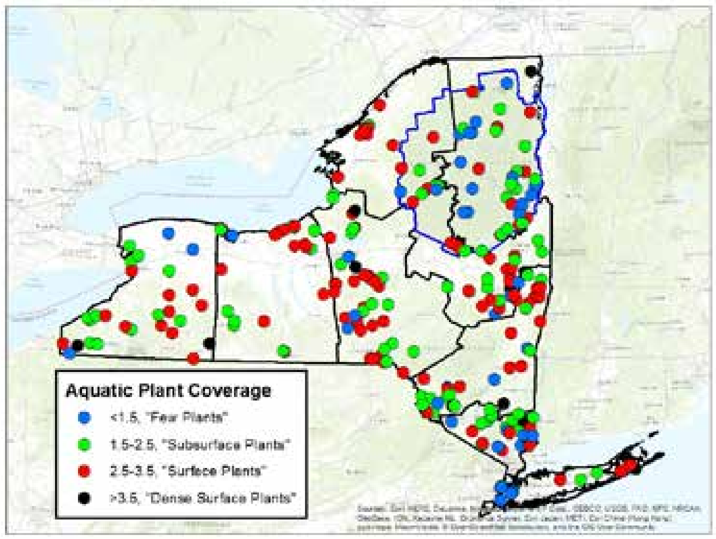


Figure 9.5: Aquatic plant coverage in CSLAP and LCI lakes, 2012-2016

Figure 9.5 shows the distribution of typical (average) aquatic plant coverage in CSLAP and LCI lakes in New York state. These assessments may be highly variable in neighboring waterbodies, and even within a specific waterbody they may not accurately portray the extent of plant coverage in all portions of the lake. However, these results do appear to be broadly indicative of regional patterns, recognizing that most shallow lakes with light transmission to the lake bottom may exhibit extensive plant coverage, and plant coverage in the deepest lakes are limited to the nearshore littoral zone. Figure 9.5 indicates the lowest extent of plant coverage is in the New York city region, where lakes are dominated by algae and turbidity, and the interior Adirondacks, where aquatic invasive species have not been found. The lakes in the western New York, Central, Finger Lakes, and Mohawk regions appear to have the most extensive coverage of aquatic plants. These regions have high percentages of lakes with Eurasian watermilfoil, water chestnut, and other canopy-forming invasive plants (Chapter 8).

The extent of aquatic plant coverage varies throughout the Mohawk region (Figure 9.6). This may be a function of both water depth and the presence of AIS. Dens surface plant growth was not reported in many lakes, although lakes with little plant growth were also not found in the region.

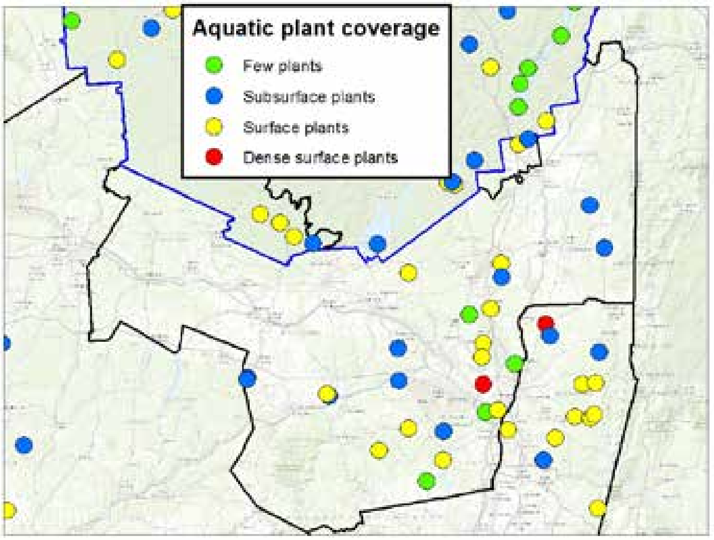


Figure 9.6: Aquatic plant coverage in CSLAP and LCI lakes in the Mohawk region, 2012-2016

Figure 9.7 shows that there is a very poor relationship between water clarity and aquatic plant coverage. Although strong light transmission in clear lakes can trigger both shallower and deeper plant growth, several invasive plants (including Eurasian watermilfoil and water chestnut) can outcompete native plants in turbid water and therefore may be more likely to grow to the surface. These competing influences may contribute to this poor relationship. It is also possible that the extent of surface plant growth is poorly characterized in these waterbodies, particularly large deep lakes with highly variable aquatic plant growth habits.

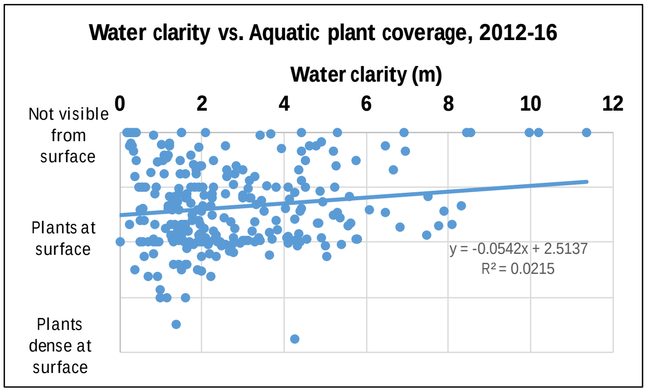


Figure 9.7: Aquatic plant coverage compared to Secchi disk transparency in CSLAP and LCI lakes, 2012-2016

Both water quality assessments and aquatic plant coverage can significantly influence recreational assessments. Figure 9.8 shows the distribution of typical recreational assessment in CSLAP and LCI lakes in New York state. These assessments may be strongly influenced by weather, factors unrelated to water quality, and recent changes in either water quality conditions of coverage of aquatic plants.

However, these results appear to be consistent with the regional distribution of water quality assessments shown in Figure 9.1. These show the most favorable assessments in the Adirondack regions and in the western portions of the Central region, and the least favorable assessments in the Mohawk region and portions of the Western and Mohawk regions. The statewide map in Figure 9.8 does not as closely mirror the statewide aquatic plant coverage map in Figure 9.5, indicating a less robust relationship between plant coverage and recreational assessments. This is further illustrated in Figures 9.10 and 9.11, which show a strong relationship between water quality perception and recreational assessments, but a weak (though positive) relationship between plant coverage and recreation.

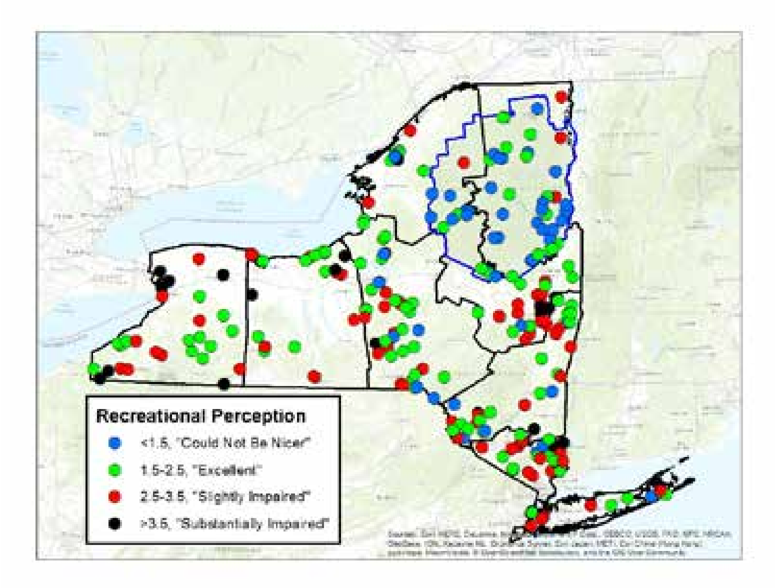


Figure 9.8: Recreational assessments in CSLAP and LCI lakes, 2012-2016

Figure 9.9 shows that recreational perception is the Mohawk region is mostly favorable, with the less favorable conditions most frequently associated with excessive algae than due to excessive weed growth.

Table 9.1 shows the percentage of waterbodies identified (by the CSLAP or LCI samplers) as "impaired" (responses #3, 4 or 5 on the third recreational perception survey), and the percentage of waterbodies for which perceived impairment was in response to algae or excessive plants (i.e. weeds).

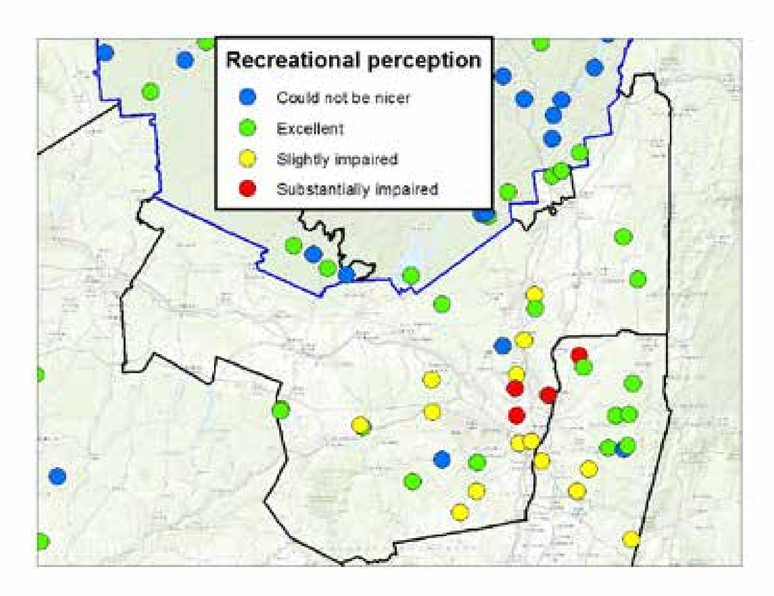
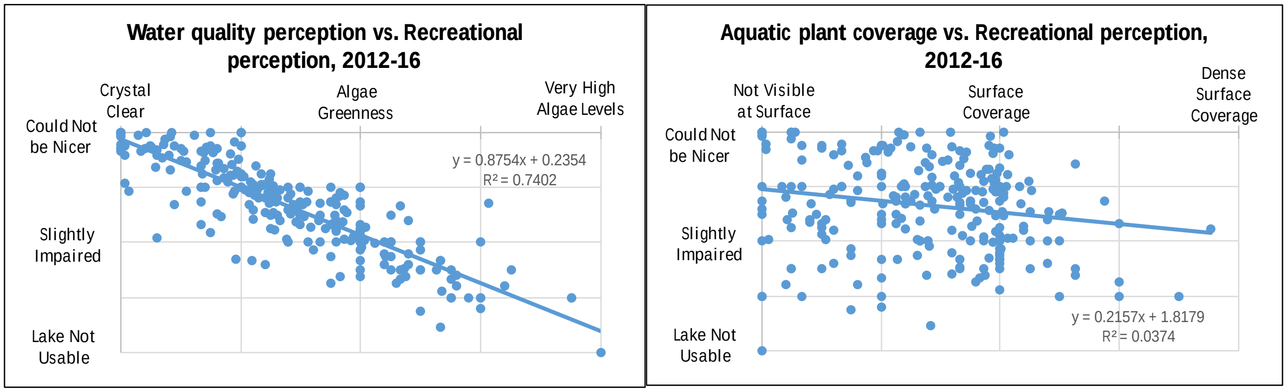


Figure 9.9: Recreational assessments in CSLAP and LCI lakes in the Mohawk region 2012-2016


Water quality perception vs. Recreational perception, 2012-16

Aquatic plant coverage vs. Recreational perception, 2012-16

Figures 9.10 and 9.11: Recreation assessments compared to water quality assessments and aquatic plant coverage in CSLAP and LCI lakes, 2012-2016

This table also shows the highest percentage of waterbodies identified as impaired can be found in the Mohawk, Finger Lakes, Western, and Mohawk regions. The relative importance of excessive algae growth (and likely association with reduced water clarity) and excessive plant growth varies from region to region. Excessive weeds are more likely influence lakes in the eastern Adirondack and Finger Lakes regions, while excessive algae affects a higher percentage of lakes in the Lower Hudson, Mohawk, and Western New York regions. The extent of “substantial” impairment is low in most regions, although it is in these lakes in which lake management is likely most urgent.

Table 9.1: Regional summary of lake perception and effects of algae and weeds, CSLAP and LCI lakes 2012-2016

	% Lakes Slightly Impaired	% Lakes Substantially Impaired	% Lakes Impaired By Algae	% Lakes Impaired by Weeds	% Lakes Substantially Impaired by Algae	% Lakes Substantially Impaired by Weeds
NYS	20%	7%	16%	14%	7%	4%
NYC-LI	8%	13%	12%	14%	6%	11%
Lower Hudson	24%	14%	29%	11%	9%	4%
Mid-Hudson	20%	3%	18%	13%	9%	2%
Mohawk	38%	11%	30%	15%	12%	6%
Eastern Adk	10%	2%	3%	10%	0%	2%
Western Adk	14%	7%	14%	9%	8%	3%
Central NY	21%	10%	13%	16%	6%	6%
Finger Lakes	28%	1%	24%	33%	8%	8%
Western NY	26%	13%	33%	20%	10%	6%

Chapter 10: Lake Assessments

Background

Although New York state's lake monitoring programs are devised to meet several objectives, lake assessments are the primary NYSDEC objectives for both CSLAP and the LCI. For some lakes, particularly small lakes and ponds with limited public access by those who don't reside on the lake shore, CSLAP and the LCI may be the sole source of data used to assess lake conditions. These data can provide broad water-quality evaluations and understanding the connection between measured water-quality indicators and the support of broadly based recreational, potable water, and aquatic life uses of sampled lakes. This connection between lake conditions and designated uses serves as the basis for the NYSDEC lake assessment program.

However, for large, multi-use lakes, or those lakes that are threatened by pollutants not captured in eutrophication-based monitoring programs, CSLAP and the LCI become less effective tools for assessing lake condition and use impairments. For example, CSLAP data have only limited utility in evaluating the following:

(a) contamination from bacteria or other organisms, particularly related to the safety of water use for potable intake or public bathing (at designated swimming areas), although recent documentation of HABs has improved the utility of these programs in evaluating use impacts

(b) contamination from inorganic (e.g., metals) and organic (e.g., PCBs, DDT) compounds, whether in water, sediment or biota (including fish)

(c) portions of a lake not well mixed with the "open water" or otherwise distant from the primary sampling site(s), including the shoreline, bottom sediment and isolated coves, although the DEC HABs program sampling and AIS surveys can help characterize nearshore threats

(d) rooted aquatic plant impacts in areas of the lake not evaluated by the sampling volunteers through public perception or quantitative plant surveys

(e) diverging perceptions of recreational-use impacts, particularly in lakes with shorelines or isolated coves exhibiting conditions very different from those sampled or evaluated by the sampling volunteers

(f) impacts to fishing, fish or other fauna due to factors unrelated to eutrophication

For these waterbodies, CSLAP and the LCI can and should continue to be part of an extensive database used to comprehensively evaluate the entirety of the lake and its uses, but absent a more complete dataset, these data should be used with caution as a sole means for evaluating the lake. Water-quality evaluations, recommended PWL listings, and other extrapolations of the data and analyses should be utilized in this context and by no means should be considered the singular assessment information for these sampled lakes. **A complete PWL assessment should include information from CSLAP, LCI and all other sources of information, not limited to the water quality data summarized in this report.**

Priority waterbody list

The Priority Waterbody List (PWL) is an inventory of all waters in New York State (lakes, ponds, reservoirs, rivers, streams, and estuaries) known to have designated water uses with some degree of impairment, or those threatened by potential impairment. These designated uses include:

- potable water—drinking—for class AA or class A waterbodies
- public bathing (at designated beaches)—for some class AA, A and B waterbodies
- recreation—swimming, boating, and angling—for all classes of waterbodies
- aquatic life—for all classes of waterbodies
- fish consumption—for all classes of waterbodies

In addition, the following “conditions” are used to provide context for these assessments:

- aesthetics—for all classes of waterbodies
- habitat—for all classes of waterbodies

However, an overarching goal of the federal Clean Water Act is for the protection and propagation of fish, shellfish, and wildlife and recreation in and on all waterbodies, broadly characterized as ensuring that all waterbodies are “swimmable (and) fishable.” Therefore, any water quality criteria established for protecting swimming will apply to all waterbodies, unless explicitly precluded by natural conditions preventing swimming (or for water supply reservoirs on which contact recreation is restricted).

The PWL is a subset of the state Waterbody Inventory, an inventory of all waterbodies in the state, which contains all available information on the condition and/or usability of the waterbody. PWL waterbodies are identified through a broad network of county and state agencies, with significant public outreach and input, and the list is maintained and

Designated use assessment categories in New York state include:

Precluded: conditions frequently prevent the cited (designated) use

Impaired: conditions occasionally prevent the cited use; or these uses are limited or discouraged; or advanced treatment is required to maintain use

Stressed: designated uses are supported but occasional conditions discourage use

Threatened: designated use is supported but may be impacted by changing land use patterns, worsening trends, or other threats

(Fully) Supporting: designated use is not compromised at any time or location

compiled by the NYSDEC Division of Water. Monitoring data from a variety of sources, including CSLAP and the LCI, have been used by state agencies to evaluate lakes for inclusion on the PWL, and the process for incorporating lakes data has become more standardized.

The “rulebook” for the assessment process is referred to as the “Consolidated Assessment and Listing Methodology”, or CALM, and can be found at http://www.dec.ny.gov/docs/water_pdf/asmtmethdrft15.pdf. This document cites specific numeric water quality criteria that have been developed to characterize sampled lakes in the use-based PWL categories. The designated use assessments have been broadly defined in the box on page 10-2. There is an equivalent federal (USEPA) assessment criteria, in which waterbodies are designated as fully supporting, partially supporting (the equivalent of the NYSDEC categories threatened or stressed), or not supporting designated uses.

Evaluations utilize the NYS phosphorus guidance value, other water-quality standards, information about biological conditions, and other limnological measures. The assessment process is generally undertaken on an annual rotating basin, with waterbodies in several drainage basins evaluated each year. Each of the 17 drainage basins in the state is assessed within every 5 years.

In general, waterbodies with “average” conditions that violate pertinent water-quality standards, as described below, are identified as *impaired* for the designated use intended to be protected by that standard. Standards violations at a frequency of greater than 10% are identified as *stressed*, and at a frequency of up to 10% are identified as *threatened*, although some evidence of use impairment (including through lake perception surveys) might also be required. However, the assessment process also includes evaluation of “administrative” information, including beach closures, presence of AIS, active management of water quality problems to enhance recreational uses, and the presence of HABs, as reported by NYSDEC, the Department of Health, and other agencies.

The state PWL use categories are further refined by the *confidence* in the assessment of designated uses. The confidence categories include:

Known- information clearly supports designated use assessment. Most CSLAP and LCI data fits in this category.

Suspected- information suggests that the designated use assessment is accurate. Limited or conflicting data may be identified as suspected

Unconfirmed- information is limited in quantity, quality, or clarity

Lakes that have been identified as precluded or impaired on the PWL are likely candidates for the federal 303(d) list, an “Impaired Waters” designation mandated by the federal Clean Water Act, indicating a federal designation of not supporting uses. Lakes on this list must be closely evaluated for the causes and sources of these problems. Remedial measures must be undertaken, under a defined schedule, to solve these water-quality problems. This entire evaluation and remediation process is known as the “TMDL” process, which refers to the Total Maximum Daily Load calculations necessary to determine how much (pollution that causes the water-quality problems) is too much.

Evaluation of designated uses in CSLAP lakes

As noted above, the PWL assessment process involves many stakeholders and sources of information, from monitoring data to an inventory of management actions to recommendations and professional judgment from those familiar with each waterbody. The CSLAP and LCI dataset can play an important role in providing some of this assessment information, although it cannot be overemphasized that a comprehensive evaluation of these waterbodies should consider all sources of information. The following section of the report summarizes each of the designated uses in New York state lakes and the existing assessment of these uses in each sampled CSLAP and LCI lake. These summaries include some relatively recent assessments, some outdated assessments, and *many (most) waterbodies that have not yet been assessed* (despite water quality data collected through CSLAP and the LCI within the last five years). The NYSDEC is attempting to bring these assessments up to date, using the CSLAP and LCI datasets and other past and recent sources of information. It is anticipated that these assessments will soon catch up to the water quality data summaries in Tables 10.1 through 10.7.

All waters in New York State are assigned a letter classification that denotes their best uses. These classifications are:

Class AA and A indicate that the best usage is as a source of drinking (potable) water, swimming and other recreation, fishing, and aquatic life;

Class B indicates that the best usage is for swimming and other recreation, fishing, and aquatic life (including some designated by public bathing);

Class C indicates that the best usage is for fishing and aquatic life (although these lakes often support swimming and other recreation).

Some waterbodies are assigned a (T) or (TS) designation referring to support of trout populations, or a “spec” designation referring to a special legal classification restricting receipt of wastewater.

Evaluation of impacts to potable water

The health and quality of potable surface waters can be influenced by a variety of factors. Most of these are not evaluated through CSLAP and the LCI, water quality monitoring program not developed to assess potable water supplies. More complete assessments of potable water use includes information collected by the drinking water provider and local health department regarding potential pollutants measured through routine source and treated water quality and operational conditions, including the use of advanced treatment and disinfectants, as well as threats to source water quality. A discussion of these assessments is beyond the scope of this report.

However, some of the information collected through these programs has some utility in evaluating water quality conditions in lakes used for drinking water. The continuing evolution of the program involves collecting better information related to potable water quality, as demonstrated in the monitoring of harmful algal blooms since 2009, and some information about taste and odor compounds (iron) and potentially dangerous pollutants (manganese and arsenic) in previous years. Since the primary assessment of potable water use comes from Department of Health information, DEC data assessments may result in a waterbody being identified as *impacted*, since these assessments may not lead to an *impaired* listing.

The CSLAP and LCI water quality indicators that can be used to assess potable water quality conditions include the following indicators:

Chlorophyll a is collected in both the CSLAP and LCI in all samples. NYSDEC studies have shown that excessive algae, as measured by chlorophyll *a*, can result in the formation of carcinogenic compounds during drinking water chlorination. These compounds, broadly referred to as disinfection by-products (DBPs), can be found at levels above the maximum contaminant level (MCL) when chlorophyll *a* levels regularly exceed 4 µg/l. For Class A waterbodies, subject to some treatments that control algae, chlorophyll *a* levels should stay below 6 µg/l. These values have not yet been adopted as water quality standards or guidance values; at present, no chlorophyll *a* standard exists.

What's the difference?

Standards and guidance values are ambient water quality values that are set to protect the state's waters, as established by NYSDEC. They both are derived according to scientific procedures that are in regulation (6 NYCRR Part 702).

A standard is a value that has been promulgated and placed into regulation. The standards for the surface water classes are extracted from Part 703 of Title 6.

A guidance value may be used where a standard for a substance or group of substances has not been established for a particular water class and type of value (section 702.15).

The federal and state government (NYSDOH) has set limits on the level of contaminants in treated drinking water. These limits, called maximum contaminant levels (MCLs), are established to ensure that the water is safe for people to drink.

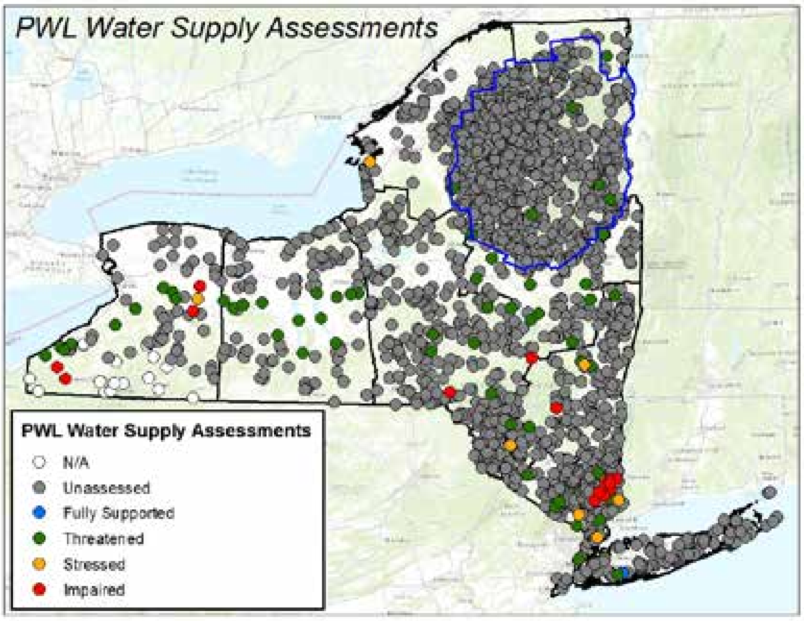
Deepwater iron (Fe), manganese (Mn) and arsenic (As) have been collected periodically through CSLAP and the LCI over the last two decades, but since 2012, these deepwater pollutants have only been measured in bottom samples from Class AA and A lakes in the LCI. The present NYSDEC water quality standards for iron and manganese have been established at 0.3 mg/l to protect the aesthetic quality of the water for drinking, although there is some discussion at the national level about identifying lower manganese levels appropriate to protect the health of those drinking these waters. The present arsenic MCL is 10 µg/l, but the USEPA has proposed the use of water quality values substantially lower to protect public health.

Deepwater ammonia has been collected through CSLAP and the LCI for many years in all classes of waterbodies. In CSLAP lakes, deepwater ammonia (and phosphorus) serve as surrogates for oxygen profiles, since ammonia can be concentrated through multiple processes, as described in Chapter 7). The New York state water quality standard for total ammonia at 2 mg/l was adopted to protect drinking water use, although deepwater ammonia levels more than 5-10x those at the surface often indicate persistent anoxia.

For both deepwater metals and ammonia, impacts to drinking water are difficult to determine since these data are usually collected from sites deeper than the water intake depth.

Cyanotoxins refer to liver, nerve, and dermal toxins produced by some cyanobacteria (blue green algae) taxa. All CSLAP open water samples, and some CSLAP and LCI shoreline bloom samples have been analyzed for blue green algae content and more than a dozen cyanotoxins. Until 2015, neither USEPA nor New York state had adopted cyanotoxin criteria for protecting drinking water use, so NYSDEC used the World Health Organization (WHO) provisional guideline for lifetime consumption of 1.0 µg/L for microcystin-LR (presumably the most common (liver) toxin found in New York state lakes) to identify potential drinking water threats. In late 2015, the USEPA issued a 10-day drinking water microcystin-LR health advisory of 0.3 µg/L for children (less than six years old), and 1.6 µg/L for older children (>6 years of age). They also issued heath advisory values for cylindrospermopsin, a liver toxin not yet been detected in thousands of New York state lake samples. It should be noted that these advisories are directed toward treated drinking water, not necessarily the “raw” water samples collected in these monitoring programs (although these advisories may be relevant for unauthorized domestic potable water intakes).

Figure 10.1: PWL potable water assessments for NYS lakes

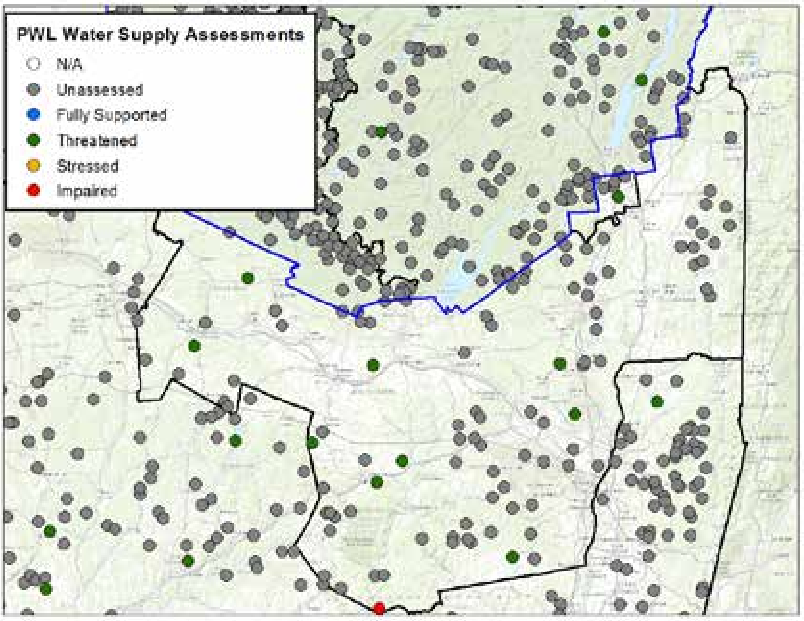


Summary of New York state and Mohawk region potable water assessments

Figure 10.1 shows that most New York state lakes are not intended to be used for drinking water. Many of the lakes and reservoirs used for drinking water have not been assessed through the NYSDEC waterbody inventory, although source water assessments have been developed by the Department of Health for these waterbodies. Most of the impaired waterbodies are found in the New York City reservoir system, due to excessive nutrients. Most of the other impacted (stressed or impaired) surface potable water supplies are found in those drainage basins (particularly the Allegheny River and Lake Erie-Niagara River basins in the “western New York” region) for which recent PWL updates have been completed.

As noted above, within the Mohawk region (Figure 10.2), several potable water supplies have been identified as *threatened* by land use changes or other factors mostly unrelated to water quality. However, many of the Class A waterbodies in region have not been assessed for this use.

Figure 10.2: PWL potable water assessments for Mohawk region lakes



This is further illustrated in Table 10.1, which shows potable water assessments in New York state and the Mohawk region in CSLAP and LCI lakes sampled in the last five years. Most sampled lakes are not classified for drinking water, but most of the sampled Class A and AA lakes in the New York City / Long Island region exhibit some impacts due to excessive algae and nutrient levels. As previously noted, most of the “impacted” assessments reflect either uncertainty about the location of the intake (depth) relative to the water sampling depths, or due to the lack of information about excessive treatment or MCL violations due to excessive algae or other water quality problems.

Table 10.1: Preliminary potable water assessments in CSLAP and LCI lakes, 2012-2016 (based on CSLAP and LCI data only)

Regions	%Supported	%Threatened	%Stressed	%Impacted	%NA
NYS	**9%**	**3%**	**6%**	**8%**	**74%**
NYC-LI	0%	0%	0%	6%	94%
Lower Hudson	0%	0%	15%	6%	79%
Mid-Hudson	3%	3%	9%	3%	82%
Mohawk	4%	4%	8%	28%	56%
Eastern Adk	37%	15%	7%	0%	41%
Western Adk	28%	0%	0%	0%	72%
Central NY	4%	4%	9%	0%	82%
Finger Lakes	0%	0%	0%	11%	89%
Western NY	7%	0%	4%	18%	71%

Evaluation of impacts to public bathing

Although waterbodies in New York state support many recreational uses, the state assessment process limits the evaluation of *public bathing* to designated swimming beaches, as regulated by the state Department of Health.

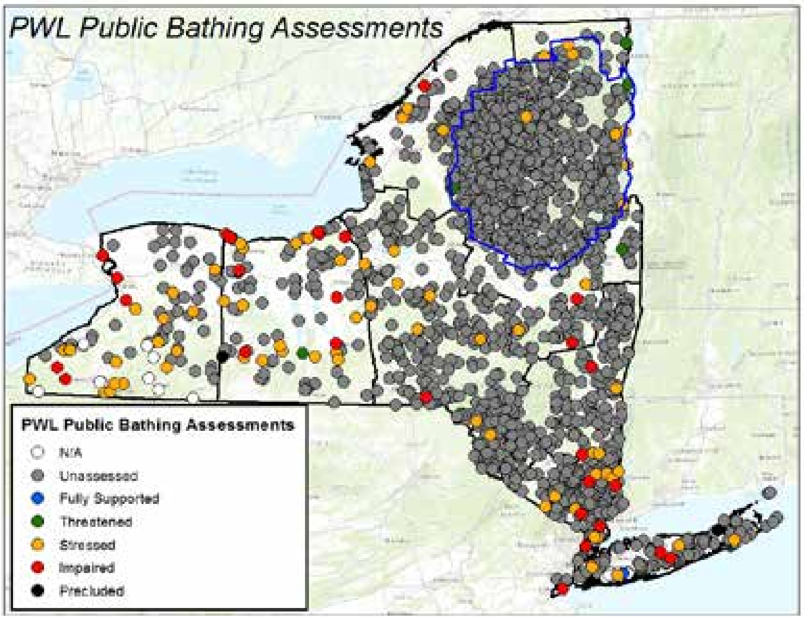
The most complete assessment of public bathing includes information maintained by the local health department about beach closures, pathogen data, bloom observations, and operational measures required to protect the health of swimmers. As with assessments of drinking water quality, an evaluation of this information is beyond the scope of this report.

The CSLAP and LCI data most relevant to assessing public bathing include the following categories, limited to those waterbodies maintaining public beaches:

Secchi disk transparency is the foundation of most professional and citizen science programs, and is measured during each CSLAP and LCI sampling session. Reduced water clarity can be an indication of excessive turbidity, most often associated with suspended algae or cyanobacteria, but low water clarity itself can represent a safety risk for swimmers trying to avoid bottom debris, and for lifeguards charged with seeing submerged swimmers. The state Public Health law requires 4 feet of water clarity to site a new swimming beach, and as an operational criteria for keeping beaches open at many locations. The assessment process also accounts for trends in water quality, including a long-term decrease in water clarity.

HABs and cyanotoxins are regularly evaluated through both CSLAP and the LCI, although not at designated swimming beaches. The state Department of Health has established a beach protocol that calls for beach closures based on visual evidence of conditions consistent with a cyanobacteria bloom, since these conditions may result in recreational exposure to cyanotoxins or other compounds associated with these harmful algae blooms (HABs). Under the same protocol, beaches cannot be reopened until after visual evidence of the bloom has ended, and beach samples collected at least 24 hours after bloom clearing indicate microcystin levels less than 10 µg/l. Persistent beach closures may indicate conditions that are impaired for public bathing. CSLAP and LCI sampling includes both quantitative measures of HABs and measurements of several cyanotoxins. Samples indicating blue green algae chlorophyll *a* levels above 25 µg/l are characterized as *confirmed* blooms, and microcystin levels above 20 µg/l are defined as *confirmed with high toxins* blooms. The occurrence of these blooms in New York lakes is documented through the DEC HABs program and summarized in weekly DEC webpage notification of These conditions at locations outside of swimming beaches represent an elevated risk for public bathing beaches, since these blooms can migrate to these designated swimming areas. Blooms approaching swimming areas may result in advisories posted by beach operators.

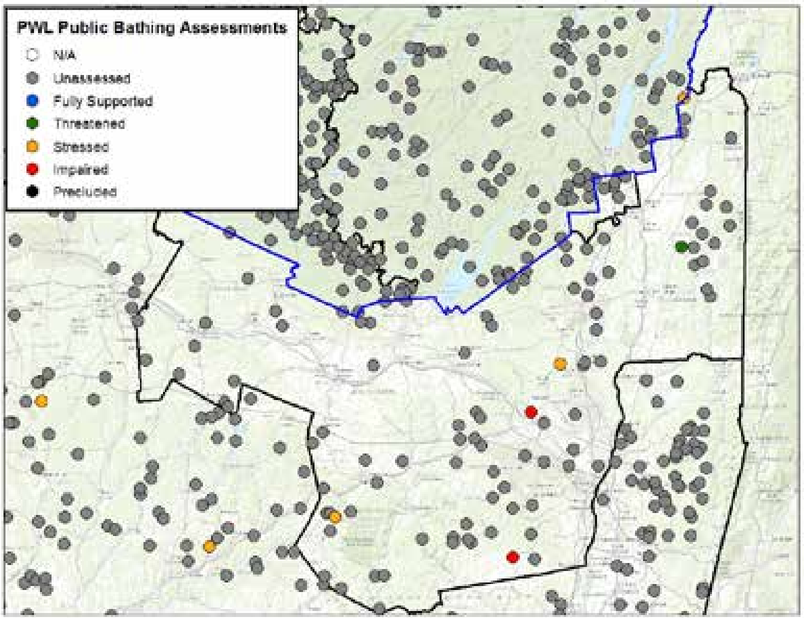
Figure 10.3: PWL public bathing assessments for NYS lakes



Summary of New York state and Mohawk region public bathing assessments

As demonstrated in Figure 10.3, most lakes in New York state and the New York City / Long Island region do not possess public swimming beaches. Most of the lakes with beaches that have been assessed are in the Western, Finger Lakes and Lower Hudson regions, generally corresponding to more recent assessments. The lakes with stressed or impaired conditions are usually impacted by excessive algae growth or poor water clarity resulting in unsafe swimming conditions.

Figure 10.4: PWL public bathing assessments for Mohawk region lakes



The Mohawk region has very few public bathing assessments; many lakes with public bathing beaches in the region have not yet been assessed for this use. The few assessments generally indicate stressed or impaired conditions, mostly in the southern portion of the region.

Table 10.2 also shows a low percentage of CSLAP and LCI lakes with public swimming beaches sampled in the last five years in New York state and in the Mohawk region. For those lakes with beaches in this region, some demonstrated threatened or stressed conditions; this may not be consistent with the larger (non-CSLAP and LCI) findings in the region shown in Figure 10.4, suggesting the need for updated assessments.

Table 10.2: Preliminary public bathing assessments in CSLAP and LCI lakes, 2012-2016 (based on CSLAP and LCI data only)

Regions	%Supported	%Threatened	%Stressed	%Impaired	%NA
NYS	**10%**	**6%**	**9%**	**4%**	**72%**
NYC-LI	0%	0%	0%	0%	100%
Lower Hudson	6%	0%	18%	12%	64%
Mid-Hudson	9%	12%	9%	0%	70%
Mohawk	0%	4%	8%	0%	80%
Eastern Adk	44%	12%	5%	0%	37%
Western Adk	8%	16%	8%	0%	64%
Central NY	13%	4%	11%	2%	62%
Finger Lakes	4%	0%	7%	7%	78%
Western NY	0%	0%	11%	11%	71%

Evaluation of Impacts to Recreation

Outside of regulated swimming beaches, lakes meet many recreational needs, including swimming in areas not authorized by public agencies but still serving individuals on their own property or in the open water. However, other recreational uses include wading and secondary contact recreational activities, and shoreline and open water fishing.

Some of these uses are not well-evaluated through monitoring data, or can be attained independent of water quality conditions. Non-contact recreational conditions—boating and fishing—are strongly influenced by several factors not measured (or measurable) through these programs, from water depth and lake access to quantity and type of fish. Some of the potential impacts to these uses may also be assessed through other designated use or condition categories, such as public bathing, aesthetics, or habitat. However, recreational impacts can also be assessed by the following indicators:

Chlorophyll *a*, as a surrogate for algae levels, can impact recreational uses in several ways:

- creating unsafe conditions for swimmers (as described in the public bathing discussion above);
- creating poor aesthetic quality that prompts public dissatisfaction with recreational conditions and desire for local action;
- forming algae blooms, or dense concentrations of algae, that can impede recreational use; and
- producing cyanotoxins at levels associated with elevated risk for swimmers

The chlorophyll *a* threshold for each of these use impacts may be unique to each waterbody, but in general, open water chlorophyll *a* levels above 10 µg/l significantly increase the likelihood of each of these phenomena. New York state has not yet adopted a chlorophyll *a* water quality standard or guidance value, but this threshold has been used for assessments of waterbodies.

Secchi disk transparency thresholds for evaluating recreation are identical to the thresholds (= 4 feet) used to evaluate public bathing.

Phosphorus limits algae growth in most New York state lakes. It is the primary water quality indicator in most lake monitoring programs, and has been collected through CSLAP and the LCI for the duration of both programs. The existing New York state guidance value of 20 µg/l was established to protect the aesthetic quality of lakes, and historically was used to define use impairments. However, the present CALM criteria uses this phosphorus threshold, and trends in phosphorus data, to evaluate stressed conditions (in the absence of elevated chlorophyll *a* readings) or the threat of future impairments.

HABs and cyanotoxins thresholds described in the public bathing assessment section above are also used to evaluate recreation. However, since most of these data are collected outside of designated beaches, they represent actual (albeit spatially variable) impacts in areas used for recreational activities. Impairment is defined by the NYSDEC when confirmed frequent and widespread blooms are documented. It should be noted that the risk is associated with the presence of these cyanobacteria blooms, not necessarily the confirmation of elevated toxin levels, although the latter represents an elevated risk.

Summary of New York state and Mohawk region recreation assessments

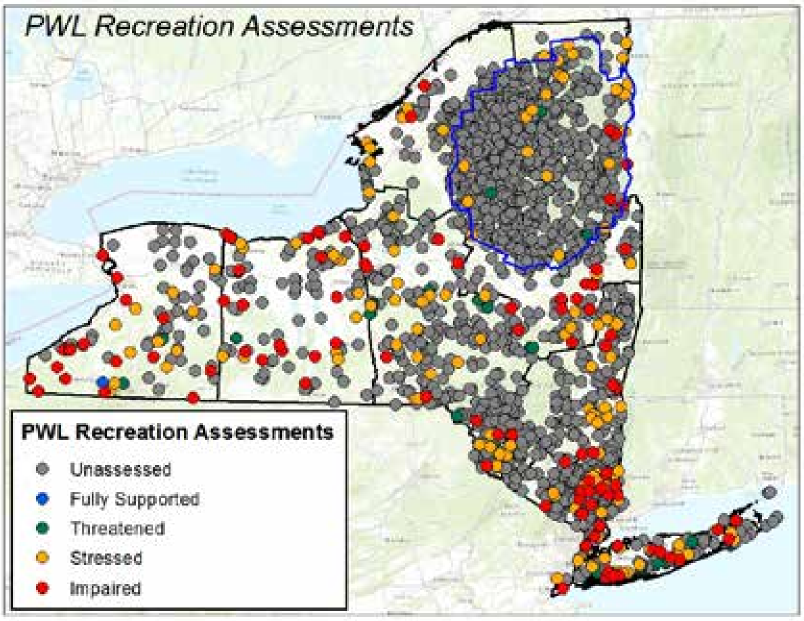


Figure 10.5: PWL recreation assessments for NYS Lakes

As with all other designated uses, most New York state and New York City / Long Island region lakes have not been assessed for recreational suitability (since most of the thousands of lakes have not been sampled), as seen in Figure 10.5. It is likely that many of the lakes presently identified as “unassessed” in the Adirondack regions and other uninhabited or forested areas would support recreation, and it is likely that a higher percentage of lakes in these areas will be identified as supporting recreation as more assessments are documented. The percentage of lakes stressed and impaired for recreation are highest in the more developed, agricultural or other areas with more active land use.

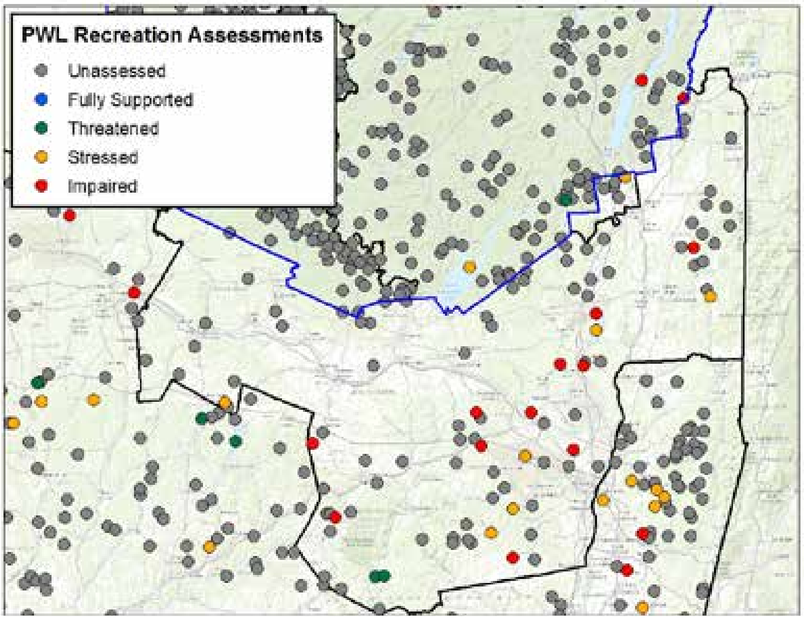


Figure 10.6: PWL recreation assessments for Mohawk region lakes

Figure 10.6 shows some lakes impacted for recreation in the southern portion of the Mohawk region (mostly likely through an assessment of the Lower Hudson River basin in recent years). However, this probably reflects the higher percentage of assessed lakes in these areas. It is likely that other lakes in the region will demonstrate similar conditions when an updated assessment is completed. This is also borne out by Table 10.3, which shows a high percentage of lakes impaired for recreation in the Mohawk region, although some lakes may fully support this use (given at least minor threats or impacts due to occasionally elevated algae and nutrient levels, or periodically low water clarity).

Recreational assessments as defined in this chapter, and existing PWL listings where available for each CSLAP and LCI lake sampled in the last five years can be found in the individual lake report scorecards at the end of this report.

Table 10.3: Preliminary recreation assessments in CSLAP and LCI lakes, 2012-2016 (based on CSLAP and LCI data only)

Regions	%Supported	%Threatened	%Stressed	%Impaired	%NA
NYS	**29%**	**2%**	**19%**	**50%**	**29%**
NYC-LI	6%	0%	25%	69%	6%
Lower Hudson	12%	0%	27%	61%	12%
Mid-Hudson	33%	0%	27%	39%	33%
Mohawk	16%	4%	12%	68%	16%
Eastern Adk	61%	12%	24%	2%	61%
Western Adk	68%	0%	12%	20%	68%
Central NY	44%	4%	20%	31%	44%
Finger Lakes	7%	0%	7%	85%	7%
Western NY	11%	0%	14%	75%	11%

Evaluation of impacts to aquatic life

CSLAP and the LCI are not well designed for assessing the health of the aquatic life in lakes. Although there are some biological indicators measured or evaluated through these programs—chlorophyll a and aquatic plant coverage—these assessments are directed toward identifying thresholds for “too much” algae or weeds. The term “aquatic life” is not well defined in state regulations, and federal guidance refers to protection of fauna, not flora. Although excessive algae and macrophyte growth can strongly influence aquatic flora, particularly if either is associated with HABs (and explosive growth associated with cyanobacteria) or invasive species, these are not strong measures of impacts to the biotic community (fauna). Both CSLAP and the LCI continue to be evaluated to include additional measures of aquatic life impacts.

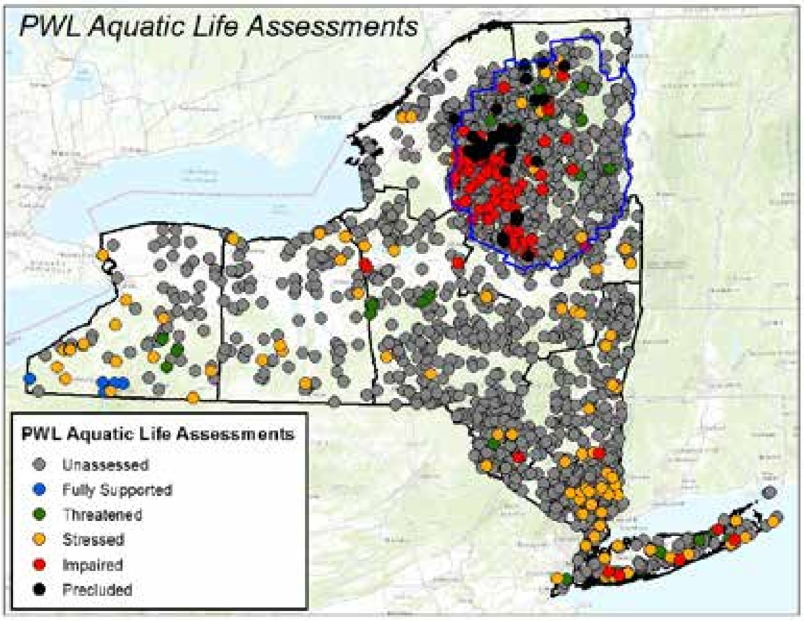
At present, the primary means for evaluating impacts to aquatic life in these monitoring programs are pH, the presence of invasive aquatic animals, and the direct and indirect (inferred) measure of dissolved oxygen.

pH has been measured in lake monitoring programs for nearly 100 years, and is included in both CSLAP and the LCI. Low or high pH can impact most aquatic organisms, although these organisms can survive (at least temporary) significant variability between these extremes. Most New York state lakes outside the higher elevation portions of the Adirondacks and Catskills have pH readings above 5.5 to 6, the lower range affecting pH-sensitive organisms, and pH excursions above 8.5 are associated with algae blooms or in waterbodies in regions with significant limestone geology. The state water quality standards are associated with the ecological thresholds cited above.

Aquatic invasive species (AIS) can create significant ecological and economic impacts, and the presence of any AIS, including zebra and quagga mussels, Asian clams, and exotic fish, as summarized in Chapter 8, may represent a threat to aquatic life. Invasive animal surveys are not conducted through CSLAP or the LCI, although the known confirmed presence of these AIS is documented in the New York iMapInvasives database (http://www.nyimapinvasives.org/).

Dissolved oxygen (DO) is the primary measure of aquatic life impact, although DO levels are usually sufficiently high to support aquatic life in the upper waters of most lakes. DO in the hypolimnion (bottom waters) can fall to sub-critical levels, and near the lake bottom can be completely exhausted shortly after deeper lakes destratify in early summer. DO levels are measured in depth profile samples in the deepest part of each LCI lake, but are not measured in most CSLAP lakes. Hypolimnetic DO levels can be inferred by comparing hypolimnetic to epilimnetic ammonia or phosphorus levels in CSLAP lakes; ratios greater than 10 usually indicate *hypoxic* (oxygen-reduced) to *anoxic* (oxygen-depleted) conditions.

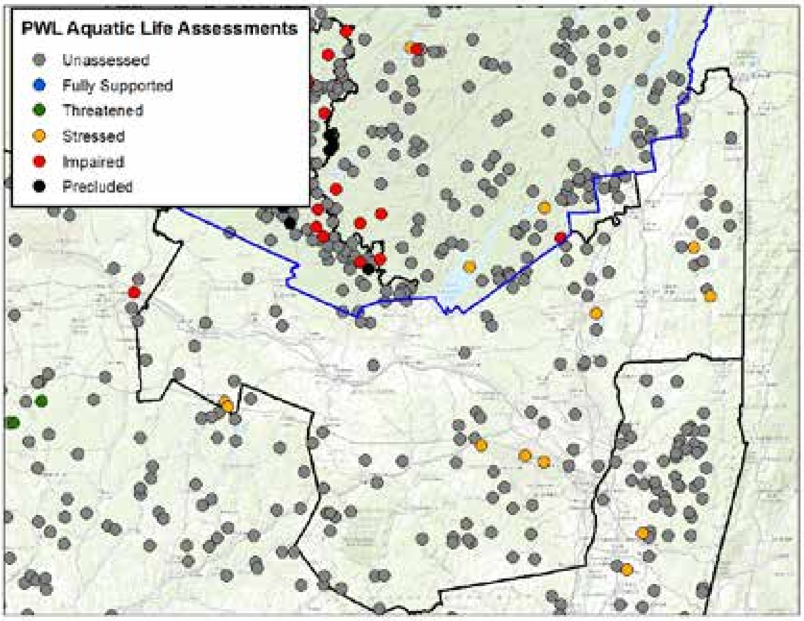
Figure 10.7: PWL aquatic life assessments for NYS lakes



In the absence of actual aquatic life impairments, which are not measured through CSLAP or the LCI, the presence of extensive AIS animals, highly elevated or depressed pH, or significant dissolved oxygen depletion may best be characterized as *impacted* rather than impaired, as summarized in Table 10.4.

Summary of New York state and Mohawk region aquatic life assessments

Figure 10.8: PWL aquatic life assessments for Mohawk region lakes



Aquatic life assessments have been conducted on a larger number of New York state lakes. Impaired and precluded conditions are generally limited to the western Adirondack region associated with acid rain impacts (in these lakes, fish propagation and survival impacts have been well documented through the Adirondack Lake Survey Corporation study of 1600 lakes in the high elevation regions of New York state). This is shown in Figure 10.7. Stressed conditions are more common in other regions of the state due to a combination of the factors reported above.

Table 10.4: Preliminary aquatic life assessments in CSLAP and LCI lakes, 2012-2016 (based on CSLAP and LCI data only)

Regions	%Supported	%Threatened	%Stressed	%Impacted
NYS	**50%**	**4%**	**38%**	**8%**
NYC-LI	38%	0%	44%	19%
Lower Hudson	58%	3%	30%	9%
Mid-Hudson	42%	3%	39%	15%
Mohawk	48%	12%	36%	4%
Eastern Adk	68%	2%	27%	2%
Western Adk	68%	4%	24%	4%
Central NY	47%	7%	40%	7%
Finger Lakes	26%	0%	70%	4%
Western NY	54%	7%	32%	4%

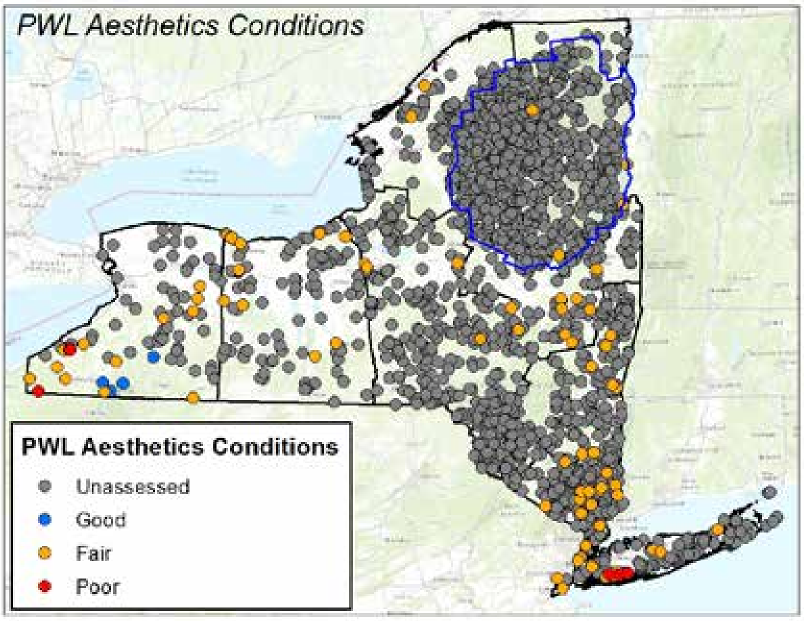
Figure 10.8 shows that few lakes have been assessed for aquatic life in the Mohawk region. These are mostly found in the eastern portion of the region, most likely due to a combination of elevated pH, measured and inferred DO depletion, and AIS animals. It is likely that similar percentages of stressed lakes are present in other portions of the region. Table 10.4, indicating more recent assessment information, shows a range of aquatic life support

and impacts similar to the range found in other regions outside of the Adirondack regions.

Evaluation of impacts to aesthetics

Aesthetics are influenced by several factors, several of which are measured through CSLAP and the LCI. These include excessive aquatic plants (weeds), whether growing up to the lake surface or forming surface canopies, and excessive algae growth, particularly when growing in bubbling mats on the lake surface. Aesthetics problems can be exacerbated when thick surface weeds serving as a platform for dense surface algal scums, and these conditions can lead to stagnant water, poor recreational conditions, and water quality problems. However, the CSLAP and LCI datasets cannot easily distinguish between these conditions and "excessive algae" or "excessive weeds." The CSLAP Field Observations form (also used in the LCI) does provide an opportunity for samplers to evaluate aesthetic problems, and while these assessments clearly undercount incidences of unfavorable lake aesthetics, these can serve as the backdrop for evaluating aesthetics impacts.

Figure 10.9: PWL aesthetic conditions for NYS lakes



Aesthetics (and habitat) are not considered designated uses by New York state or the US EPA, although both represent *conditions* that can affect several designated uses, particularly recreation and aquatic life. These are evaluated in New York as *good, fair,* and *poor* based the degree of nuisance plant growth (and associated management) and the recreational assessments. Exotic plant impacts to lake condition are characterized under habitat (below), not aesthetics.

Lake perception is used to evaluate aesthetic condition through the responses to field observations form, as discussed in greater detail in Chapter 9. There are no water quality standards associated with perception survey responses, although NYSDEC has developed criteria through the development of numeric nutrient criteria, based in part on water quality standards adopted in Vermont and Minnesota (using the same survey forms). *Poor* aesthetics are associated with a preponderance of perceived "slightly impaired” conditions, and *fair* aesthetics may be attributed to occasional impaired conditions or frequent surface weed growth. Excessive nutrient levels may also trigger sub-optimal aesthetics.

Figure 10.9 shows that aesthetics has not been evaluated in most New York state lakes. Most of the existing PWL assessments have been conducted for lakes outside the two Adirondack regions, with *fair* conditions usually associated with poor recreational assessments (due to either excessive algae or weeds) and elevated nutrient levels. In the Mohawk region (Figure 10.10), most of these assessments have occurred in the southern portion of the region, most likely in association with the Lower Hudson River basin PWL updates. This is consistent with the areas where assessments of other designated uses have occurred (Figures 10.2, 10.4, 10.6 and 10.8).

Figure 10.10: PWL aesthetic conditions for Mohawk region lakes

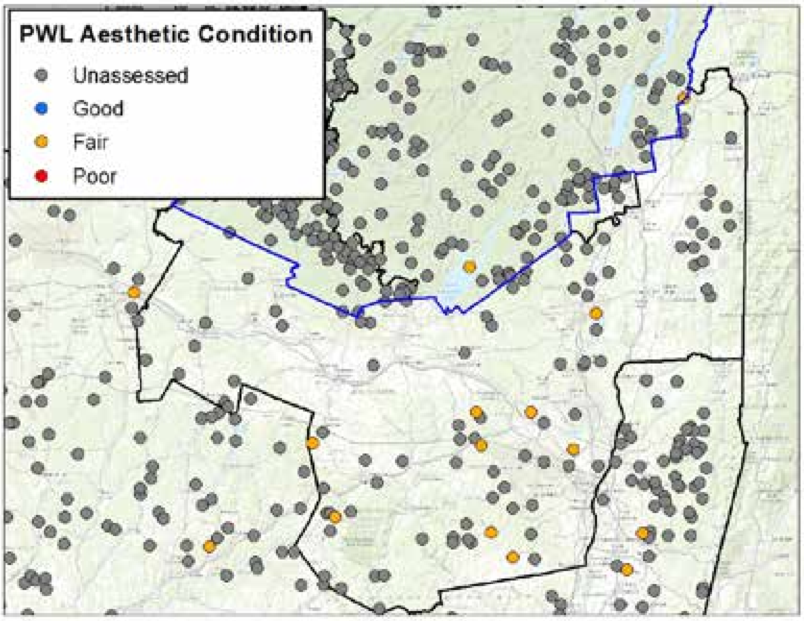


Table 10.5: Preliminary aesthetic conditions in CSLAP and LCI lakes, 2012-2016 (based on CSLAP and LCI data only)

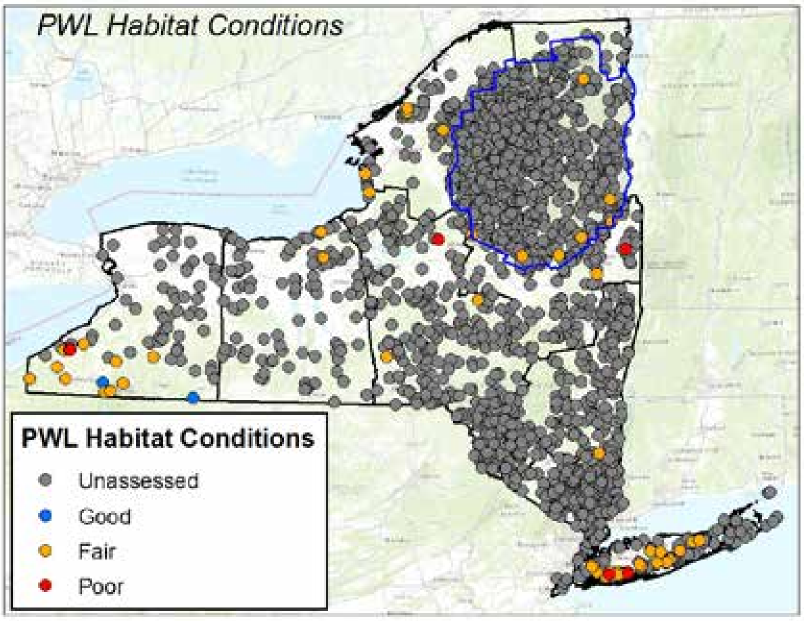
Regions	%Good	%Fair	%Poor
NYS	**8%**	**52%**	**40%**
NYC-LI	0%	56%	44%
Lower Hudson	3%	33%	64%
Mid-Hudson	12%	48%	39%
Mohawk	4%	56%	40%
Eastern Adk	15%	59%	27%
Western Adk	16%	40%	44%
Central NY	13%	40%	47%
Finger Lakes	4%	59%	37%
Western NY	4%	71%	18%

Table 10.5 shows that an “updated” assessment in the Mohawk region would indicate a very high percentage of fair and poor aesthetic conditions, at least according to the state CALM criteria. These assessments may be associated with excessive algae and weeds, excessive nutrients, and other impacts to recreational assessments. In some cases, samplers report that the lake “looks bad” or may have evidence of shoreline harmful algae blooms. Waterbodies with no evidence of at least periodic algae blooms, surface plant growth, or poor recreational assessments are not common in most regions of the state,

particularly the New York City / Long Island region.

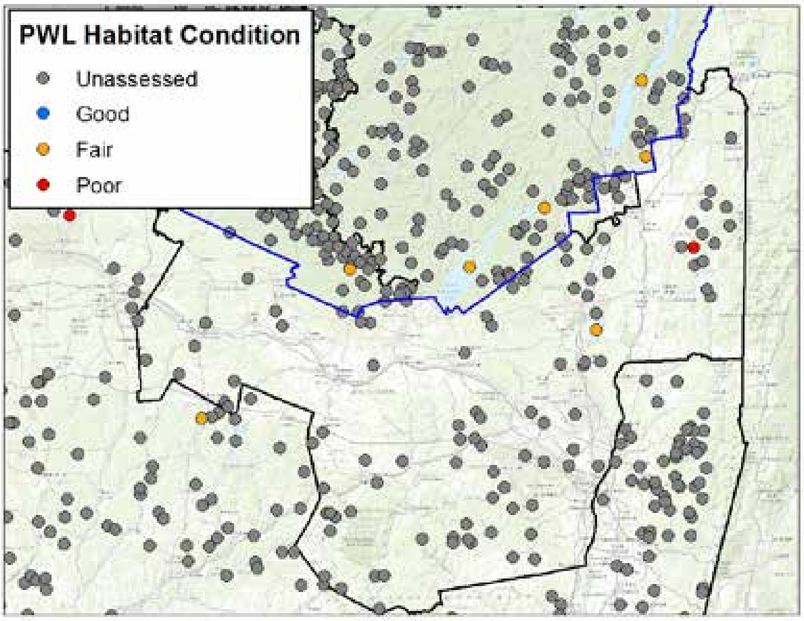
Evaluation of impacts to habitat

Figure 10.11: PWL habitat conditions for NYS lakes



Habitat conditions in New York have been evaluated through the assessment process for many years, mostly in the realm of aquatic life impacts in flowing waters. Macroinvertebrates and other biota can be strongly influenced by flow and hydrology, which are influenced by flow manipulation by dams, sedimentation, diversions, and other alterations. These in turn can influence oxygen, temperature, and other factors influencing aquatic life. In lakes, the assessment process considers the presence of aquatic invasive plants as most strongly influencing habitat, since invasive plants are much more likely to create dense underwater architecture and surface canopies that can dominate aquatic plant communities and ultimately crowd out all other underlying plants. Water quality impacts, such as reduced oxygen and rising water temperatures, can also be associated with these habitat changes.

Figure 10.12: PWL habitat conditions for Mohawk region lakes



As such, the primary CSLAP and LCI habitat indicators are aquatic plant coverage associated with invasive plants, since surface coverage of AIS will either mean extensive underwater coverage leading to dense surface canopies (as occurs with Eurasian watermilfoil) or significant nearshore surface coverage of plants that alter flow (such as water chestnut). Particularly dense AIS plant growth is often manifested in the use of plant management actions, such as mechanical harvesting or aquatic herbicides.

Table 10.6: Preliminary habitat conditions in CSLAP and LCI lakes, 2012-2016 (based on CSLAP and LCI data only)

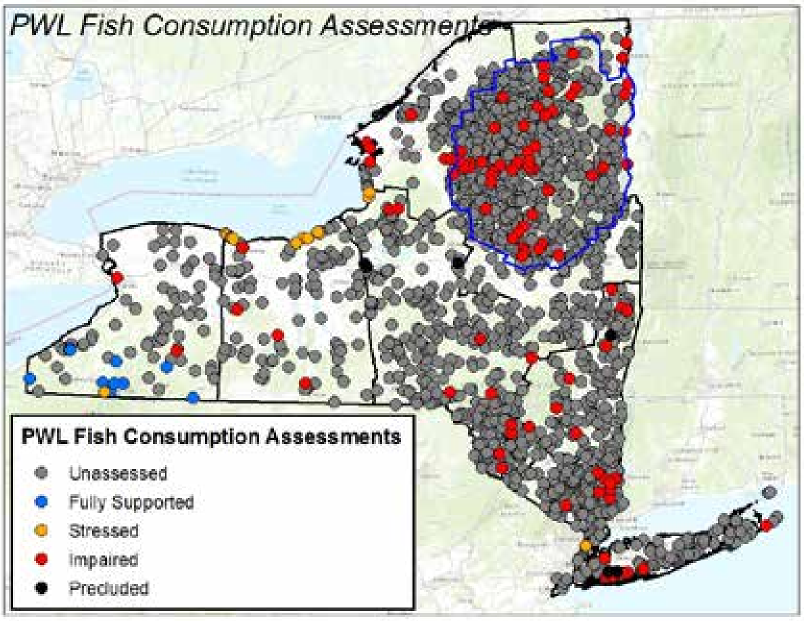
Regions	%Good	%Fair	%Poor
NYS	**24%**	**53%**	**23%**
NYC-LI	38%	50%	13%
Lower Hudson	9%	58%	33%
Mid-Hudson	24%	48%	27%
Mohawk	20%	64%	16%
Eastern Adk	22%	56%	22%
Western Adk	24%	44%	32%
Central NY	18%	56%	27%
Finger Lakes	19%	59%	22%
Western NY	39%	46%	14%

Figure 10.11 shows that habitat assessments have not been conducted for most New York state lakes; the available assessments are generally found in those portions of the state (the Allegheny River basin, the Atlantic Ocean/Long Island Sound basin, and the Mohawk River basin) in which the PWL has been most recently updated. However, Table 10.6 shows a range of habitat conditions are common in the CSLAP and LCI lakes sampled in the last few years (updated PWL assessments have not been conducted for these waterbodies) in New York state and in the Mohawk region. This reflects both the high frequency of AIS in the region, and the large number of lakes for which active management of these plants continues to occur.

Summary of fish consumption advisories

The lakes in New York state are used by many lake residents, anglers, and others for fish consumption. CSLAP and the LCI does not collect any information to evaluate fish consumption. However, each year the NYS Department of Health issues fish consumption advisories for the waters (and fish) of the state, based on fish sample collections by the NYSDEC Division of Fish and Wildlife. Several of these lakes have been the subject of fish consumption advisories, usually due to the bioaccumulation of atmospheric pollutants such as mercury. Figure 10.13 shows the regional summary of fish consumption advisories in

Figure 10.13: PWL fish consumption advisories for NYS lakes



New York state lakes, weighed heavily toward the Adirondack region. However, fish tissue contamination has been documented in lakes and ponds throughout the state. *Stressed* conditions have been reported in waterbodies with hydrologic access to waterbodies with fish consumption advisories. The most recent assessments (in the Allegheny River basin) also include locations where the lack of fish consumption advisories have been explicitly reported.