2017 Annual Report

Onondaga Lake Ambient Monitoring Program

Final, February 2019

Onondaga County

J. Ryan McMahon II, County Executive

Tom Rhoads, P.E., Commissioner

Save the Rain

Onondaga County Department of WATER ENVIRONMENT PROTECTION

Onondaga County Department of Water Environment Protection

VISION

To be a respected leader in wastewater treatment, stormwater management, and the protection of our environment using state of-the-art, innovative technologies and sound scientific principles as our guide.

MISSION

To protect and improve the water environment of Onondaga County in a cost-effective manner ensuring the health and sustainability of our community and economy.

CORE VALUES

Excellence
Teamwork
Honesty
Innovation
Cost-Effectiveness
Safety

Onondaga County Department of
WATER
ENVIRONMENT
PROTECTION

Save the Rain

http://www.savetherain.us

ONONDAGA LAKE AMBIENT MONITORING PROGRAM
2017 ANNUAL REPORT

ONONDAGA COUNTY, NEW YORK

Final, February 2019

Prepared for

ONONDAGA COUNTY, NEW YORK

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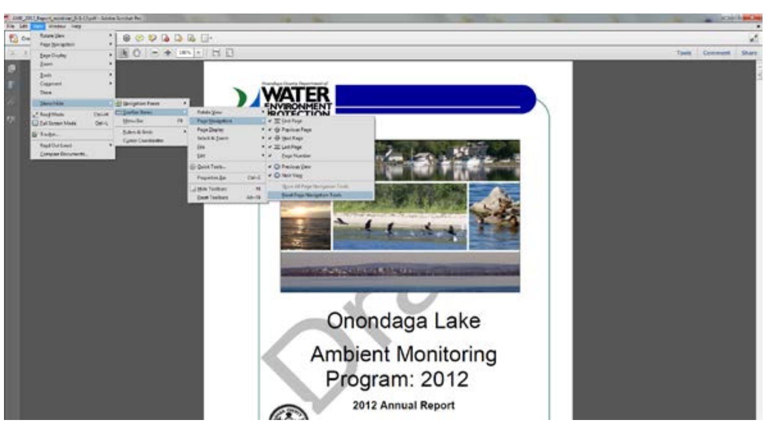

Key Features in this Report

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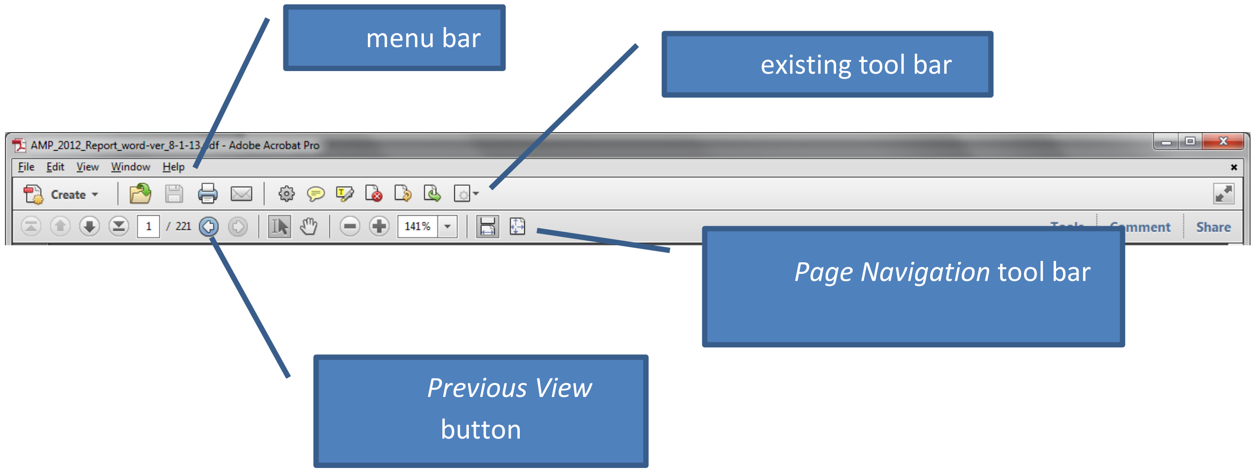

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View of Onondaga Lake from the Northeast Shore.

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Executive Summary

Introduction

Onondaga County has been monitoring Onondaga Lake and its tributary streams annually since 1970. In 1998, under the terms of an Amended Consent Judgment (ACJ) agreement, the long-term monitoring program was expanded to focus on the response of Onondaga Lake and its tributary streams to a planned series of improvements in wastewater collection and treatment infrastructure. The expanded program, known as the Ambient Monitoring Program (AMP), provides information to resource managers, elected officials, state and federal regulators, and the public, regarding the state of the lake.

This 2017 AMP Annual Report documents status and trends in water quality, external loading to Onondaga Lake, compliance with regulatory standards, habitat conditions, and the biological community. A more concise format has been adopted for the 2017 AMP Annual Report. However, additional details on all aspects of the AMP are provided in appendices to this report.

Many factors have contributed to a changing Onondaga Lake ecosystem; most factors relate directly or indirectly to the remedial efforts designed to bring the lake into compliance with regulatory requirements and community goals. Major remedial efforts include advanced treatment at the Syracuse Metropolitan Wastewater Treatment Plant (Metro), the reduction in Combined Sewer Overflows (CSOs), and the removal and inactivation of legacy industrial wastes. Biological factors, such as invasive species and the abundance of alewives, also affect lake water quality. The AMP strives to integrate the chemical and physical conditions of the waterways with implications for the biological community.

Highlights of 2017

Precipitation

2017 was a wet year; total rainfall was 46 inches, well above the long-term average of 39 inches. Higher than average rainfall persisted into July and was followed by extremely dry conditions in August and September. Above-average rainfall returned in October and November.

External Loading

Similar to average conditions post 2005, Metro contributed about 25% of the external annual total phosphorus load, while the watershed contributed the remaining 75%. The percentages vary based on weather—in dry years, the contribution from the Metro outfalls is larger. The largest contributors to fecal coliform loading in 2017 were Metro (34%), Ninemile Creek (25%), and Ley Creek (24%).

Trophic State

The AMP measures and reports several indicators of trophic state (level of primary productivity) in Onondaga Lake: water clarity, concentrations of chlorophyll-a, and total phosphorus concentrations. Taken together, the 2017 indicator parameters confirm that the lake's trophic state has been stable over the past decade. Onondaga Lake has met the criteria for a mesotrophic (moderately productive) lake since 2008.

Regulatory Compliance

Similar to recent years, Onondaga Lake waters were generally in compliance with NYS ambient water quality standards and guidance values. Exceptions include elevated total dissolved solids (TDS) concentrations, dissolved oxygen concentrations in the lower waters, and fecal coliform bacteria concentrations at the south end of the lake. Elevated TDS is a result of watershed geochemistry, not human activities. Depletion of DO in the lower waters is common in moderately productive stratified lakes where the volume of the hypolimnion is relatively small. Although most of the lake meets water quality standards for fecal coliform bacteria, nearshore sites in the south end continue to exceed the standard during periods of wet weather.

Ammonia, nitrite-N, and phosphorus have largely met applicable standards since completion of the advanced ammonia and phosphorus treatment at Metro. Dissolved oxygen (DO) concentrations continue to be low in the deepest waters of the lake during the summer period of thermal stratification. This phenomenon is observed in many relatively small mesotrophic lakes in NYS.

The 2017 tributary data indicate that the major tributaries were generally in compliance with ambient water quality standards (AWQS) for most monitored parameters. The primary exceptions were total dissolved solids, fecal coliform bacteria, and dissolved mercury. Five of the tributary monitoring sites regularly exceeded the AWQS for fecal coliform bacteria: Harbor Brook, Ley Creek, Onondaga Creek, Sawmill Creek, and Trib. 5A. Note that only Harbor Brook, Onondaga Creek, and Ley Creek receive CSOs.

Stormwater Capture

Substantial progress has been made in abating CSOs to Onondaga Creek, Harbor Brook, and Ley Creek. At the start of the ACJ in 1998, 72 overflow points directed a mix of stormwater and sanitary wastewater to the CSO-affected tributaries during wet weather. At present, 51 of the original 72 CSOs have been closed or abated. Through 2017, 206 green infrastructure projects have been completed as part of continuing efforts to reduce stormwater inputs to tributaries.

The Fourth Stipulation to the ACJ identifies two specific metrics to determine compliance: CSO capture and compliance with Ambient Water Quality Standards (AWQS). The 2017 update to the Storm Water Management Model (SWMM) indicates that the annual percent capture of combined sewage has surpassed 97%. The improvements to the sewerage system through green and gray infrastructure are ahead of ACJ-required target of 95% capture by December 2018. A determination of compliance with the ACJ Stage IV Percent Capture Milestone Value will be made as part of the 2018 ACJ Annual Report review.

Post Construction Compliance Monitoring

Onondaga County is required to sample CSO-affected streams during storms to evaluate the effectiveness of the gray and green infrastructure measures and to determine if CSOs are causing or contributing to exceedances of AWQS. In 2017, Harbor Brook water quality was monitored at four locations. Starting upstream, the sites included Velasko

Rd. (upstream of the urban corridor), Fowler High School (in the urban corridor above the first CSO outfalls), Hiawatha Blvd. (long-term AMP site below CSOs), and at the culvert where Harbor Brook flows into Onondaga Lake. Large increases in fecal coliform bacteria were measured at all sites during the storms. These increases, which are largely attributable to CSOs, resulted in exceedances of water quality standards for bacteria. Floatables (street litter, packaging, etc.) were observed during one of the three storm events, and only at the two most downstream sites on two of ten sample collections.

Biological Community

The major improvements to the wastewater treatment processes at Metro have also had a reverberating impact across the lake ecosystem. Lower phosphorus concentrations have reduced the biomass of phytoplankton (algae and cyanobacteria) and essentially eliminated the occurrence of nuisance blooms.

The reduction in phytoplankton has resulted in increased water clarity. This in turn has had a major influence on the physical structure of aquatic habitat in the lake by allowing rooted aquatic plants (macrophytes) to increase in both density and coverage. Aquatic macrophytes provide critical spawning and nursery habitat for many littoral zone fishes, and species such as largemouth bass, bluegill, and yellow perch have increased in Onondaga Lake as a result of this habitat enhancement.

Less phytoplankton production has also resulted in lower rates of oxygen depletion in the deep waters, expanding the volume of habitat to support fish and benthic macroinvertebrates.

The same improvements to Onondaga Lake's water quality and habitat that have allowed the native fish community to thrive have also provided opportunities for invasive species to colonize and prosper in the lake. Invasive fishes that are becoming more prominent in the lake include alewife, round goby, green sunfish, and rudd. The impact of these and other invasive species on the Onondaga Lake ecosystem becomes more relevant as lake conditions continue to improve and become suitable for more species.

Executive Summary

Spectators Enjoying the Onondaga Cup and Lakefest, July 16, 2016.

Executive Summary

Connect the Drops ad campaign.

Section 1. Onondaga Lake and its Watershed

Watershed Size and Hydrology

The Onondaga Lake watershed encompasses approximately 285 square miles (740 km^2), almost entirely within Onondaga County, including six natural sub-basins: Onondaga Creek, Ninemile Creek, Ley Creek, Harbor Brook, Bloody Brook, and Sawmill Creek (Figure 1-1).

In addition to the natural tributaries, treated wastewater is discharged to the lake, as is storm runoff from developed areas. Onondaga Creek is the largest water source to the lake, followed by Ninemile Creek, Metro, Ley Creek, Harbor Brook, minor tributaries, and direct runoff (Figure 1-2).

Much of the annual volume of water flowing to Onondaga Lake through the Metro treatment plant originates outside of the watershed. Water supply for the City of Syracuse is drawn from Skaneateles Lake. Onondaga Lake discharges into the Seneca River, which flows in a northerly direction and joins the Oneida River to form the Oswego River, ultimately discharging into Lake Ontario.

Sailing on Onondaga Lake.

Land Use

Compared with other lakes in central New York, the watershed of Onondaga Lake is relatively urbanized; the National Land Cover Dataset classifies the watershed as 18% developed (urban/suburban), 34% forested or scrub/shrub, 9% developed open space, and 29% cultivated lands or pasture (Appendix B-1). The remaining 10% is comprised of wetlands, lakes and barren land. Urban areas of the City of Syracuse, two towns (Geddes and Salina) and two villages (Liverpool and Solvay) border the lake.

Physical Characteristics of Onondaga Lake

Onondaga Lake is relatively small, with a surface area of 12 square kilometers and a maximum depth of 19.5 meters (Table 1-1). The lake basin is characterized by two minor depressions, referred to as the northern and southern basins, separated by a shallower region near the center of its longitudinal axis (Figure 1-3). The littoral zone, defined as the region of the lake where light reaches the sediment surface and can support plant growth of rooted plants, is narrow. Under current water clarity conditions, the littoral zone extends to a water depth of approximately 6 meters.

The Onondaga Lake shoreline is highly regular with few embayments. Onondaga County owns most of the shoreline, and maintains a popular park and trail system. Syracuse residents and visitors use the parklands for varied recreational activities and cultural entertainment. The lake is increasingly popular for boating; sailboats, motorboats, kayaks and canoes are familiar sights on summer days. Local and regional fishing tournaments attract anglers to the lake each year.

Section 1. Onondaga Lake and its Watershed

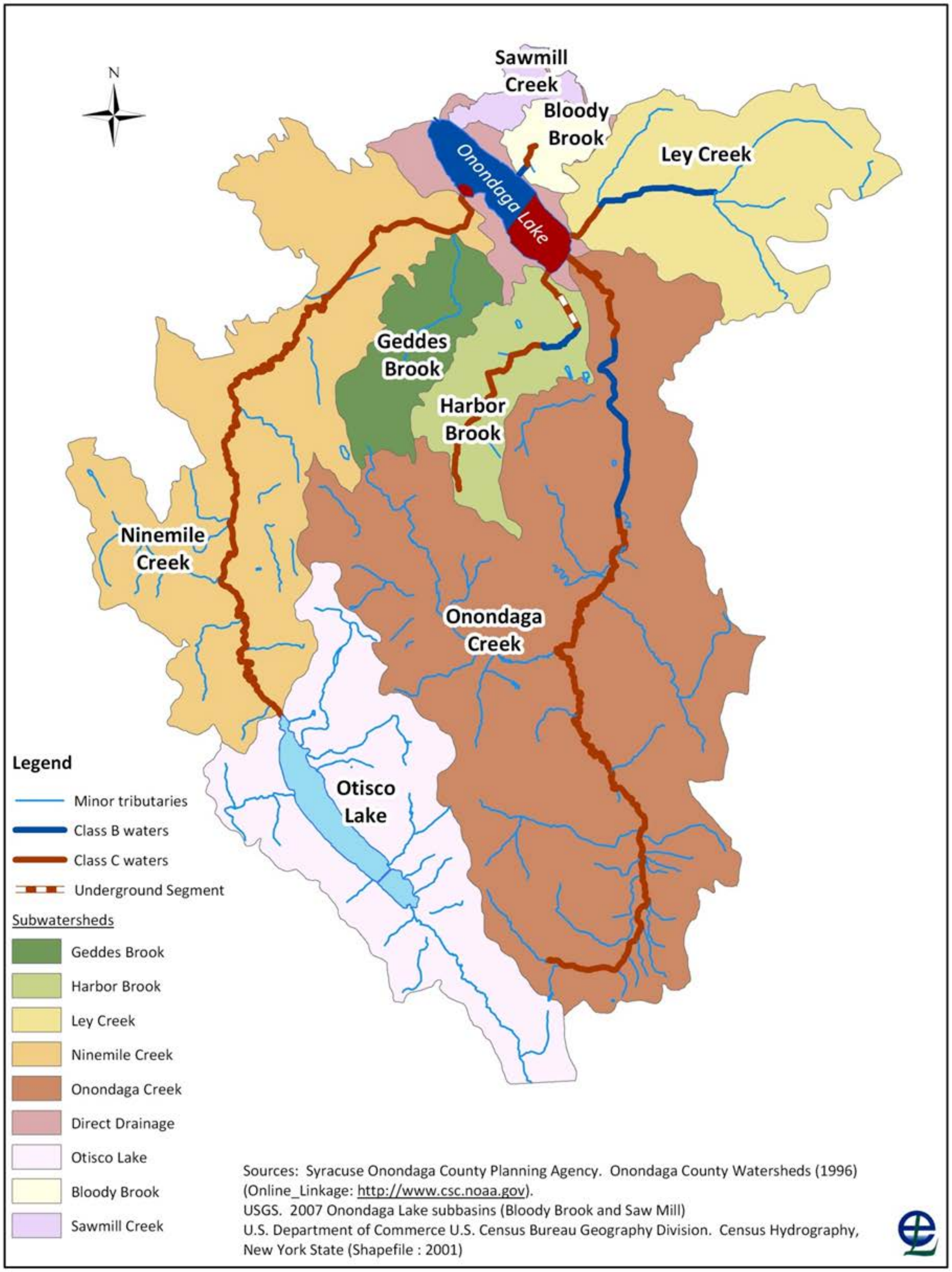


Figure 1-1. Tributary and lake regulatory classifications (6 NYCRR) and subwatershed boundaries.

Section 1. Onondaga Lake and its Watershed

Water residence (the average time water remains in the lake) is dependent on the ratio of inflow volume to lake volume. A large watershed with a small lake volume, such as Onondaga Lake, will result in a relatively short water residence time. In Onondaga Lake the average water residence time is about three months.

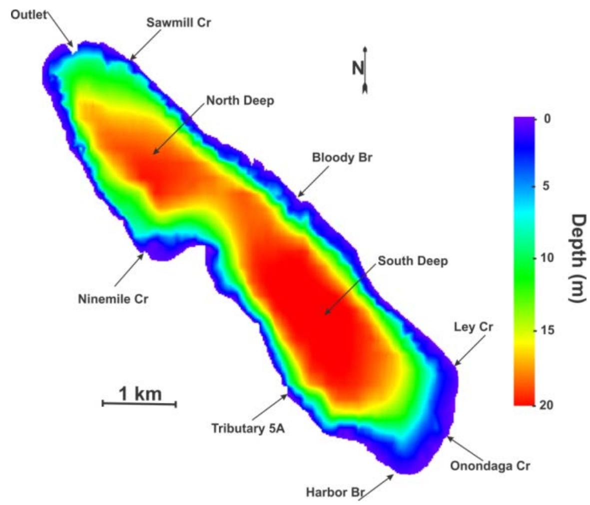


Figure 1-3. Bathymetric map of Onondaga Lake, with tributaries and primary sampling locations (South Deep, North Deep) identified.

Note: bathymetry based on data from CR Environmental Inc. 2007.

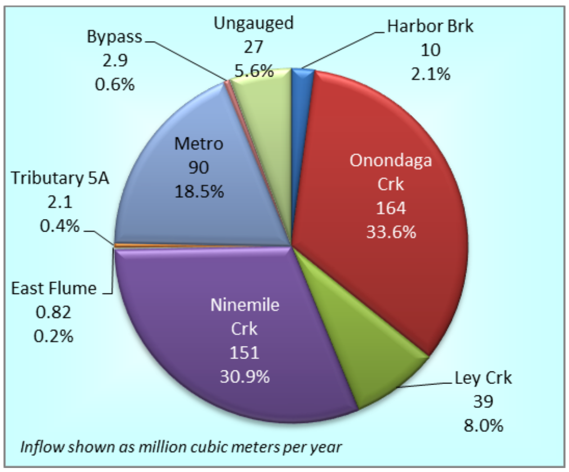


Figure 1-2. Annual average inflows (gauged and ungauged) to Onondaga Lake, 1990–2017.

Table 1-1. Physical characteristics of Onondaga Lake.

Characteristic	Metric	English
Surface area	12 km^2	4.6 square miles
Volume	131 x 10^6 m^3	35 billion gallons
Length	7.6 km	4.6 miles
Width	2 km	1.2 miles
Maximum depth	19.5 m	64 feet
Average depth	11 m	36 feet
Average elevation*	111 m	364 feet
Average flushing rate	4 times per year	4 times per year

Sources:
http://www.upstatefreshwater.org/NRT-Data/System-Description/system-description.html
http://www.dec.ny.gov/chemical/8668.html
*Elevation references to mean sea level.

Section 1. Onondaga Lake and its Watershed

Fishing on Onondaga Lake.

Section 2. Regulatory Requirements

Classification and Best Use

NYSDEC classifies surface waters with respect to both human uses and ecosystem protection. Onondaga Lake and its tributaries are classified as Class B and Class C waters (Appendix A-1; Figure 1-1). The best uses of Class B waters are for primary and secondary water contact recreation and fishing (NYCRR Part 701.7). Class B and Class C waters shall also be suitable for fish, shellfish, and wildlife propagation and survival. The best usage of Class C waters is fishing and they shall be suitable for primary and secondary water contact recreation, although other factors may limit the use for these purposes.

NYSDEC Division of Water is responsible for evaluating whether water quality and habitat conditions fully support each resource's designated best use. Those waterbodies with water quality and/or habitat conditions that do not fully support the designated uses are compiled on a biannual listing and given priority for assessment and action. A listing of water quality impairments in Onondaga Lake and its watershed, based on the Final New York State 2016 Section 303(d) List of Impaired Waters Requiring a TMDL/Other Strategy, is provided in Appendix A-2.

History and Sources of Impairment

Onondaga Lake and several of its tributary streams have been included in the NYSDEC list of impaired waters. Among the cited water quality impairments were: elevated concentrations of ammonia-N that exceeded ambient water quality standards for protection of aquatic life; elevated concentrations of phosphorus resulting in overabundant algae that impaired recreational and aesthetic uses; and depletion of dissolved oxygen from the overabundant algae that impaired aquatic habitat. Several water quality issues (ammonia, phosphorus, dissolved oxygen, fecal coliform bacteria) were linked to municipal discharges from Metro and the CSOs.

Aerial View of the City of Syracuse and Onondaga Lake.

Combined sewer overflows (CSOs) serve older portions of the City of Syracuse. These utilities carry both sewage and stormwater in a single pipe. During heavy rains and snowmelt, the capacity of the pipes to direct all flows to Metro can be exceeded. Relief points along creeks allow the mixture of stormwater and untreated sewage flows to overflow into Onondaga Creek, Harbor Brook, and Ley Creek, ultimately reaching Onondaga Lake. When these overflows occur, CSOs may carry bacteria, floating trash, organic material, nutrients and solid materials to the waterways.

Amended Consent Judgment

In 1998, Onondaga County, New York State, and the Atlantic States Legal Foundation signed an agreement to mitigate the adverse impacts of municipal discharges on the waterways. The agreement, known as the Amended Consent Judgment (ACJ), required Onondaga County to design and implement improvements to the County's wastewater collection and treatment infrastructure, and to measure and report on their effectiveness. The ACJ called for a phased program to be implemented over a 15-year period.

The ACJ has been modified four times since 1998, most recently by stipulation in 2009. Modifications to the 1998 document incorporate emerging information regarding appropriate technologies to mitigate the impacts of Metro and the CSOs on local waterways. Links to the ACJ and the Fourth Stipulation are posted on the Onondaga County web site.

Lakeview Amphitheater during Dave Matthews Band Concert, July 2016

ACJ Milestones

The ACJ (1998) stipulates a series of specific engineering improvements to the County's wastewater collection and treatment infrastructure. Onondaga County has agreed to undertake a phased program of Metro improvements (Appendix A-4). The Fourth Stipulation of the ACJ (2009) requires phased reductions of CSO volume, and improvements to the wastewater collection and treatment infrastructure are scheduled through 2018.

The schedule of the percentage of CSO volume that must be captured or eliminated on a system-wide annual average basis is provided in Table 2-1. The 2017 annual stormwater management model (SWMM) update reflects changes to the system during 2017 and new or improved data; this update of the model is referred to as the "2017 conditions model."

Table 2-1. CSO capture compliance schedule.

ACJ Compliance Stage	ACJ Percent CSO Capture by Volume	Onondaga County Save the Rain Program Status Percent CSO Capture by Volume[1,2]	ACJ Compliance Deadline
Stage I	89.5%	92.9%	December 31, 2013
Stage II	91.4%	96.2%	December 31, 2015
Stage III	93.0%	97.4%	December 31, 2016
Stage IV	95%	TBD	December 31, 2018

[1] SWMM results based on the 1991 (selected as the typical year) precipitation record.
[2] TBD = To Be Determined

SWMM results showed that the annual combined sewage percent capture for the 2017 system conditions was 97.6%, and continues to be ahead of schedule with respect to the mandated Stage IV compliance milestone. A determination of compliance with the ACJ Stage IV Percent Capture Milestone Value will be made as part of the 2018 ACJ Annual Report review.

A total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake was developed by NYSDEC and approved by USEPA on June 29, 2012. A total phosphorus concentration limit of 0.10 mg/L on a 12-month rolling average basis was established for Metro outfall 001, and became effective upon TMDL approval. In addition, phosphorus loading reductions are to be implemented for other SPDES permits by 1/1/2016, CSOs and Metro outfall 002 by 12/31/2018, agricultural lands by 12/31/2022, and for MS4 areas by 12/31/2025. Phosphorus loading reductions from small farms are voluntary and incentive based.

OCDWEP Technicians sampling zooplankton from Onondaga Lake.

AMP Objectives and Design

The primary objectives of the AMP are to evaluate the effectiveness of improvements to the wastewater collection and treatment infrastructure, and to assess the need for additional measures to bring the waters into compliance. The AMP is designed to provide data and information required for this assessment. As a consequence, the annual report focuses on compliance and trends.

In 2017, trained field technicians collected representative samples from a network of permanent long-term sampling locations in nearshore and deep regions of Onondaga Lake (Appendix B-2) and along the lake tributaries (Appendix B-3). In 2017, all analyses were completed by laboratories certified by the Environmental Laboratory Approval Program (ELAP). The OCDWEP Environmental Laboratory conducted analysis for all parameters, with the exception of methylmercury analyzed by Test America and free-cyanide analyzed by Eurofins Spectrum Analytical.

The AMP Five-Year Work Plan (2014–2018), a roadmap for monitoring and assessment of Onondaga Lake and its tributaries, is reviewed annually to address changing conditions and new information. The 2017 AMP Work Plan included monitoring programs to:

- Support evaluation of the trophic status of Onondaga Lake
- Determine whether designated best uses are supported in Onondaga Lake and its tributaries
- Assess various biological communities, including phytoplankton, zooplankton, macroinvertebrates, dreissenid mussels, and fish

- Evaluate effectiveness of improvements to the CSO network (Post Construction Compliance Monitoring (PCCM))

Parameters measured in the 2017 AMP are used to support compliance assessment, loading calculations, and analysis of lake ecology (Appendix A-3). The 2017 Onondaga Lake, Onondaga Lake Tributary, and Onondaga Lake Biological sampling programs remained unchanged from the 2016 programs. The 2017 PCCM program included high frequency sampling of Harbor Brook during three wet weather events and continued sampling of CSO facility influent chambers during storm events.

Each year, Onondaga County reviews the laboratory data for quality assurance/quality control criteria (Appendix D-1) prior to uploading the annual data set to the long-term database and use in the Annual AMP Report. This custom database archives the complete set of Onondaga Lake and tributary monitoring results collected since 1970. In addition, annual field audits of the tributary (Appendix D-2) and lake (Appendix D-3) water quality monitoring programs were conducted in 2017 by the AMP consultant UFI to ensure appropriate sampling protocols are followed by the sampling staff.

The Onondaga County Laboratory voluntarily participates in the Environment and Climate Change Canada Proficiency Testing Program for total phosphorus and total mercury analyses in natural waters (Appendix D-4). These biannual blind tests include multiple academic, government, and private laboratories. In 2017, the performance of the laboratory for total phosphorus and low-level total mercury analyses was rated as "very good", which is the highest laboratory rating.

The County maintains a bibliography of published materials related to Onondaga Lake (Appendix I-1). The bibliography serves the AMP team and the community at large by compiling references to investigations by agencies of local government, regulatory agencies, university researchers, and private companies working on various aspects of the Onondaga Lake restoration effort. The findings of these investigations help inform the AMP team in data analysis and interpretation.

Onondaga Lake at the 2018 Clean Water Fair.

Use of Metrics to Measure and Report Progress

Onondaga County Department of Water Environment Protection, in consultation with NYSDEC and the Onondaga Lake Technical Advisory Committee (OLTAC), has developed a suite of metrics to help organize and report on the extensive AMP data set each year. These metrics relate to the lake's designated "best use" for water contact recreation, fishing, and protection of aquatic life. As summarized in Table 2-2 (Appendix A-5 for additional details), the Class B segments of the lake demonstrate water quality conditions that support the lake's designated best uses. Major reductions in loading of ammonia-N and phosphorus from Metro to Onondaga Lake have resulted in marked improvements in the lake's suitability for water contact recreation, aesthetic appeal, aquatic habitat, and recreational fishing. Metrics selected for Onondaga Lake address both human uses and ecosystem function:

- water contact recreation
- aesthetics
- aquatic life protection
- sustainable recreational fishery

In addition to the annual snapshot provided in the table of metrics, a series of more detailed tables are presented to describe progress toward improvement with respect to specific water quality and biological attributes of Onondaga Lake (Appendix C). This appendix provides an overview of the monitoring program design, criteria used to evaluate progress, and a summary of temporal trends, including:

- total phosphorus (Appendix C-1)
- chlorophyll-*a* (Appendix C-2)
- Secchi disk transparency (Appendix C-3)
- dissolved oxygen (Appendix C-4)
- ammonia-N (Appendix C-5)
- nitrite (Appendix C-6)
- bacteria (Appendix C-7)
- phytoplankton (Appendix C-8)
- macrophytes (Appendix C-9)
- zooplankton (Appendix C-10)
- fish (Appendix C-11)

Metrics related to water contact recreation, aesthetic appeal, and aquatic life protection are also tracked in the tributaries to Onondaga Lake as part of the AMP. Tributaries are monitored for fecal coliform bacteria and compared to standards developed for contact recreation, although other factors limit recreational access and use of these urban streams. Bacteria data are also used to identify potential sources and track the effectiveness of stormwater management efforts. The occurrence of floatables is documented to demonstrate effectiveness of floatable control measures and support assessment of aesthetic conditions in the streams affected by CSOs. Many water quality parameters measured in the tributaries are indicators of suitability for aquatic life, e.g., dissolved oxygen, pH, and ammonia-N.

Sunset on Onondaga Lake.

Table 2-2. Summary of metrics, Onondaga Lake 2017.

Metric	Target	2017 Results	Comments
Indicator bacteria	100% compliance with AWQS (April-October)	100% and 71-100% compliance in Class B and Class C waters, respectively	Class B segments of Onondaga Lake met the bacteria standard for water contact recreation
Water clarity	Secchi depth ≥ 1.2 m	92% and 87% compliance in Class B and Class C waters, respectively	Nearshore areas in the southern end of the lake (Class C) do not consistently meet the water clarity guidelines for swimming safety
Algal blooms	≤ 15% of Chl-a values > 15 µg/L and ≤ 10% of Chl-a values > 30 µg/L	4 of the 20 (20%) South Deep measurements exceeded 15 µg/L; no values exceeded 30 µg/L	Chl-a exceeded 15 µg/L on four consecutive sampling dates in September
Algal community	Cyanobacteria represent ≤ 10% of algal biomass	Cyanobacteria represented 16% of the algal biomass during summer	Cyanobacteria were a major component of the algal community from mid-August through September
Ammonia	100% compliance with AWQS (upper waters)	100% of measurements in compliance	Based on these metrics, the designated use for aquatic life protection (warm water fishery) was met in the upper waters
Nitrite	100% compliance with AWQS (upper waters)	100% of measurements in compliance	
Dissolved oxygen	100% compliance with AWQS (upper waters)	100% of measurements in compliance	
Habitat quality	40% macrophyte coverage	50% (2013 results)	Littoral zone macrophyte coverage provides high quality habitat for warm water fish community
Fish reproduction	Reproduction of target species	Evidence for all target species except black crappie, walleye, and northern pike	Rock Bass reproduction was documented for the first time in 2017
Fish community	Species richness comparable to other regional lakes	Adults representing 26 species were identified during electrofishing, comparable to regional lakes	The lake's natural temperature and dissolved oxygen conditions limit habitat for cold water species

Section 3. Onondaga County Actions and Progress

Onondaga County Projects and Milestones

By signing the ACJ in 1998, Onondaga County agreed to design and construct a series of engineering improvements to the wastewater collection and treatment infrastructure within the Metro service area. Improvements to Metro have reduced phosphorus concentrations and altered the speciation of nitrogen in the fully-treated effluent, associated with year-round nitrification treatment (Appendix A-6).

Abating the combined sewer overflows (CSOs) is a significant challenge (Appendix B-4). The Combined Sewer System tributary to Metro includes an area of 7,337 acres or approximately 11 square miles. CSOs are tributary to three receiving waters, Onondaga Creek, Harbor Brook, and Ley Creek. At the start of the ACJ, 72 overflow points were active during wet weather conditions, and directed a mix of untreated stormwater and sanitary wastewater to the CSO-affected tributaries and ultimately to the lake. The ACJ includes a phased schedule for CSO compliance, with the goal of capturing, for treatment or elimination, no less than 95 percent by volume of CSO by 2018. At present, 51 of the original 72 CSOs have been closed or abated.

The County has employed four strategies to reduce wet weather discharges from the combined sewer system to the Metro treatment plant: (1) sewer separation, (2) construction of regional treatment facilities, (3) capture of floatable materials, and (4) maximization of system storage capacity, or "gray infrastructure" (Appendix A-7, Appendix A-8). A fifth strategy, Green Infrastructure (GI) was subsequently added to this list with the 2009 agreement to amend the ACJ by stipulation.

Green Infrastructure Facility Installed at the Intersection of Amy Street, Delaware Avenue and Grand Avenue.

In response to the stipulation adding GI to the strategy list, Onondaga County created the Save the Rain (STR) program in 2009. This award-winning initiative encompasses both green and gray infrastructure improvements designed to keep stormwater from entering the combined sewer system. All five strategies are used. Seventeen (17) GI projects were completed in 2017 as part of the STR program. Through 2017, a total of 206 GI projects have been implemented in Onondaga County through the STR program. Results from the County's recently calibrated Storm Water Management Model (SWMM) indicate that GI projects are reducing stormwater runoff by 154 million gallons per year and providing CSO reduction of approximately 74 million gallons per year. For additional information on STR projects visit the Save the Rain website (savetherain.us).

The County has completed construction on all gray infrastructure projects required in the ACJ. Going forward, the County will focus on optimizing the performance of its CSO control facilities, while continuing to implement green infrastructure in priority areas, perform maintenance on both gray and green facilities, implement best management practices (BMPs) and floatables control measures, and monitor system performance.

Rain Barrel Installation.

Crew Practice on Onondaga Lake.

Section 4. Tributary Water Quality

Tributary Monitoring Program

The primary objectives of the tributary monitoring program are: (1) assess compliance with ambient water quality standards (AWQS) in the tributary streams and (2) estimate loading of materials to the lake, including contributions from combined sewer overflows (CSOs). Tributary monitoring data are also used to support long-term trend analysis. Seven tributaries to the lake are monitored, as are Metro discharges and the Onondaga Lake outlet. Sampling is conducted over a range of streamflow conditions, including high flow events.

The post construction monitoring program (PCCM) supports evaluation of green and gray CSO controls through monitoring of receiving waters and the influent chambers of CSO facilities. High frequency monitoring during storm events is an important component of the PCCM efforts. In 2017, Harbor Brook was monitored during three storm events (see Appendix F-17 for details).

Additional information on the tributary monitoring program can be found in the Five-Year (2014–2018) AMP Work Plan. Results for key parameters and tributary sampling locations are presented in this section.

Meteorological Drivers and Streamflow

Meteorological conditions in the Central New York region are subject to substantial seasonal and year-to-year variations. Air temperature is the primary determinant of stream temperatures, which can affect the fate and transport of these inflows in the lake. However, precipitation, as the primary driver of stream flow, is the single most important meteorological attribute affecting material loading from the tributaries.

Annual precipitation totaled 46.0 inches in 2017, 6.9 inches more than the 32-year historic (1985–2016) average of 39.1 inches. Monthly precipitation totals were higher than the long-term averages during January through July, October, and November (Figure 4-1). Precipitation was particularly high during May and October. The months of August, September, and December were dryer than the long-term average. Just 3.2 inches of rainfall was measured during August and September of 2017 compared to the long-term average of 7.3 inches. Snowfall for the winter of 2016–2017 totaled 135 inches, well above the 1951–2015 average of 119 inches.

Harbor Brook Wetland.

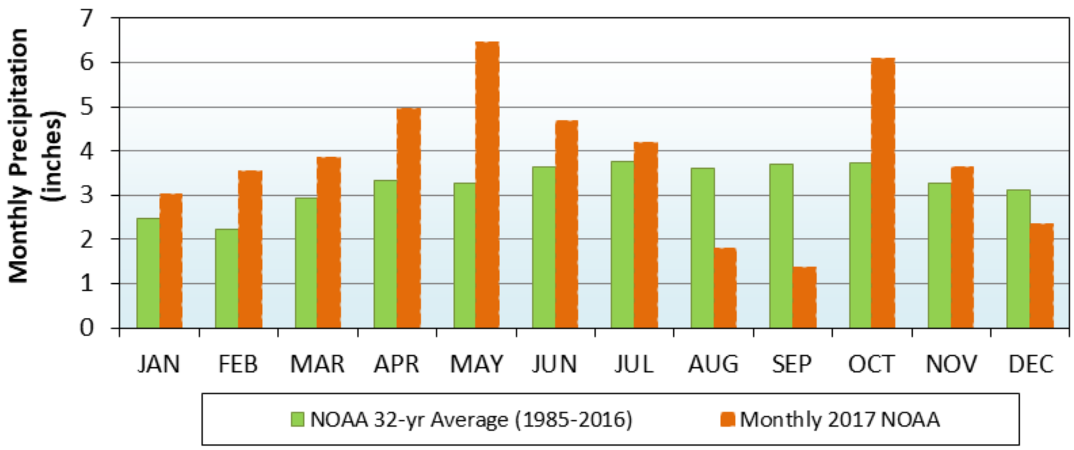


Figure 4-1. Monthly precipitation in 2017 compared to the long-term (1985–2016) average.

By the end of 2017, the higher rainfall caused the annual average discharge of Onondaga Creek to be 24% higher than the long-term mean (Appendix F-1). The rainfall and stream discharge patterns are tightly coupled; daily streamflow measurements for Onondaga Creek in 2017 depict a series of major runoff events from January through mid-July, followed by a dry period that lasted through late October (Figure 4-2a). Daily rainfall totals exceeded one inch on April 4, May 5, July 1, October 29, and October 30 (Figure 4-2b).

Additional statistical comparisons of 2017 precipitation compared with other years are summarized in Appendix F-1 and Appendix F-2.

Because concentrations and loading rates of many water quality constituents depend on stream flow conditions, the AMP targets a broad range of flow conditions to reduce uncertainty in annual loading estimates. Most loading occurs during high flows; the AMP is designed to target at least five sampling events during high flow conditions (defined as stream flow at the Onondaga Creek-Spencer St. gauge of at least one standard deviation above the long-term monthly average). In 2017, at least 10 high flow events were sampled in Onondaga Creek, Ninemile Creek, Ley Creek, and Harbor Brook (Appendix F-3).

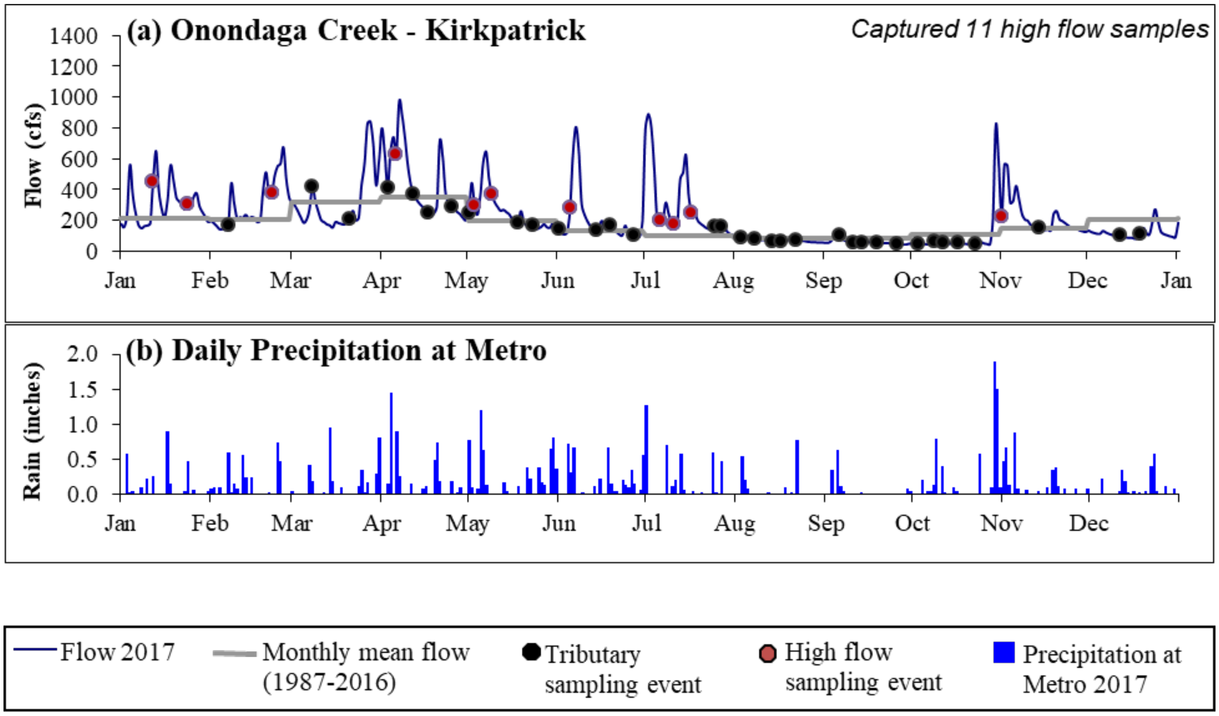


Figure 4-2. Hydrographs showing USGS tributary flows in 2017 compared with the 30-year average (1987–2016) flow for (a) Onondaga Creek, and (b) daily precipitation at Metro.

Note: high flow samples are indicated by red circles and other samples are indicated by black circles.

Loading Estimates

Methodology

Dr. William Walker developed customized software for WEP staff to calculate annual loads using the program AUTOFLUX. This software was used to compute all of the loading estimates presented in this report. Annual loading estimates for selected parameters are presented in Appendix F-4. Loading estimates for additional constituents are provided in Appendix F-5 and relative standard errors of these estimates can be found in Appendix F-6. Tributary loading calculations were supported by at least 23 observations within the year, except for Honeywell Manhole 015 (n=4) and Tributary 5A (n=4), as per the 2017 AMP Work Plan. Fecal coliform samples were collected more frequently (5 samples per month during April-October) to allow for determination of compliance with the AWQS.

Results for Key Constituents

The largest total phosphorus (TP) loads to Onondaga Lake in 2017 were delivered by Onondaga Creek (22.1 metric tons), Metro 001+002 (14.9 metric tons), and Ninemile Creek (13.4 metric tons; Appendix F-4). Onondaga Creek was the predominant source of TP, contributing 39% of the total load; Metro, Ninemile Creek, and Ley Creek contributed 26%, 24%, and 10%, respectively (Table 4-1; Figure 4-3).

Section 4. Tributary Water Quality

Table 4-1. Percent contribution to total annual loading by gauged inflow in 2017.

Parameter	TP	NH_3-N	FC[1]	Water
Metro:				
Treated Effluent (001)	17.1%	46.3%	36.2%	17.1%
Bypass (002)	9.3%	18.9%	1.5%	0.9%
Watershed				
Harbor Brook	0.9%	0.5%	1.2%	2.1%
Ley Creek	9.8%	7.4%	24.4%	8.2%
Ninemile Creek	23.8%	19.7%	24.8%	36.2%
Onondaga Creek	39.1%	7.1%	11.6%	35.3%

[1] the annual loading contribution for the Treated Effluent (001) includes samples collected during months when disinfection is not required and at the BAF Influent site from 10/15/17-12/31/17, as the HRFS facility was off-line during this time period due to construction.

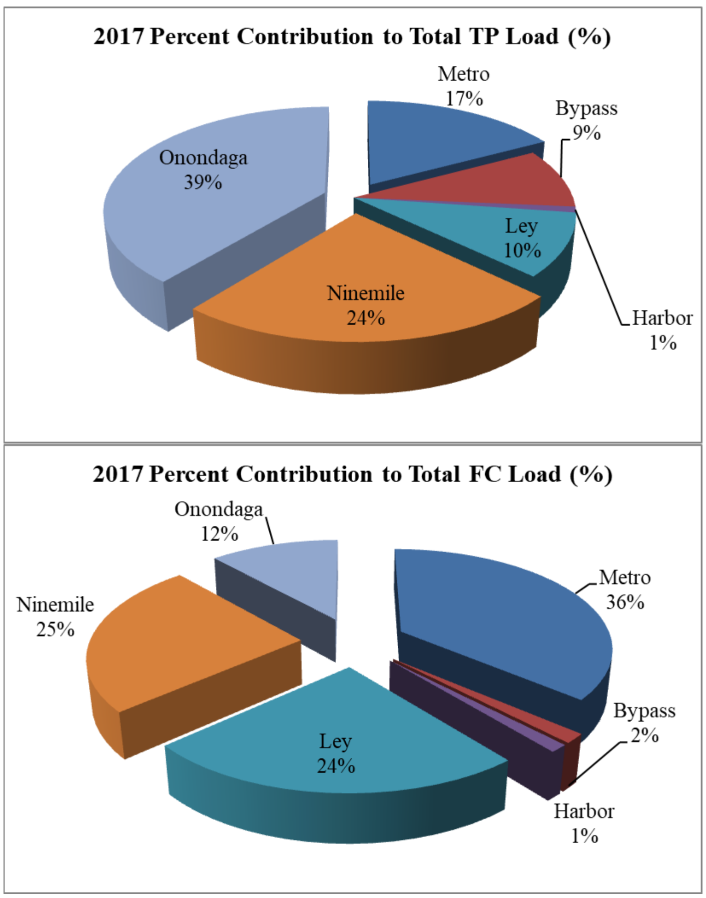


Figure 4-3. Percent contributions to 2017 total load to Onondaga Lake for (a) total phosphorus and (b) fecal coliform bacteria.

Metro's contribution to TP loading decreased dramatically with implementation of the Actiflo® treatment in 2005 (Figure 4-4). Moreover, Metro's contribution to the total annual phosphorus load decreased from 61% over the 1990 to 2004 interval to 23% during 2007–2017 (Figure 4-5). Seasonal phosphorus loading information for Metro and the natural tributaries is provided in Appendix F-10 and Appendix F-11.

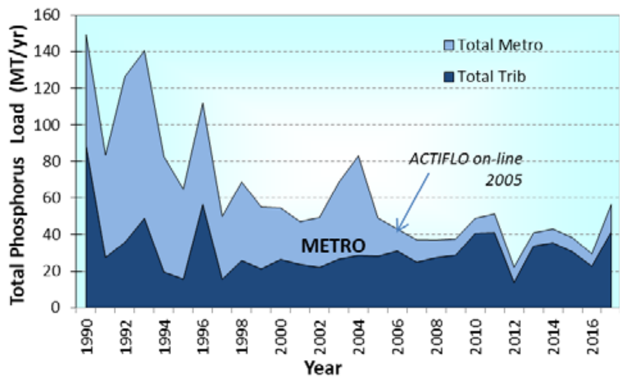


Figure 4-4. Time plot of the annual daily average Metro (outfalls 001+002) TP loading (metric tons per year) to Onondaga Lake, 1990–2017.

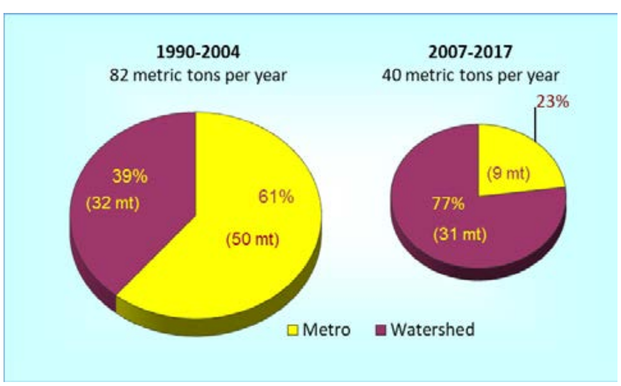


Figure 4-5. Contributions of Metro (outfalls 001+002) and the watershed to the annual input of TP to Onondaga Lake, average for 1990–2004 compared to the average of 2007–2017.

The phosphorus TMDL for Onondaga Lake established both an average TP load allocation (77,668 pounds per year) and a maximum TP load allocation (114,975 pounds per year). The lake model projections used to develop the TMDL indicate that the average TP load will protect the lake from adverse impacts of eutrophication over time; the maximum load reflects the reality of fluctuating TP load based on annual rainfall and streamflow conditions. The estimated total phosphorus load to the lake in 2017 was 124,080 pounds (Appendix F-4). All elements of the lake phosphorus TMDL have not yet been fully implemented. Phosphorus loading reductions associated with CSOs and the Metro Bypass are scheduled to be fully implemented by 12/31/18. The implementation dates for agricultural lands and MS4s are 12/31/22 and 12/31/25, respectively.

The Metro effluent (outfalls 001+002) was the largest source of both total nitrogen (TN; 66%) and ammonia nitrogen (NH_3-N; 65%) to the lake in 2017 (Appendix F-4, Table 4-1). The second largest source of ammonia-N in 2017 was Ninemile Creek (20%). The ammonia concentration of the Metro effluent decreased by 98% with completion of the BAF treatment upgrade in 2004 (Figure 4-6). Efficient, year-round nitrification of ammonia reduced Metro's contribution to the total annual load (Metro + tributaries) from 91% to 49% (Figure 4-7).

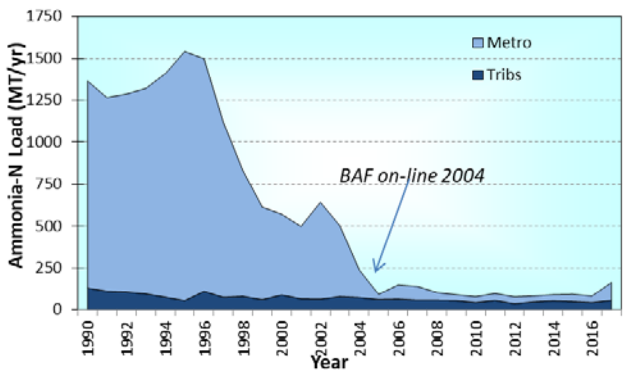


Figure 4-6. Time plot of the annual daily average Metro (outfalls 001+002) and tributary ammonia loading (metric tons per year) to Onondaga Lake, 1990–2017.

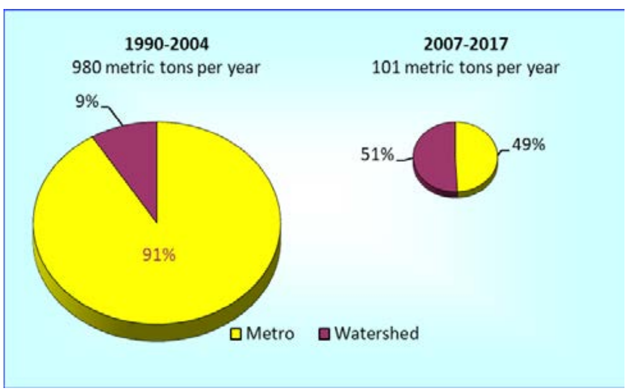


Figure 4-7. Contributions of Metro (outfalls 001+002) and the watershed to the total annual input of ammonia-N to Onondaga Lake, average for 1990–2004 compared to the average for 2007–2017.

The total suspended solids (TSS) load was dominated by inputs from Onondaga Creek (77%) and Ninemile Creek (16%), which combined to account for 93% of the total load to Onondaga Lake (Appendix F-4). The high TSS load in Onondaga Creek is attributed, at least in part, to inputs from the mud boils in upstream portions of its watershed.

The primary sources of fecal coliform bacteria were Metro (36%), Ninemile Creek (25%), and Ley Creek (24%) (Table 4-1; Figure 4-3). Note that estimated fecal coliform loads for the Metro Bypass and Ninemile Creek are highly uncertain, with relative standard errors of 88% and 92%, respectively (Appendix F-6). The combined loading from these three sources accounted for 85% of the total fecal coliform bacterial load to the lake.

Ninemile Creek, Onondaga Creek, and Metro accounted for nearly 90% of the water inflow to Onondaga Lake in 2017 (Table 4-1). Total annual loads to Onondaga Lake for the 1996–2017 interval are presented in Appendix F-7. Flow-weighted concentrations for 2017 are presented in Appendix F-8 and Appendix F-9.

Metro Performance

A schematic of the Metro treatment process, including the various outfalls, is available on page 32 of the Metro SPDES permit (Appendix E-1). Flow exits Metro through four outfalls, depending on the level of wastewater treatment:

- headworks bypass – Outfall 01B
- secondary bypass – Outfall 002
- tertiary bypass – Outfall 01A
- fully treated – Outfall 001

Metro provided full treatment to an average flow of 70.4 million gallons per day (mgd) in 2017, which was discharged to the lake through Outfall 001. On an annual basis, discharge from Outfall 001 was more than 25.7 billion gallons. During particularly high runoff intervals, inflows to Metro can exceed the capacity of the facility to provide full treatment of wastewater. Portions of this inflow receive partial treatment, usually primary treatment and disinfection, and are discharged via Outfall 002 (secondary bypass; Appendix E-2). There were 45 secondary bypasses in 2017, which had a combined duration of 549 hours and a total volume of 1,378 million gallons. Less frequently, the inflow receives secondary treatment and disinfection prior to discharge via Outfall 01A (tertiary bypass; Appendix E-3). In 2017 there were 26 tertiary bypasses that contributed a total of 28 million gallons over a period of 51 hours. Rarely, under particularly extreme runoff conditions or plant construction, a small portion of the inflow to the facility receives no treatment and is discharged via Outfall 01B (plant headworks are bypassed; Appendix E-4). There were 20 headworks bypasses in 2017 that lasted 74 hours and discharged a total volume of 171 million gallons. Note that the plant was operating a reduced capacity during parts of 2017 associated with the secondary bypass disinfection project.

Metro's annual discharge volumes for 2010–2017 are summarized in Appendix E-5. The extent to which bypasses occur depends primarily on precipitation (both total volume and intensity) and construction projects at the plant.

Metro performance, relative to the requirements of the SPDES permit dated July 1, 2017, is summarized in Appendix E-6. No violations of permit limits were reported for Outfall 001 in 2017 for the following parameters: flow, suspended solids, fecal coliform bacteria, pH, cyanide, and total mercury. The SPDES permit limits for $CBOD_5$ percent removal, settleable solids, ammonia-N, and TP were each exceeded on a single occasion. Although the SPDES limit for total phenols was exceeded four times, the July 2017 permit modification eliminated a numerical limit and changed the requirement to "monitor only".

The seasonal regulatory limits for ammonia concentrations in Metro effluent are 1.2 mg/L from June 1 to October 31 and 2.4 mg/L for November 1 to May 31. Monthly average concentrations met these limits by wide margins in 2017; 2016 conditions are included for reference (Appendix E-7).

Compliance with the effluent TP limit is calculated as a 12-month rolling average concentration; the current limit is 0.10 mg/L. (Appendix E-8). Metro's TP limit has been met since the Actiflo® treatment process came on line. In 2017, the average total phosphorus concentration in the Metro effluent was 0.095 mg/L. The higher TP values in 2017 were caused by the phosphorus treatment optimization Project, which required shutdown of tertiary treatment beginning in October. The County has requested interim construction limits related to these exceedances.

Ten SPDES limit violations were documented for Metro Outfall 01A, 002, and the aggregate outfall (calculated sum of Outfalls 001, 01A, 01B, and 002) during 2017 (Appendix E-6). Four were related to the TP limit for Outfall 002. Two of these reported violations may have been the result of overestimated flows. Interim limits for TP during construction related to phosphorus treatment optimization were requested on October 23, 2017.

Section 4. Tributary Water Quality

Prohibited Combined and Sanitary Sewer Overflows

OCDWEP tracks the occurrence and volumes of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) within the Onondaga County service area each year. Certain overflows are prohibited; these include dry weather overflows and bypasses of the collection and treatment system, known as sanitary system overflows (SSOs). Documentation of the prohibited CSO and SSO events that occurred during 2017 is presented in Appendix E-9 and Appendix E-10. Annual summaries for the 2010–2017 period are presented in Appendix E-11. Significant SSO events during October and November 2017 were associated with emergency replacement of the 42-inch Ley Creek force main.

Fish from Onondaga Lake on Display at the 2018 Clean Water Fair at Metro.

Compliance with Ambient Water Quality Standards

Several segments of Onondaga Lake's tributary streams are included on the 2016 NYSDEC compendium of impaired waters. NYSDEC places waterbodies on this list when there is evidence that water quality conditions do not meet applicable standards, and/or the water bodies do not support their designated use. Results of Onondaga County's AMP are among the primary data sets used to evaluate compliance with standards and use attainment. The 2017 tributary data indicate that the major tributaries were generally in compliance with AWQS for most monitored parameters (Table 4-2; Appendix F-12). The primary exceptions were total dissolved solids (TDS), fecal coliform bacteria (FC), and dissolved mercury. The AWQS for TDS (500 mg/L) was exceeded at all of the tributary monitoring sites, and often by a wide margin. Contravention of this standard is primarily associated with watershed hydrogeology, not anthropogenic effects. Compliance with the TDS standard was not among the goals of the remediation program.

The AWQS for fecal coliform bacteria is calculated as the geometric mean of a minimum of five observations per month; this value may not exceed 200 colony forming units (cfu) per 100 milliliters (mL). Fecal coliform bacteria counts in the tributaries are primarily affected by stormwater runoff and CSOs, although elevated counts are occasionally measured during dry conditions. CSO remedial measures and improved stormwater management measures remain underway.

Among the objectives of the AMP is to track changes in the input of bacteria to Onondaga Lake during wet weather. WEP also tracks bacterial abundance during non-storm periods; these observations can help identify potential illicit connections of sanitary waste to the stormwater collection system, or portions of the sewerage infrastructure in need of repair.

Section 4. Tributary Water Quality

Five of the tributary monitoring sites regularly exceeded the AWQS for fecal coliform bacteria: Harbor Brook at Hiawatha, Ley Creek, Onondaga Creek at Kirkpatrick, Sawmill Creek, and Trib. 5A. Note that only Harbor Brook, Onondaga Creek, and Ley Creek receive CSOs. In fact, volume-weighted fecal coliform concentrations in non-CSO Ninemile Creek exceeded those in Onondaga Creek and Harbor Brook.

Dissolved mercury concentrations were also out of compliance at several monitoring locations in 2017. This parameter was monitored once each quarter. Only three sites met the AWQS for all four sampling events: Onondaga Creek at Dorwin, Onondaga Creek at Kirkpatrick, and Ninemile Creek. A number of researchers have identified wetlands as major sources of mercury to downstream waters (Hall et al. 2008, Hurley et al. 1995, Rudd, 1995, St. Louis et al. 1994), and the wetland located near the mouth of Sawmill Creek likely contributes importantly to elevated levels of dissolved mercury in this stream. Atmospheric deposition affects mercury concentrations as well.

Occasional exceedances of AWQS for pH and ammonia at Harbor Brook-Hiawatha have been associated with a milky discharge observed in the vicinity of the bridge at Hiawatha Blvd. Ley Creek, Sawmill Creek, and Trib. 5A exhibited minor violations of the dissolved oxygen standard during 2017, as highlighted in Table 4-2.

Table 4-2. Summary of tributary compliance (percent of observations in compliance) with ambient water quality standards (AWQS), 2017.

Site	Field Data		Solids	Nitrogen	Metals	Bacteria[1]
	Dissolved Oxygen (4mg/L)	pH	TDS	Ammonia-N	Dissolved Mercury	Fecal Coliform
Bloody Brook at Onon. L. Parkway	100% (36)	100% (32)	0% (5)	100% (4)	25% (4)	71% (37)
Harbor Brook at Hiawatha Blvd.	100% (78)	96% (74)	10% (58)	95% (58)	75% (4)	0% (91)
Harbor Brook at Velasko Rd.	100% (74)	100% (69)	15% (54)	100% (53)	75% (4)	71% (93)
Ley Creek at Park St.	96% (81)	100% (77)	8% (24)	96% (23)	25% (4)	13% (82)
Ninemile Creek at Lakeland	100% (44)	100% (39)	0% (24)	100% (23)	100% (4)	57% (45)
Onondaga Creek at Kirkpatrick St.	100% (44)	100% (39)	0% (24)	100% (23)	100% (4)	29% (45)
Onondaga Creek at Dorwin Ave.	100% (44)	100% (32)	33% (24)	100% (23)	100% (4)	71% (46)
Sawmill Creek at Onon. L. Rec. Area	97% (36)	100% (32)	25% (4)	NS (0)	0% (4)	29% (37)
Trib. 5A at State Fair Blvd.	97% (36)	100% (32)	0% (4)	100% (4)	25% (4)	29% (37)

[1]Fecal coliform compliance is assessed monthly, based on the geometric mean of at least 5 samples.

Note: occurrences of less than 100% compliance are highlighted in red text; the number of observations is shown in parentheses; NS is not sampled.

Fecal Coliform Bacteria in CSO Tributaries

Fecal coliform concentrations in the CSO-affected tributaries (Onondaga Creek, Harbor Brook, Ley Creek) during 2017 are presented for both wet and dry weather conditions (Figure 4-8). Wet weather samples are those collected following at least 0.1 inches of rain in the preceding 48 hours; all other samples were classified as dry weather samples. Both upstream and downstream results are reported for Onondaga Creek (at Dorwin Ave., Kirkpatrick St.) and Harbor Brook (at Velasko Rd., Hiawatha Blvd.). Only downstream samples are available for Ley Creek (Park St.).

Harbor Brook.

Fecal coliform bacteria counts were generally higher at downstream sampling sites and during wet weather conditions (Figure 4-8). These increases were associated with bacterial inputs from CSOs and other urban sources. Note, however, that fecal coliform concentrations at the upstream sampling locations of Onondaga Creek at Dorwin and Harbor Brook at Velasko also exceed the AWQS of 200 counts/100 mL during the summer months (Appendix F-13). Extremely high bacterial counts in Ley Creek were associated with the failure of the 42-inch Ley Creek force main in late October and early November 2017.

A distinct seasonality in fecal coliform counts is evident, with higher values measured during June–September (Appendix F-13), suggesting that fecal coliform abundance is closely related to temperature.

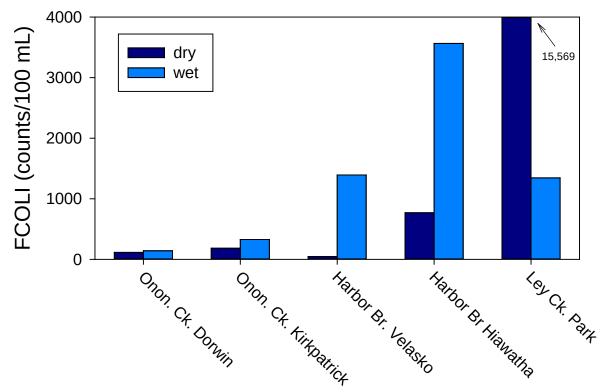


Figure 4-8. Comparisons of wet weather and dry weather fecal coliform concentrations (geometric means) in Onondaga Lake tributaries during 2017.

Long-Term Trends

The long-term AMP monitoring data set provides managers with the opportunity to assess water quality trends in tributaries to Onondaga Lake. The 2017 AMP report includes a series of graphs and tables to examine long-term trends in both concentrations and loads. Details are provided in Appendix F-7, Appendix F-14, Appendix F-15, Appendix F-16, and Appendix F-17.

The major findings related to **concentration trends in Metro effluent** include:

- The decreasing concentration of wastewater-related parameters (ammonia, TP, TDP) in Metro effluent in response to the engineering improvements.

- Similarly, increasing concentrations parameters (nitrate, total dissolved solids, calcium, and dissolved oxygen) in the Metro effluent are directly related to the changes in treatment processes.
- Decreasing fecal coliform bacteria counts at both Metro outfalls, most noteworthy at the Metro Bypass where levels have dropped at the rate of 34.2% per year.

The major findings related to **concentration trends for the natural tributaries** include:

- Decreasing counts of fecal coliform bacteria at the downstream Onondaga Creek site (Kirkpatrick), and the upstream Harbor Brook site (Velasko).
- Decreasing ammonia concentrations in Ley Creek.
- Increasing concentrations of organic nitrogen and total Kjeldahl nitrogen at the upstream sampling locations on Onondaga Creek and Harbor Brook. The reason for these increases is unknown.
- Decreasing TP and SRP concentrations at Harbor Brook – Hiawatha.

The major findings related to **loading trends for Metro and the natural tributaries** include:

- Long-term decreases in total P and total dissolved P loads have been driven by reductions in the Metro contribution. Year-to-year variations in TP loading from the watershed reflect differences in the timing and magnitude of runoff.
- Long-term decreases in ammonia-N loading and increases in nitrate loading are associated with implementation of efficient, year-round nitrification at Metro. Variations in ammonia-N and nitrate loading from the tributaries have been modest in comparison.
- Noteworthy reductions in fecal coliform bacteria loads are evident, and are attributed to disinfection of the Metro bypass. The increased fecal coliform loading in 2017 was the result of temporary construction related bypasses at Metro.

WEP Technician Sampling Ninemile Creek 2016

Post Construction Compliance Monitoring Program (PCCM)

Overview of the PCCM Program

Onondaga County is required by the ACJ Fourth Stipulation to conduct a PCCM program to evaluate the effectiveness of both green and gray CSO controls, to assess whether ambient water quality standards (AWQS) are being met, and determine whether the remaining CSOs cause or contribute to violations of AWQS. The PCCM program includes monitoring of water quantity and water quality of CSOs and the receiving streams (Onondaga Creek and Harbor Brook).

Since 2015, Onondaga County DWEP has completed 12 PCCM events, seven on Harbor Brook and five on Onondaga Creek. The monitoring targeted storms with rainfall intensities of at least 0.35 inches of rain per hour. Based on modeling and observations, most of the operational CSOs discharge when the rainfall intensity meets this threshold. Monitoring was conducted upstream and downstream of CSO discharges to evaluate water quality impacts during wet weather. Data analysis focused on patterns in fecal coliform concentrations and estimated loadings. Results from the 2015 and 2016 PCCM events indicated that CSO discharges contributed importantly to elevated fecal coliform levels in Onondaga Creek and Harbor Brook during the wet weather sampling events.

The 2017 PCCM Program

Onondaga County WEP completed three PCCM events on Harbor Brook during 2017 (Table 4-3). The target intensity of 0.35 inches per hour was met for each of the events and total rainfall ranged from 0.62 to 1.04 inches. Event mean concentrations (EMC = event load ÷ event flow) for fecal coliform bacteria exceeded 27,000 cfu/100 mL. Floatables (described as non-sanitary street litter) were only observed during the May 1-2 event. Detailed summaries of all three PCCM events are provided in Appendix F-17.

Salient findings from the 12 PCCM events completed on Harbor Brook and Onondaga Creek include:

- CSOs are not contributing significantly to the occurrence of floatables; observed floatables were not sanitary related
- CSOs continue to contribute to elevated fecal coliform concentrations and exceedances of AWQS during wet weather
- Dry weather sources of fecal coliform exist along the lower portion of Harbor Brook

Table 4-3. Summary of the 2017 PCCM events.

Event	Date	Stream	Total Rainfall (in)	Maximum Intensity[1] (in/hr)	Peak Stream Flow (cfs)	EMC[2] (cfu/100mL)	Floatables
1	May 1	Harbor Brook	0.87	0.53	70	27,802	Y[3]
2	July 8	Harbor Brook	1.04	0.75	91	62,949	N
3	August 22	Harbor Brook	0.62	0.40	30	33,595	N

[1]Maximum intensity (in/hr) represents the maximum amount of rainfall recorded at Metro during any one-hour period.
[2]Event Mean Concentration - EMC (cfu/100 ml) is calculated as the total event load divided by the total event flow volume for the results at the Hiawatha Blvd. sampling location.
[3]The observed floatables were not sanitary related

Section 5. Onondaga Lake Water Quality

Onondaga Lake Sampling Program

The Ambient Monitoring Program (AMP) encompasses multiple physical, chemical, and biological parameters of Onondaga Lake (Appendix A-2). Trained Water Environment Protection (WEP) technicians collect samples from various locations and depths within Onondaga Lake to characterize water quality and biological conditions. Most sampling occurs between April and November when the lake is free of ice. The lake monitoring program focuses on evaluation of compliance with ambient water quality standards (AWQS) and assessment of progress toward attainment of designated uses. Results for key parameters and lake sampling locations are presented in this section.

WEP also tracks physical factors, such as the development and extent of ice cover (Appendix G-1). Since the winter of 1987-1988, the duration of lake-wide ice cover has averaged 35 days and ranged from a minimum of 0 days in the winter of 1997-1998 to a maximum of 95 days in 2013-2014. During the winter of 2016–2017, ice cover extended for just 7 days in the north basin and 4 days lake wide. Ice cover was first reported on December 16, 2016 and last reported on March 23, 2017.

The main sampling station in the lake, referred to as South Deep, is located near the deepest point in the southern basin. South Deep has been the long-term reference monitoring location on Onondaga Lake since the County initiated monitoring in 1970. In addition to the routine biweekly sampling at South Deep, WEP technicians collect samples for a reduced number of parameters from the deepest point of the lake's northern basin (North Deep) four times each year. Results from North Deep and South Deep remained comparable in 2017 (Appendix G-2). The AMP also includes sampling of a network of ten near-shore locations for three parameters related to suitability for water contact recreation: Secchi disk transparency, turbidity, and fecal coliform bacteria.

Mermaid at 2016 Onondaga Cup and Lakefest.

Trophic State

The trophic state of a lake refers to its level of primary production (production of organic matter through photosynthesis). Highly productive lakes are termed eutrophic, while lakes with low levels of productivity are termed oligotrophic. Those with intermediate levels of productivity are described as mesotrophic. Excessive productivity can result in conditions that impair a waterbody for particular uses, such as water supply or contact recreation.

Primary production in Onondaga Lake, like most lakes in the Northeast, is limited by the availability of the nutrient phosphorus. Addition of phosphorus to lakes causes increased primary production, described as eutrophication. This is generally accompanied by higher concentrations of algae, especially cyanobacteria (blue-green algae), which can have deleterious effects on water quality. Certain cyanobacteria are capable of producing noxious blooms and harmful toxins, referred to as harmful algal blooms (HABs). Additional information on HABs is available on NYSDEC's website.

Decay of settled algae contributes to the depletion of dissolved oxygen in the lower stratified layers of lakes. Where this decay is substantial, oxygen can be depleted to levels that make these layers uninhabitable for fish and other aquatic organisms.

Much effort has been directed at decreasing primary production in Onondaga Lake through reductions in phosphorus loading. The effectiveness of this program has been tracked by monitoring multiple measures of the trophic state of the lake, including total phosphorus (TP), chlorophyll-*a* (Chl-*a*), and Secchi disk (SD) transparency. TP, Chl-*a*, and SD are all related to the amount of phytoplankton (microscopic algae) present in the water column.

Phosphorus

Total phosphorus (TP) concentrations in the upper waters of the lake remained near 20 µg/L for much of the 2017 monitoring period (Figure 5-1a). Only following major runoff events in early June, early July, and early November, did TP concentrations exceed 25 µg/L. Note that these higher TP levels did not coincide with increases in algal biomass (Figure 5-1b). Total phosphorus concentrations in the upper waters of the lake averaged 22 µg/L during the summer (June–September) of 2017, slightly higher than the New York State guidance value of 20 µg/L. Concentrations of total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) remained low during the summer months and increased in November (Figure 5-1a).

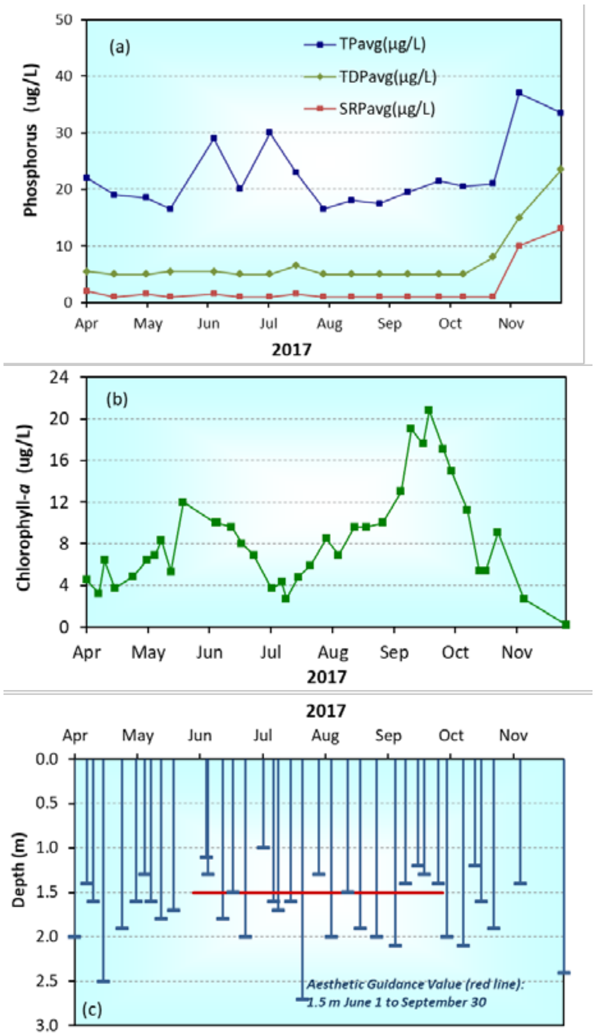


Figure 5-1. Time series of concentrations in the upper waters (0-3 meters) of Onondaga Lake during 2017 for (a). total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP), (b) chlorophyll-*a*, and (c) Secchi disk transparency.

Concentrations of TP in the upper waters have decreased substantially since the early 1990s (Figure 5-2a). Beginning in 2007, summer average total phosphorus concentrations in the upper waters of Onondaga Lake have been close to the guidance value of 20 µg/L. With the advanced treatment system at Metro producing consistently low effluent total phosphorus, the year-to-year variability in lake phosphorus levels largely reflects changes in watershed loading, and food web structure. Summer average concentrations of both TDP and SRP have been consistently low since 2007.

Brown Trout Caught While Fishing on Onondaga Lake.

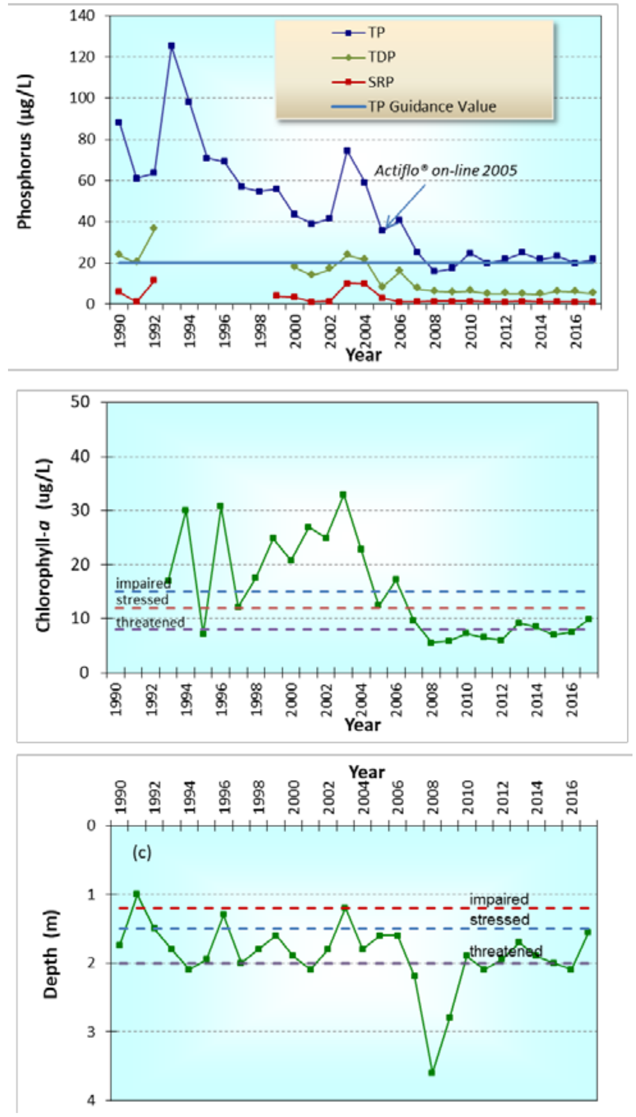


Figure 5-2. Summer (June to September) average concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2017 for (a) total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP), (b) chlorophyll-*a*, and (c) Secchi disk transparency (median values).

Note: TDP and SRP data not collected during 1993-1998. NYSDEC values corresponding to impaired, stressed, and threatened conditions are shown.

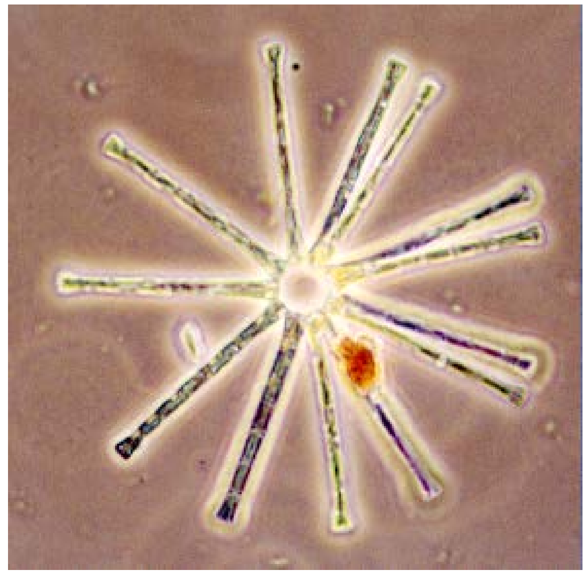
Chlorophyll-*a*

Chlorophyll-*a* (Chl-*a*) concentrations in the upper waters of the lake in 2017 ranged from 0.2 µg/L on November 28 to a peak of 20.8 µg/L on September 21 (Figure 5-1b). The summer average Chl-*a* concentration in 2017 was 9.9 µg/L, an increase from recent years (Figure 5-2b). Elevated Chl-*a* levels during the second half of September were associated with an extended interval of warm, calm weather conditions. In 2017, this late summer increase in algal abundance was measured in lakes across central NY, including all 11 Finger Lakes.

Summer average concentrations of Chl-*a* in Onondaga Lake have declined substantially, particularly since the Actiflo® upgrade at Metro in 2005 (Figure 5-2b). Chl-*a* concentrations, which commonly exceeded a summer average of 15 µg/L during 1990–2004, have remained below 12 µg/L since 2007 (Figure 5-2b).

Summer data (June–September) are used to track suitability of the lake for recreational uses. NYSDEC (2009) defines Chl-*a* thresholds for suitability for recreational use as follows: above 8 µg/L recreational uses are stressed; above 12 µg/L they are threatened, and above 15 µg/L the uses are impaired.

Algal blooms are generally aesthetically undesirable and potentially harmful depending on the dominant taxa. In the absence of state or federal criteria, the AMP has used subjective thresholds of 15 µg/L and 30 µg/L to represent minor blooms (impaired conditions) and major blooms (noxious conditions), respectively. According to these criteria, and based on laboratory measurements of 20 samples, there were four minor algal blooms in Onondaga Lake during late summer 2017 (Figure 5-1b; Figure 5-3). These minor blooms were documented on four consecutive sampling dates (September 12, 18, 21, 28) when Chl-*a* ranged from 17.1 to 20.8 µg/L (Figure 5-1b).



Two Diatom Species Found in Onondaga Lake.

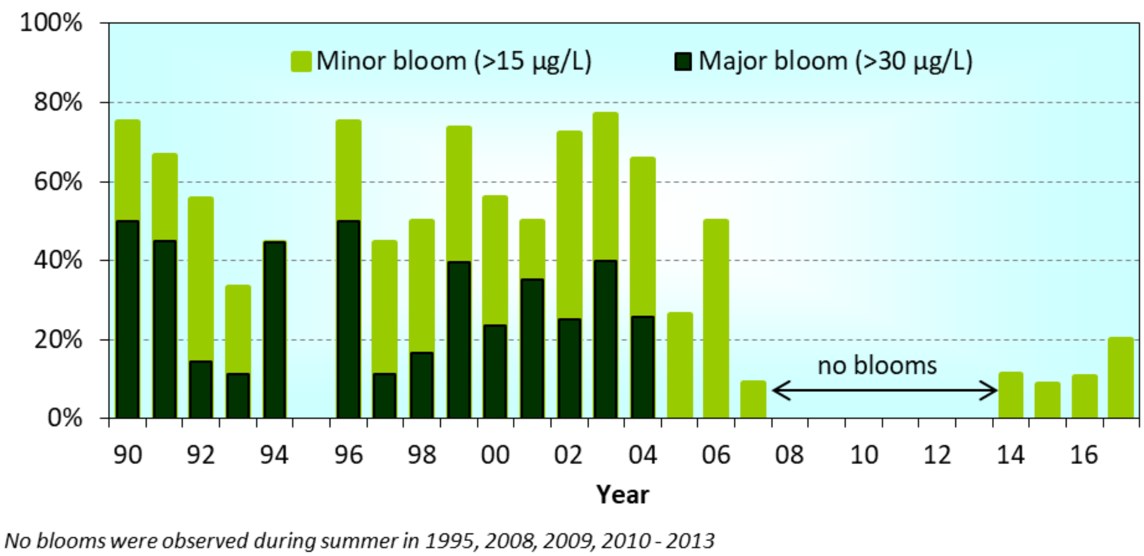


Figure 5-3. Percent occurrence of summer (June to September) algal blooms in Onondaga Lake evaluated annually for the 1990–2016 period, based on chlorophyll-*a* measurements taken at South Deep.

Secchi Disk Transparency

The Secchi disk, a 25 centimeter diameter disk with alternating black and white quadrants, is a standard tool for measuring lake clarity. The depth at which it can no longer be seen in the water is known as the Secchi disk transparency. Greater depth indicates clearer waters with lower concentrations of particles, often in the form of phytoplankton.

Secchi disk transparency greater than 1.2 meters (4 feet) is required to meet swimming safety guidance at designated beaches. There is no New York State standard or guidance value for Secchi disk transparency for off-shore waters. Most lake monitoring programs in the state make Secchi disk measurements at a mid-lake station overlying the deepest water, comparable to the Onondaga Lake South Deep station. A summer average Secchi disk transparency of at least 1.5 meters at South Deep has been established for Onondaga Lake as a target for improved aesthetic appeal (Appendix A-5).

Based on South Deep measurements, the average water clarity of Onondaga Lake during the summer of 2017 was 1.6 meters and ranged from 1.0 to 2.7 meters (Figure 5-1c). Unusually low water clarity during the summer of 2017 (Figure 5-2c) was likely caused by elevated algal biomass and the influx of inorganic particles during storms. The unusually high water clarity observed in both 2008 and 2009 was the result of grazing by large *Daphnia* populations. The *Daphnia* were able to thrive due to low abundance of alewife, a planktivorous fish, during these years.

Dissolved Oxygen

Adequate dissolved oxygen (DO) content is critical for aquatic life and a common focus of water quality monitoring programs. Vertically detailed in-situ profiles of DO, temperature, specific conductance, and chlorophyll-*a* were collected at South Deep during 2017 and are displayed as color contour plots (Appendix G-4). These daily measurements were made at 1 meter depth increments over the spring to fall interval at South Deep with a monitoring buoy courtesy of Honeywell (http://www.upstatefreshwater.org/NRT-Data/Data/data.html).

A high priority goal for rehabilitation of the lake was the elimination of severe DO depletion in the upper waters during the approach to fall turnover in October (Figure 5-4) and contravention of the related AWQS. This goal has been achieved through reductions in Metro loading of both ammonia-N and total phosphorus.

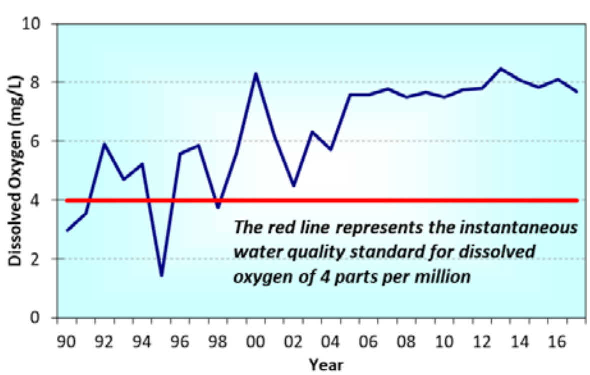


Figure 5-4. Minimum dissolved oxygen (DO) concentration in the upper waters (0-4 meter average) of Onondaga Lake during October, annually 1990–2017.

Onondaga Lake.

Ammonia, Nitrite, and Nitrate

Onondaga Lake was impaired by elevated concentrations of ammonia-N (NH_3-N) prior to the treatment upgrades at Metro designed to achieve efficient year-round nitrification of wastewater. Concentrations of this potentially harmful form of nitrogen exceeded the AWQS for protection of aquatic life.

Upgraded aeration treatment at Metro in the late 1990s and implementation of the biologically aerated filter (BAF) technology in 2004 significantly reduced ammonia-N concentrations in the upper waters of the lake (Figure 5-5), enabling a more diverse biota. The lake is now in full compliance with the ambient water quality standards for ammonia-N and in 2008 was officially removed from the New York State's 303(d) list of impaired waterbodies for this water quality parameter.

Efficient year-round nitrification treatment at Metro resulted in increased nitrate (NO_3-N) concentrations in Onondaga Lake (Figure 5-5b), which in turn caused diminished release of phosphorus and mercury from the sediments during intervals of anoxia (Matthews et al. 2013). To further abate sediment release of methylmercury, Honeywell has augmented nitrate levels in the hypolimnion through a program of targeted nitrate addition conducted annually during 2011-2017.

Historically, nitrite (NO_2-N) concentrations commonly exceeded the AWQS of 0.1 mg/L intended to protect against possible toxicity effects. In-lake concentrations of nitrite, and exceedances of the AWQS, were greatly reduced following treatment upgrades to the biological aerated filter (BAF) at Metro.

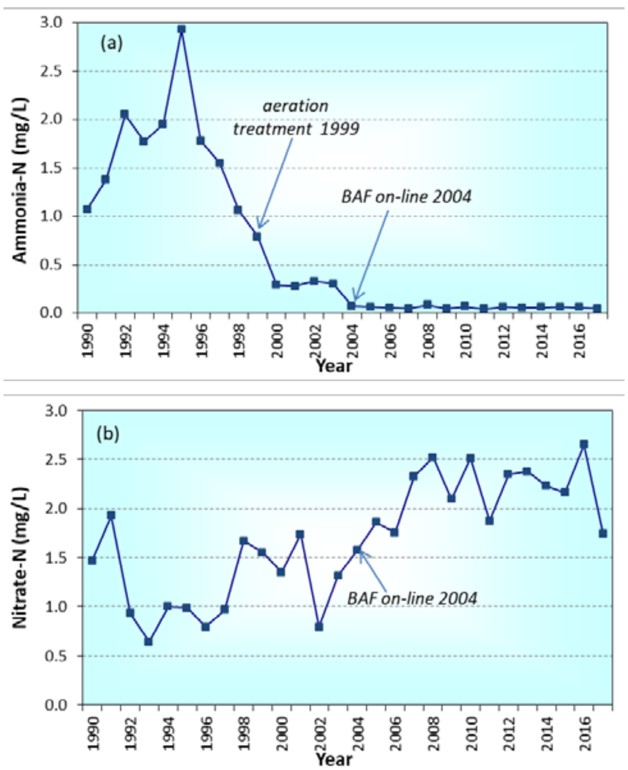


Figure 5-5. Summer average concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2017 for (a) ammonia-N, (b) nitrate-N.

Note: 2015 ammonia-N and 2013-2015 nitrate-N and nitrite-N data based on discrete depths (epilimnion = 3m; hypolimnion = average of 15 and 18m.

Kayak Rentals at Willow Bay.

Compliance with AWQS

The 2017 monitoring results indicate that the open waters of Onondaga Lake were in compliance with most ambient water quality standards (AWQS), with exceptions noted in Table 5-1. The concentration of total dissolved solids (TDS), which primarily reflects the concentration of the major ions, exceeded the AWQS of 500 mg/L by a wide margin. Exceedance of this standard is associated with the natural hydrogeology of the lake and its watershed.

New York State has promulgated a narrative standard for phosphorus in water: "None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSCRR §703.2). For ponded waters the narrative standard is interpreted using a guidance value of 20 µg/L, calculated as the average total phosphorus concentration in the lake's upper waters between June 1 and September 30.

A total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake was approved by USEPA in 2012. The TMDL is intended to achieve the in-lake guidance value of 20 µg/L. The summer average total phosphorus (TP) concentration in 2017 was 22 µg/L, slightly higher than the state's guidance value.

Table 5-1. Percentage of measurements in compliance with ambient water quality standards (AWQS) and guidance values in the upper and lower waters of Onondaga Lake at South Deep in 2017.

Parameter	AWQS/Guidance Value	Upper Waters % compliance (depth)	Lower Waters % compliance (depth)
Dissolved Oxygen	≥ 4 mg/L instantaneous[1]	100%	***47%***
Dissolved Oxygen	≥ 5mg/L daily average[1]	100%	***44%*** (12 m)
pH	6.5-8.5	100%	100%
Total Phosphorus	≤ 20 µg/L summer average[2]	***0%*** (22 µg/L)	--
Ammonia-N	Variable[3]	100%	100%
Nitrite	≤0.1 mg/L	100%	100%
Total Dissolved Solids	≤500 mg/L	***0%***	***0%***
Dissolved Mercury	≤0.7 ng/L	100%	100%
Fecal Coliform Bacteria	≤200 cfu/100 mL monthly geomean[4]	100%	--

Notes:
Dashed lines indicate that compliance was not evaluated; occurrences of less than 100% compliance are highlighted in italic red text.

[1]Dissolved oxygen compliance based on buoy data from 2m and 12m depths (one to three profiles per day).

[2]Total phosphorus compliance based on the 0-3m average for the June 1-September 30 period.

[3]The AWQS for ammonia-N varies as a function of pH and temperature.

[4]The AWQS for fecal coliform bacteria is specified as the monthly geometric mean of at least 5 samples being less than or equal to 200 colony forming units (cfu) per 100 milliliters (mL) during the period of Metro disinfection (April 1-October 15).

Section 5. Onondaga Lake Water Quality

Dissolved oxygen (DO) concentrations met the AWQS in the upper waters of Onondaga Lake throughout the 2017 sampling period (Table 5-1). DO concentrations in the lower waters were below the minimum 4 mg/L during most of the summer stratified period. However, this situation is not uncommon in stratified lakes where the volume of the hypolimnion is relatively small. NYSDEC recognizes that low DO concentrations are likely to occur at lower depths of stratified lakes as the result of natural conditions (NYSDEC Consolidated Assessment and Listing Methodology, March 2015). In Onondaga Lake, the onset of anoxia in the lower waters is occurring later in the summer, suggesting improved water quality and habitat conditions.

Throughout the April–October interval of 2017, fecal coliform levels were in compliance with the AWQS at both offshore sampling locations (South Deep and North Deep). In addition, seven of ten nearshore sampling sites were in continuous compliance with the AWQS throughout the April–October period (Figure 5-6). Three nearshore sites, located within the Class C segment of the lake's southeastern shoreline (Figure 5-6), exceeded the standard for fecal coliform bacteria during the month of October. Note that Metro does not disinfect after October 15. One of these sites also exceeded the AWQS in April. Graphical results for 2008-2017 are provided in Appendix G-6.

Onondaga Lake Marina.

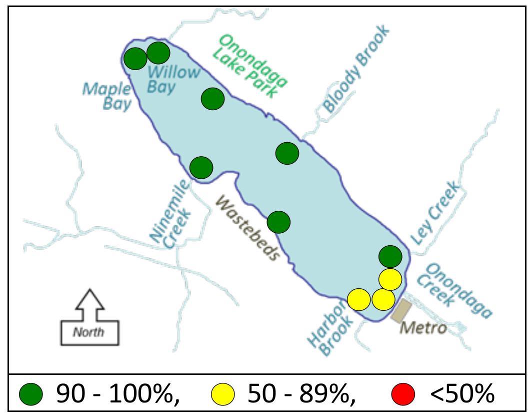


Figure 5-6. The percentage of months in compliance with the water quality standard for fecal coliform bacteria for nearshore stations in Onondaga Lake, April–October 2017.

Note: Compliance is calculated for each location by comparing the monthly geometric mean of a minimum of five samples with the AWQS (200 cfu/100 mL).

Water clarity is measured five times per month during June–September with a Secchi disk at the same network of ten near shore stations. While there is no NYSDEC standard for water clarity, the NYSDOH has a swimming safety guidance value for designated bathing beaches of 4 feet (1.2 meters). The NYSDOH guidance value was met for at least 90% of measurements at five of the ten nearshore sites (Figure 5-7) Sampling locations in the southern end of the lake, near the wastebeds, and near the mouth of Bloody Brook, failed to meet this guidance value on 15-20% of the monitored days (Figure 5-7). Graphical results for 2008-2017 are provided in Appendix G-7.

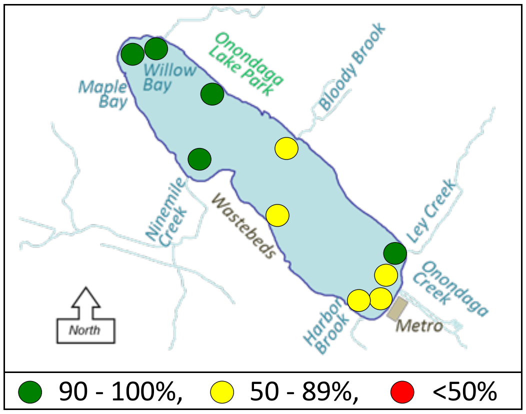


Figure 5-7. Percentage of nearshore Secchi disk transparency measurements greater than 1.2 meters (4 feet) during June–September 2017.

AMP Sampling for Zooplankton Onondaga Lake, 2016.

Long-Term Trends in Water Quality

Advanced wastewater treatment at Metro has resulted in major reductions in loading of total phosphorus, ammonia-N, and nitrite to Onondaga Lake. The lake responded positively to these loading reductions, with major improvements documented for a number of key water quality parameters and recovery of lost uses. In this section long-term trends are objectively identified using statistical approaches.

10–Year Water Quality Trends: 2008–2017

Water quality trends for the last 11 years (2007–2017) were evaluated statistically using the two-tailed seasonal Kendall test (Appendix G-8). Significant decreasing trends were identified for Secchi depth, ammonia-N in the south basin, and both total phosphorus and soluble reactive phosphorus in the lower waters (Appendix G-8). Nitrate addition has contributed to increased nitrate levels and decreased concentrations of soluble reactive phosphorus in the hypolimnion since 2011. Increases in total suspended solids were noted in the south basin and fecal coliform levels increased in the north basin.

N to P Ratios and Cyanobacteria

The ratio of the major plant nutrients nitrogen and phosphorus is an important determinant of the composition of the phytoplankton community. The relative concentrations of bioavailable nutrients on phytoplankton speciation can have water quality management implications, particularly with respect to avoiding proliferation of cyanobacteria (blue-green algae).

Cyanobacteria can cause noxious and potentially toxic conditions when present in high concentrations.

The maintenance of high nitrogen to phosphorus ratios (N:P) in the upper waters of Onondaga Lake has been a long-term management strategy to discourage cyanobacteria. As reported by Smith (1983), data from a wide range of temperate lakes suggest that a total N to total P ratio (TN:TP) of 29:1 (by mass) differentiates between lakes with cyanobacteria dominance (TN:TP<29:1) and lakes without such dominance (TN:TP>29:1).

The time series of the summer average (June 1–September 30) TN:TP ratio for the upper waters is presented for the 1998–2017 period (Figure 5-8). The TN:TP ratio has remained above the literature N:P threshold for increased risk of cyanobacteria dominance since 1998 (Figure 5-8). The higher values after 2007 reflect systematic decreases in total phosphorus loading from Metro, with mostly unchanging TN concentrations. The common occurrence of dense populations of filamentous cyanobacteria in summer from the late 1980s to early 2000s was likely due to a combination of much lower N:P ratios and higher levels of P. Although cyanobacteria have not been an important component of the algal community in recent years, there was a noteworthy increase in cyanobacteria in August and September of 2017.

Sunset at Onondaga Lake.

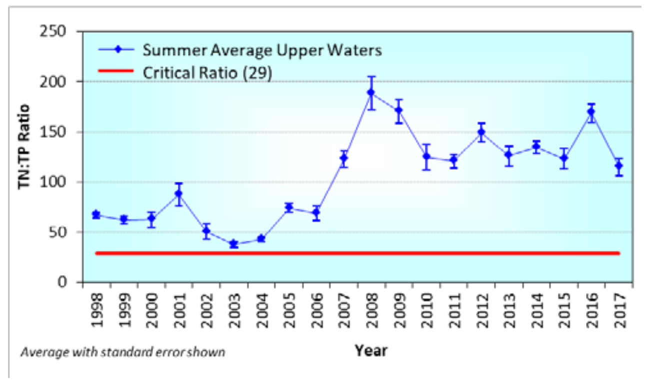


Figure 5-8. Summer average ratio of total nitrogen to total phosphorus (TN:TP, by weight) in the upper waters of Onondaga Lake, 1998–2017.

Note: Error bars represent plus and minus 1 standard error.

Section 6. Biological Conditions and Long Term Trends

Introduction

In addition to the focus on water quality compliance and trends, the AMP is designed to examine how the Onondaga Lake ecosystem—the community of plants and animals—is responding to changing conditions. The ACJ directed the County to design and implement biological monitoring programs to meet three goals: evaluate aquatic habitat of the lake and streams, track primary productivity (trophic state), and characterize the lake's biological community. In consultation with OLTAC and other academic advisors, the County has executed a comprehensive monitoring program that incorporates multiple levels of the lake's food web. The findings are discussed in this final section of the Annual Report.

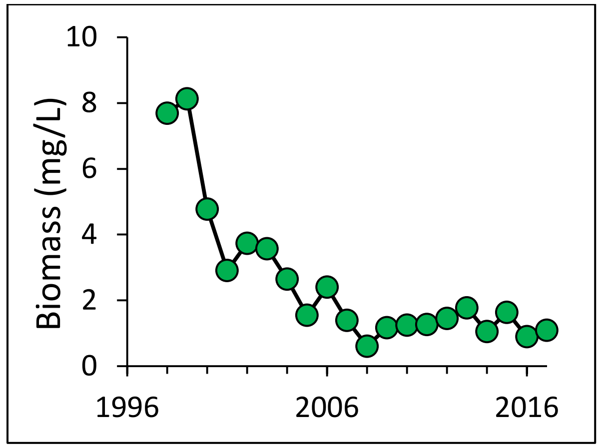


Figure 6-1. Average annual phytoplankton wet biomass (April – October) in Onondaga Lake, 1998-2017.

Phytoplankton

The average and peak biomass of phytoplankton (including algae and cyanobacteria) in Onondaga Lake has declined sharply over the last two decades. Following completion of the advanced phosphorus removal facilities at the Metro wastewater treatment plant, algal biomass has remained below 2 mg/L (Figure 6-1). While phosphorus concentrations have remained relatively constant, there is year-to-year variability in phytoplankton abundance related to other ecosystem factors such as zooplankton grazing pressure.

Alewife

In 2017, algal biomass peaked at 3.4 mg/L with relatively high cyanobacteria biovolume on September 11 (Figure 6-2). Diatom abundance was higher in 2017 than in 2016 but continued to be low. A spring diatom bloom was present but not large in 2017. The most abundant algal genera in 2017 were the diatom (*Fragilaria),* the haptophyte (*Chrysochromulina*), the cryptophyte (*Cryptomonas*), and the cyanobacteria (*Pseudanabaena*). Cyanobacteria (bluegreen "algae") was the second most common group after diatoms, primarily due to a high value on September 11 and somewhat high values on surrounding dates. Cyanobacterial blooms were prevalent in other area lakes during September 2017, including Oneida Lake and all 11 Finger Lakes, (Jackson et al. 2018, Hearn 2018). Although the proportion of cyanobacteria has increased significantly since 2005, bluegreens are still rare in Onondaga Lake compared to nearby Oneida Lake, which has similar phosphorus concentrations (Idrisi et al. 2016). A detailed report of the 2017 phytoplankton community structure is in Appendix H-1.

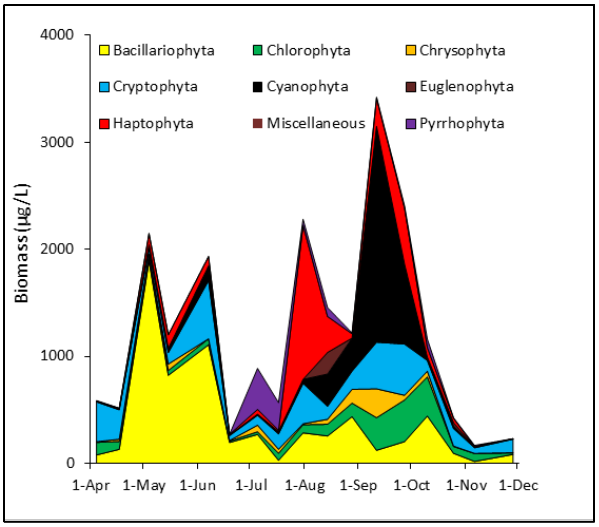


Figure 6-2. Temporal trends in phytoplankton wet biomass divisions in Onondaga Lake, 2017.

Zooplankton

Zooplankton play a key role in structuring the phytoplankton community and are in turn strongly affected by predation from planktivorous fishes. Zooplankton biomass in Onondaga Lake in 2017 was low but comparable to years 2011-2016 (Figure 6-3). *Daphnia* (large cladoceran zooplankton that effectively graze phytoplankton) were not abundant in 2017. *Bosmina* (small cladocerans) and cyclopoid copepods (both *Diacyclops* and *Mesocyclops*) were the most abundant crustacean zooplankton. Zooplankton density and biomass were highest in June through August, consisting mostly of *Bosmina* and *Mesocyclops* (Figure 6-4). *Diacyclops* was the dominant copepod in spring and fall. *Daphnia* were present in mid-July and August in small numbers. Zooplankton species and size composition in 2017 were similar to 2003-2007 and 2010-2016 when planktivorous alewife were abundant in the lake. A detailed report assessing the 2017 zooplankton community structure is in Appendix H-1.

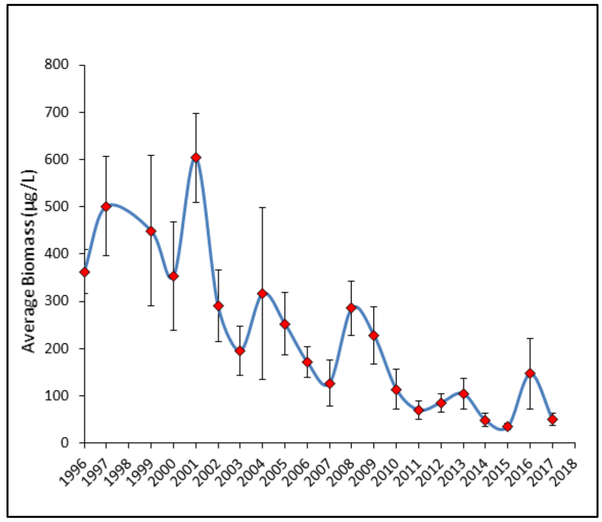


Figure 6-3. Average annual zooplankton dry biomass (April – October) in Onondaga Lake, 1996-2017.

Dreissenid Mussels

Dreissenid mussels [zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*)] are invasive species of filter-feeding mussels. Both species were first found in Onondaga Lake in 1992, and their abundance and distribution in the lake have been monitored as part of the AMP since 2005. Because dreissenid mussels can reach high densities and are highly efficient filterers, they can significantly impact an ecosystem through filtering the water column and altering the benthic habitat.

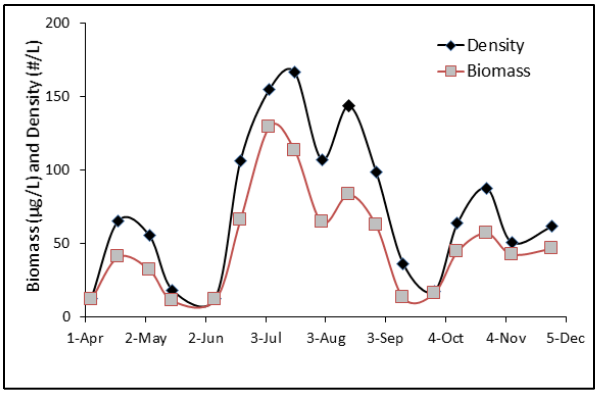


Figure 6-4. Density (#/L) and dry biomass (µg/L) of zooplankton in Onondaga Lake in 2017 from 15-m deep tows.

Dreissenids were relatively rare in Onondaga Lake prior to 1998, but increased considerably in abundance by 1999, likely due to decreasing ammonia levels in the lake resulting from improvements to Metro treatment. Zebra mussels were initially the dominant dreissenid in the lake, but by 2009 they were surpassed by quagga mussels (Figure 6-5). Displacement of zebra mussels by quagga mussels in other lakes has been attributed to quagga mussels growing faster at low food concentrations and being better adapted to living in colder temperatures and colonizing soft substrates than zebra mussels.

However, beginning in 2013, the proportion of dreissenid biomass composed of quagga mussels began to decline. In 2017 zebra mussel density was higher or similar to quagga mussel density in all depth zones sampled (0-9 m) (Figure 6-5). Such a decline in quagga mussels after the species became dominant has not been observed elsewhere (Strayer et al. 2019), making Onondaga Lake the first documented system in which zebra mussels returned to dominance after being largely displaced by quagga mussels.

A detailed report of the 2017 dreissenid community is in Appendix H-2.

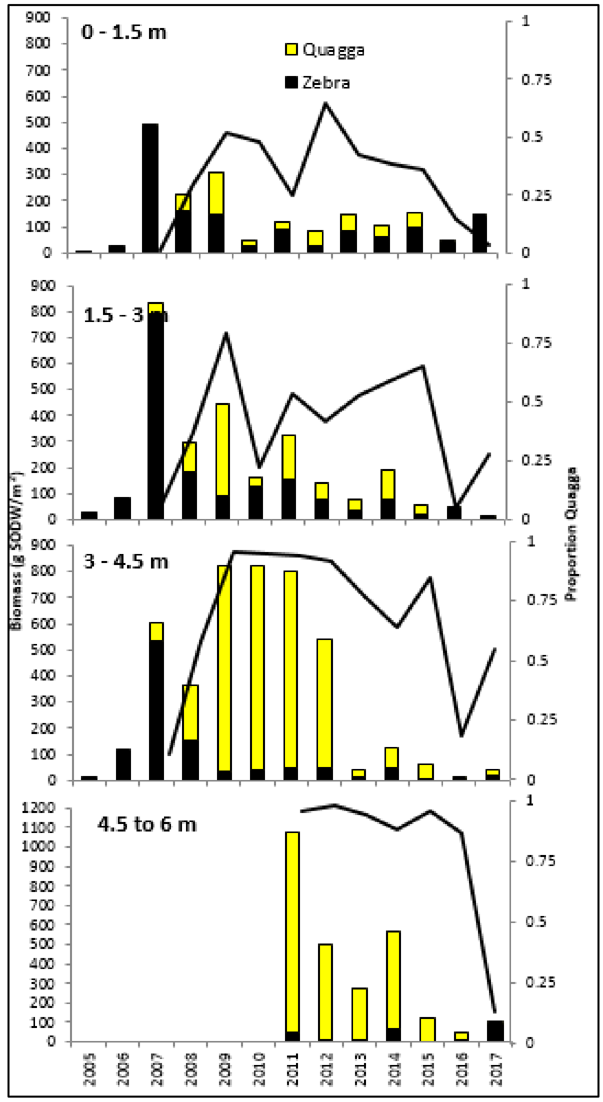
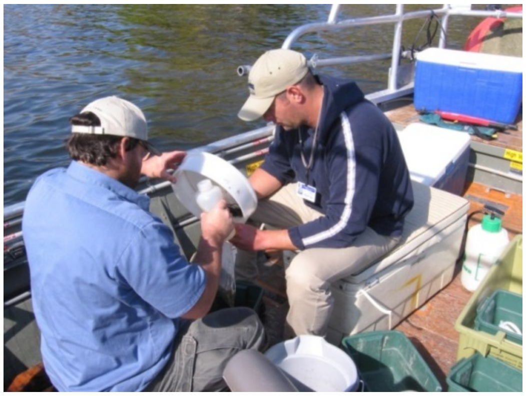


Figure 6-5. Shell-on dry weight of dreissenid mussels in four depth zones (0–1.5 m, 1.5–3 m, 3–4.5 m and 4.5–6 m) of Onondaga Lake, 2005–2017. Lines represent the proportion of quagga mussels.

Section 6. Biological Conditions and Long Term Trends



OCDWEP Technicians Sampling Dreissenid Mussels

Lake Benthic Macroinvertebrates

Aquatic benthic macroinvertebrates (e.g., insects, worms, snails, mussels, leeches, crustaceans) are an important component of the Onondaga Lake food web. These organisms provide the link in the food web between microscopic organisms and fish, and facilitate the transfer of energy and materials between the terrestrial and aquatic ecosystems.

The lake macroinvertebrate community was previously sampled at five locations (NW corner, west side, south end, SW corner, and NE corner) in 2000, 2005, and 2010 and was again sampled in 2017. The health of the macroinvertebrate community was assessed using NYSDEC protocols to score the level of impact using a series of metrics combined to generate a Biological Assessment Profile (BAP).

The 2017 BAP scores showed varying degrees of change from the 2010 assessment as (Figure 6 6).

Two of the five stations showed improvement, changing from severely impacted to moderately impacted for the South site (Metro) and from moderately impacted to slightly impacted for the NW site (Maple Bay). The BAP score for West site (Wastebeds) improved from 2010, but the overall assessment as slightly impacted did not change. The BAP score for the SW site (Ley Creek) was essentially unchanged, remaining as slightly impacted. Only

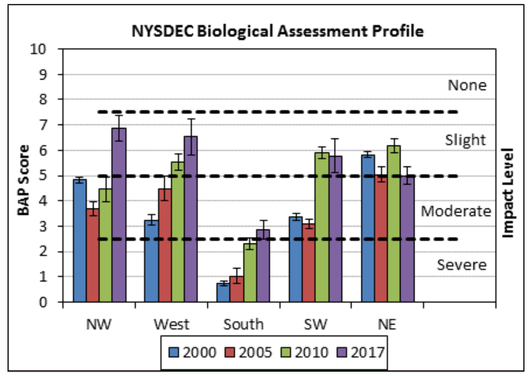


Figure 6-6. Biological assessment of the macroinvertebrate community at five locations in Onondaga Lake in 2000, 2005, 2010, and 2017.

the NE site (Hiawatha Point) showed a declining BAP score going from slightly impacted in 2010 to slightly/moderately impacted in 2017. With the exception of the NE site, the BAP scores at all sites improved since 2000. A detailed report assessing the 2017 macroinvertebrate community structure is in Appendix H-3.

Fish Community

The fish community of Onondaga Lake has undergone considerable change and improvement since inception of the AMP fish community sampling program in 2000. The number of fish species (species richness) recorded annually has increased over time (Figure 6-7). Altogether, 53 species of fish have been reported from Onondaga Lake since 2000 (Table 6-1). The increase in species richness is attributed to improved water quality (resulting

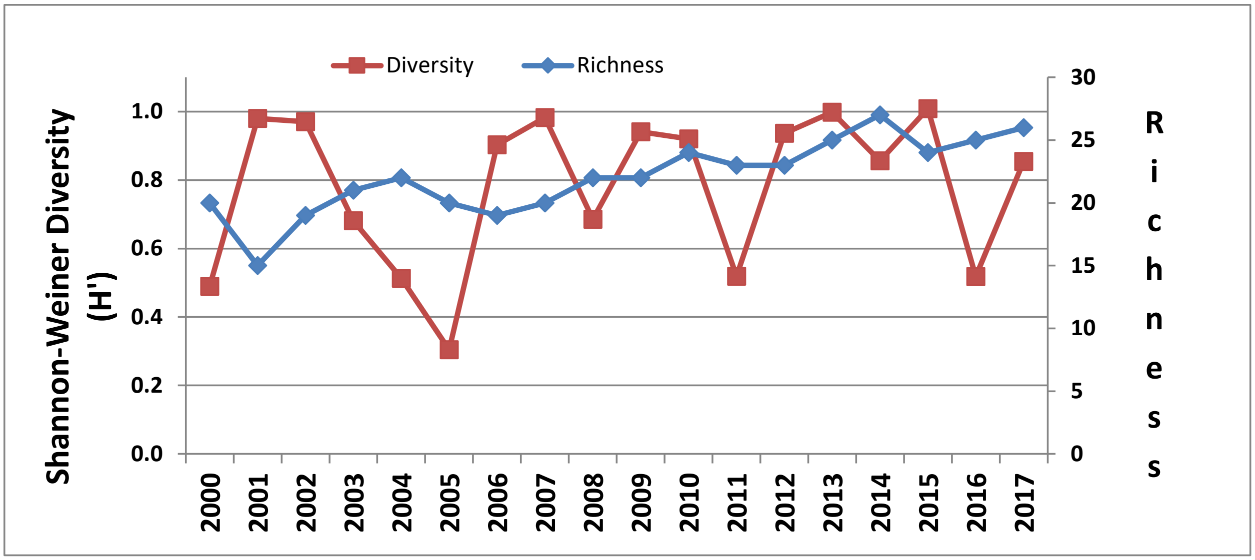


Figure 6-7. Trends in adult fish Shannon-Weiner diversity (H') and species richness for fish captured by electrofishing, Onondaga Lake, 2000–2017.

Table 6-1. Fish species identified in Onondaga Lake, 2000–2017 (total catch, all gear types, and all life stages).

Abundant Species (>1000 individuals)		Common Species (50-1000 individuals)		Uncommon Species (<50 individuals)	
Alewife	Golden Shiner	Bluntnose Minnov	Northern Pike	Black Bullhead	Northern Hog Sucker
Banded Killifish	Largemouth Bass	Bowfin	Rock Bass	Black Crappie	Quillback
Bluegill	Pumpkinseed	Channel Catfish	Shorthead Redhorse	Brook Stickleback	Rainbow Smelt
Brown Bullhead	Smallmouth Bass	Emerald Shiner	Tessellated Darter	Brown Trout	Rainbow Trout
Common Carp	White Perch	Fathead Minnow	Tiger Muskie	Chain Pickeral	Rudd
Gizzard Shad	White Sucker	Freshwater Drum	Walleye	Creek Chub	Silver Redhorse
Brook Silverside	Yellow Perch	Logperch	Yellow Bullhead	Goldfish	Spotfin Shiner
Round Goby		Longnose Gar	Green Sunfish	Greater Redhorse	Spottail Shiner
				Johnny Darter	Tadpole Madtom
				Lake Sturgeon	Trout Perch
				Longnose Dace	White Bass

Largemouth Bass Collected from Onondaga Lake, 2016.

from the higher level of wastewater treatment) and more diverse habitat (e.g., expansion of aquatic macrophytes).

Fish diversity (the number and relative abundance of species in the community) has shown mild improvement over the long term, but has been highly variable due primarily to large fluctuations in the abundance of two clupeid species, alewife and gizzard shad. The swings in abundance of these species are influenced by occasional severe winter mortality and the periodic production of very strong year classes.

Diversity declines sharply when one of the two clupeid species dominates the community; this tends to occur every 3-5 years. In 2017, gizzard shad was the most abundant species in the lake-wide electrofishing catch but composed only 25% of the electrofishing catch lake wide. The moderate diversity value for 2017 reflects this moderate level of dominance.

The AMP fish community sampling targets four life stages: larval, young-of-year, juvenile, and adult. Nesting also is monitored for bass, sunfish, and bullhead. Monitoring across multiple life stages aids in interpreting population and community dynamics that may not be detected using a single life stage since not all species use the lake equally for all life stages. Data summaries for the various fish life stage sampling efforts in 2017 and for the entire fish community are provided in Appendix H-4.

Gizzard shad was the most abundant species in the electrofishing catch of adult fish in 2017, composing 25% of the catch (Figure 6-8). Brown bullhead was second in abundance (20%), followed by largemouth bass (13%), and yellow perch (12%). All remaining species individually composed less than 10% of the catch.

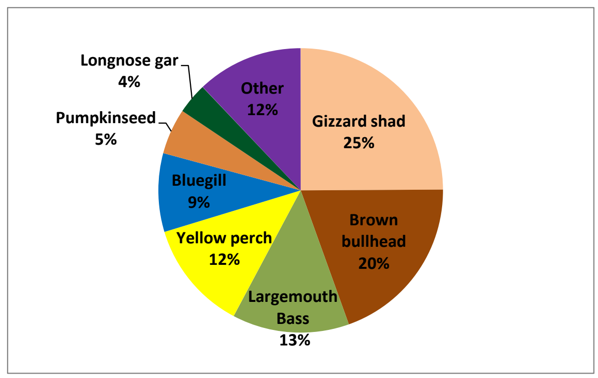


Figure 6-8. Lake-wide relative abundance of adult fish electrofished from Onondaga Lake, 2017.

Catch rates of individual species are variable. Smallmouth bass and channel catfish catch rates have declined overall. In contrast, largemouth bass and brown bullhead have shown relatively consistent increases in catch rate since 2000. Pumpkinseed, yellow perch, and northern pike have shown relatively large increases in catch rate, but these rates have now declined. Still other species, such as bluegill, walleye, and gizzard shad have shown wide swings in catch rates between years, with no evident trend.

Since 2008, SUNY-ESF students have conducted monthly (May – October) trap net sampling at ten locations as part of the Honeywell monitoring program. The composition of trap net catches has varied considerably among years, with bluegill, banded killifish, or alewife usually representing the dominant species in a given year. Banded killifish was again the dominant species (40% of catch) in 2017. Largemouth bass (22%) and bluegill (14%) were the other most abundant species. Although not a dominant component of the community, the relative abundance of round goby more than doubled from 4% in 2016 to 10% in 2017, suggesting that the population is expanding rapidly. The 34 species collected by trap net in 2017 was the highest since 35 species were collected in 2013.

Alewife are challenging to sample using electrofishing or trap nets. Consequently, the AMP has relied on a combination of hydroacoustics and gill netting to estimate alewife abundance since 2004. Lake-wide alewife density in the spring of 2017 (4119 fish/hectare) far exceeded the previous spring high of 2328 fish/hectare in 2006 (Figure 6-9). Alewife size-at-age was smaller than in 2016, but still similar to many of the survey years. This general pattern was consistent with the zooplankton composition in the lake in 2017, which was dominated by small cladocerans and copepods. The relatively low growth rate of alewife in the lake is consistent with high abundance. A detailed report of the 2017 alewife community is in Appendix H-5.

Fish collected in Onondaga Lake as part of the AMP are examined for tumors and abnormalities using a standardized protocol known as DELT-FM. Data are used for trend analysis and to compare fish collected in the

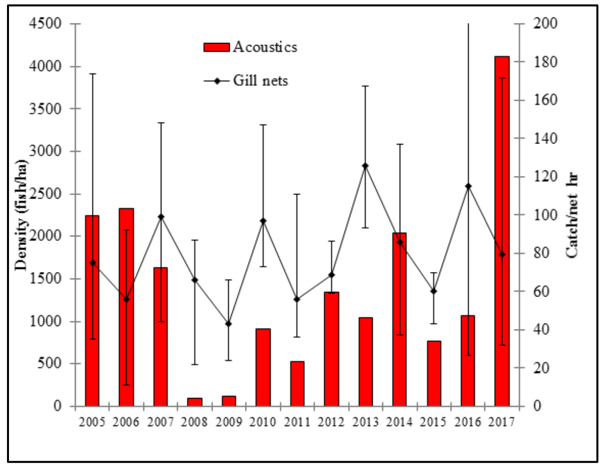


Figure 6-9. Alewife densities determined by gill net catch (catch/hour, right scale) and hydroacoustics (fish/ha, left scale) from May/June surveys of Onondaga Lake, 2005-2017.

lake to those collected in other regional waters. Fish tumors and abnormalities can result from chemical contamination, biological agents such as bacteria, viruses or fungi, or an interaction among multiple stressors.

The majority of abnormalities in the Onondaga Lake fish community are seen in the brown bullhead; eroded barbels are the most common. The percent of fish exhibiting abnormalities increased from 2000 to 2009, reaching a peak of 5.5%. This proportion has declined to and remained steady at approximately 2% since 2015. The relative abundance of bullhead in the fish community has also increased over this period. The incidence of lesions and tumors in brown bullhead in Onondaga Lake is now within the range associated with regional reference sites.

The ability of Onondaga Lake to support cold- and cool-water fishes has been modeled since 2009. A “fish space” metric was developed for Onondaga Lake as a useful tool for evaluating cool-water and cold-water fish habitat. The metric is based on dissolved oxygen (DO) and water temperature, two primary variables that determine the ability of fish species to maintain a viable population. This tool is a means to display changes in suitable habitat over both time and depth in the water column. As has been the case in past years, during most of summer 2017, high water temperatures at the surface and low DO conditions in deeper cooler zones rendered much of the lake unsuitable for cold-water species such as salmonids (Figure 6-10). In contrast, at least some suitable conditions for cool-water fish species such as walleye existed throughout the summer of 2017 (Figure 6-11).

Although the amount of suitable habitat for cold-water species was slightly lower in 2017 than in recent years, the length of time conditions were unsuitable was approximately a month shorter in 2017 (second week of July to last week of August) than in 2016 (second week of July to last week of September). This was due primarily to surface water cooling earlier in 2017.

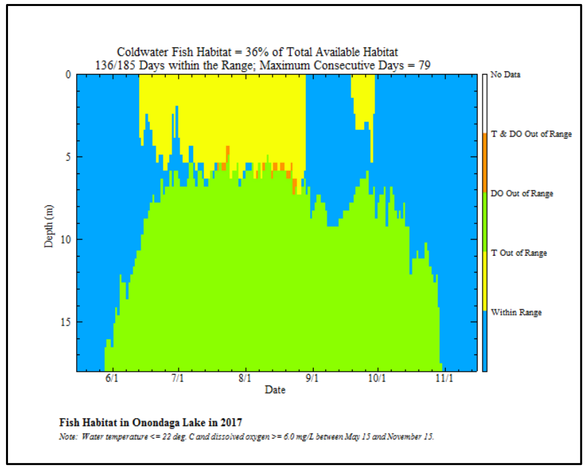


Figure 6-10.Available cold-water fish habitat in Onondaga Lake, May 15 through November 15, 2017.

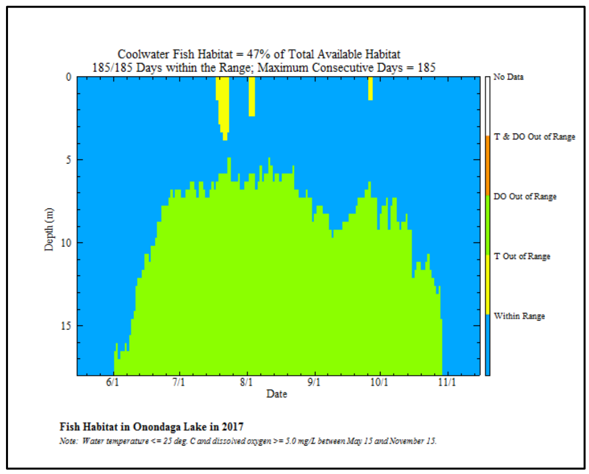


Figure 6-11.Available cool-water fish habitat in Onondaga Lake, May 15 through November 15, 2017.

Integrated Assessment of the Food Web

Onondaga Lake is a complex ecosystem influenced by a myriad of factors throughout its approximately 285 square-mile watershed. The lake is influenced not only by the physical and chemical characteristics of the basin, but by its biological characteristics as well. Some of these numerous and varied components have changed little since the inception of the AMP, but many have changed markedly. Understanding which of these factors have changed, and to what extent, is one of the main goals of the AMP. The information gained through the AMP provides a means of evaluating the effectiveness of improvements to Onondaga County's wastewater collection and treatment infrastructure stemming from the Amended Consent Judgment.

Many of the largest changes seen in the Onondaga Lake ecosystem are directly or indirectly linked to improvements in wastewater treatment at Metro. The large and sustained reduction in phosphorus since the early 2000s has reduced lake primary productivity.

The lower production of phytoplankton has resulted in increased water clarity. This in turn has had a major influence on the physical structure of aquatic habitat in the lake by allowing aquatic macrophyte growth to increase in both density and area. Reduced phytoplankton production has also resulted in lower rates of oxygen depletion in the hypolimnion, resulting in declines in the degree and duration of anoxic conditions below the thermocline. This has expanded the volume of the lake that provides suitable habitat for fish and benthic macroinvertebrates.

Zebra Mussel (Left side) and a Quagga Mussel (Right side)

The major reduction in ammonia-N resulting from implementation of the biologically aerated filter (BAF) at Metro in 2004 brought the entire lake into compliance with the ammonia standard. The BAF converts ammonia to nitrate, a non-toxic form of nitrogen. The increased nitrate loading from Metro is supplemented by nitrate additions by Honeywell designed to reduce the formation of methyl mercury (Matthews et al. 2013). The elevated nitrate concentrations have also suppressed phosphorus release from the lake sediments. Biological repercussions of the reduction in ammonia-N and increased nitrogen:phosphorus ratio included elimination of the periodic, nuisance algal blooms that formerly plagued the lake and expansion of suitable habitat for ammonia-sensitive aquatic invertebrates and early life stages of fish.

Aside from nutrients, grazing pressure from zooplankton and benthic mussels can strongly influence phytoplankton abundance and water clarity. Observed reductions in phytoplankton abundance and increases in water clarity might have been even greater if not for intense predation of zooplankton by the invasive alewife. Zooplankton biomass and average size have declined over the course of the AMP and have remained relatively low for the last several years. This is due in large part to the abundance of alewife, which preferentially prey on the largest zooplankton. These large zooplankton (most commonly *Daphnia* spp.) are the most effective grazers of phytoplankton. This intensive predation increases the dominance of small-bodied species in the community. This is quite different from what was observed in 2008 and 2009 when the Onondaga Lake alewife population was low. During those years, *Daphnia* abundance was higher, chlorophyll-*a* concentrations were lower, and water clarity was higher than at any other time since the AMP began.

Chain Pickerel (*Esox niger*) Captured from Onondaga Lake in 2016.

However, continued improvements to lake water quality may be leading to more favorable conditions for zooplankton. For the first time since the AMP began, zooplankton densities below the 6-m depth were higher than densities shallower than 6 m for part of the 2017 monitoring period (4 of 10 sampling occasions). High abundance of zooplankton in the metalimnion during the day is found in lakes with clear waters and abundant planktivorous fish if oxygen concentrations in the hypolimnion are above ~1 mg/L (e.g. Klumb et al. 2004, Rudstam et al. 2015). The increase in the proportion of zooplankton in deeper water in 2017 was likely due to improved oxygen conditions in the hypolimnion allowing zooplankton to move deeper to avoid alewife predation.

The substantial increase in the density, biomass, and areal coverage of aquatic macrophytes in response to higher water clarity has resulted in increased habitat complexity. This complexity provides a wide range of microhabitats that can support a more diverse and abundant aquatic macroinvertebrate community. Expansion and diversification of the macrophyte community also increased available habitat for many fish species. Aquatic macrophytes provide critical spawning and nursery habitat for many littoral zone fishes, and species such as largemouth bass, bluegill, and yellow perch have expanded as a result of this habitat enhancement.

Improvements to water quality and the resultant changes in the lower trophic levels of Onondaga Lake have produced marked changes in the fish community at the top of the food web. Fish species richness has shown a consistent gradual increase. Several fish species have benefited from expansion and diversification of the aquatic macrophyte community. Others, such as walleye, and possibly smallmouth bass, have benefited from improvements in water quality in the hypolimnion and other open-water areas of the lake. Brown bullhead is an example of a species that has benefited in multiple ways, from habitat expansion and improvement to reduced incidence of tumors and abnormalities.

Round Goby.

The same improvements to Onondaga Lake's water quality and habitats that have allowed the native fish community to thrive have also provided opportunities for invasive species to colonize and prosper in the lake. The influence of alewife was previously mentioned. Other invasive fishes that are becoming more prominent in the lake include round goby, green sunfish, and rudd. The potential influences of these species are poorly understood and could be negative, positive, or neutral. For instance, round goby is known to prey on the eggs of native species such as largemouth bass and sunfish, but it also can serve as an important prey item to bass, walleye, and other sportfishes. Round goby may also be contributing to the overall decline in invasive dreissenid mussels in the lake. The impact of these and other invasive species on the ecology of Onondaga Lake becomes more relevant as lake conditions continue to improve and become suitable for more species.

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List of Acronyms

AMP	Ambient Monitoring Program
ACJ	Amended Consent Judgment
ASLF	Atlantic States Legal Foundation
AWQS	Ambient Water Quality Standards
BAF	Biological Aerated Filter
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CFU	Colony Forming Units
CPUE	Catch Per Unit Effort
CSO	Combined Sewer Overflow
DO	Dissolved Oxygen
DVT	Data Visualization Tool
EPA	Environmental Protection Agency
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HRFS	High Rate Flocculated Settling
METRO	Metropolitan Syracuse Wastewater Treatment Plant
MRL	Method Reporting Limit
N	Nitrogen
NYCRR	Official Compilation of the Rules and Regulations of the State of New York
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priority List
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health

OCDWEP	Onondaga County Department of Water Environment Protection
OLTAC	Onondaga Lake Technical Advisory Committee
OLWQM	Onondaga Lake Water Quality Model
PWL	Priority Waterbodies List
RSE	Relative Standard Error
SPDES	State Pollution Discharge Elimination System
SRP	Soluble Reactive Phosphorus
SSO	Sanitary Sewer Overflow
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TRWQM	Three Rivers Water Quality Model
TSS	Total Suspended Solids
UFI	Upstate Freshwater Institute
USGS	United States Geological Survey

GLOSSARY OF TERMS

Term	Abbreviation	Definition
303(d List)	**--**	the list of impaired and threatened waters (stream/river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval every two years on even-numbered years. The states identify all waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards, and establish priorities for development of TMDLs based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors (40C.F.R. §130.7(b)(4)).
Ambient Monitoring Program	**AMP**	Onondaga County's comprehensive program to evaluate the quality of the waterways [in Onondaga County] and track changes brought about by the improvements to the wastewater collection and treatment infrastructure and reductions in watershed sources of nutrients.
Amended Consent Judgment	**ACJ**	A legal finding or ruling. In this case, in 1998, an Amended Consent Judgment (ACJ) between Onondaga County, New York State and Atlantic States Legal Foundation was signed to resolve a lawsuit filed against Onondaga County for violations of the Clean Water Act. The lawsuit alleged that discharges from the Metropolitan Syracuse Wastewater Treatment Plant (Metro) and overflows from the combined sewer system (CSOs) precluded Onondaga Lake from meeting its designated best use. The ACJ obligates the County to undertake a phased program of wastewater collection and treatment improvements that will extend though the year 2012, monitor water quality response, and report annually on progress towards compliance.
Ambient Water Quality Standard	**AWQS**	Enforceable limits on the concentration of pollutants designed to protect a designated use of the waterbody. Standards are promulgated by NY State and approved by the U.S. Environmental Protection Agency.
ammonia-N	**NH_3-N**	An important form of nitrogen that is the end product of the decomposition of organic material; it is used by phytoplankton for growth.
assimilative capacity	**--**	The capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects to its designated use (e.g., without damage to aquatic life or humans who consume the water).
AUTOFLUX	**AUTOFLUX**	A customized software package developed by Dr. William Walker and used by Onondaga County WEP staff to estimate loading of water quality constituents (nutrients) to Onondaga Lake. The program uses continuous flow data and less frequent (often biweekly) tributary water quality

Term	Abbreviation	Definition
		samples to estimate annual loading rates.
biochemical oxygen demand 5 day	**BOD_5**	The amount of oxygen a water sample's chemical and biological composition will consume over a 5 day incubation period. The higher the BOD_5, the more oxygen used by the sample. Generally, the higher BOD_5 means lower water quality.
Biological Aerated Filter	**BAF**	A combination standard filtration with biological treatment of wastewater. BAF usually includes a reactor filled with a filter media either in suspension or supported by a gravel layer. The dual purpose of this media is to support highly active microbes which remove dissolved nutrients from wastewater and to filter particulates.
Best Management Practices	**BMPs**	A combined group of activities designed minimize the amount of pollution that reaches a body of water. BMPs can be applied to agricultural, urban, and/or industrial areas as preventative measures to protect water quality.
bicarbonate	**HCO_3^-**	Serves a crucial biochemical role in the physiological pH buffering water in natural systems and thereby minimize the disturbance of biological activities in these systems.
calcium	**Ca**	A nutrient required by aquatic plants and some algae for proper metabolism and growth. Calcium, normally as calcium carbonate, is also a common contributor to water hardness.
catch per unit effort	**CPUE**	An indirect measure of the abundance of a target species
chloride	**Cl**	A halogen element usually associated with metallic elements in the form of salts.
chlorophyll-*a*	**Chl-*a***	A pigment used by plants and algae for photosynthesis. Chlorophyll concentration in lakes is used as a surrogate for estimating the amount of algae present.
combined sewer overflows	**CSOs**	A discharge of untreated sewage and stormwater to a water body; CSOs occur when the capacity of a combined storm/sanitary sewer system is exceeded by storm runoff.
conductivity	**--**	The measure of the ability of water to conduct electricity
cultural eutrophication	**--**	An increase in a water body's biological production due to human activities. Cultural eutrophication usually results in negative water quality impacts such as loss of clarity, increased algal blooms, decreased oxygen resources, and accumulation of reduced species
dissolved oxygen	**DO**	Dissolved form of oxygen, (dissolved in water) an indicator of the quality of water to support fish and aquatic organisms.
ecosystem	**--**	An interrelated and interdependent community of plants, animals, and the physical environment in which they live

Term	Abbreviation	Definition
Environmental Protection Agency	**EPA**	The federal agency responsible for the conservation, improvement, and protection of natural resources within the US.
eutrophic	**--**	Systems with high levels of productivity.
fecal coliform bacteria	**FC**	Microscopic single-celled organisms found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation or for consumption. Their presence indicates contamination by the wastes of warm-blooded animals and the possible presence of pathogenic (disease producing) organisms.
frustules	**--**	Silica-rich external cell walls of diatoms.
guidance value	**--**	Best professional judgment of the maximum concentration of certain pollutants that will protect a designated use.
High-Rate Flocculated Settling	**HRFS or Actiflo®,**	An advanced process used in the treatment of municipal wastewater. Actiflo™ is a compact process that operates with microsand (Actisand™) as a seed for floc formation. Actisand™ provides surface area that enhances flocculation and also acts as a ballast or weight to aid a rapid settlement.
Hilsenhoff Biological Index	**HBI**	An index that uses species-defined pollution tolerance levels to assess the overall tolerance level of a community of organisms, and is an indicator of water quality.
hypolimnion	**--**	Deep, cold waters of a stratified lake; portion of the lake volume that remains isolated from atmospheric exchange during periods of thermal stratification.
hypoxia	**--**	Low dissolved oxygen conditions of a water body which is detrimental to aerobic organisms.
indicator bacteria	**--**	Bacteria used to indicate the potential presence of pathogenic (disease-causing) microorganisms in water (see also fecal coliform bacteria).
interrelatedness	**--**	The degree to which organisms in an ecosystem interact and are influenced by other organisms. Pathways of interaction between species in an ecosystem
littoral zone	**--**	Shallow water zone at the edges of lakes, where light reaches the sediment surface
magnesium	**Mg**	A metallic element required by algae for the production of chlorophyll.
metrics	**--**	Quantifiable physical, chemical and/or biological attributes of an ecosystem that responds to human disturbances; also, measurable attributes of the ecosystem that indicate whether a desired state has been achieved. Good metrics are cost-effective to measure, associated with low uncertainty, relevant to stakeholders and sensitive to

Term	Abbreviation	Definition
		anticipated changes.
mercury	**Hg**	A trace metal element that is toxic to aquatic life and humans.
mesotrophic	**--**	Systems with mid-levels of productivity; between eutrophic and oligotrophic.
Metropolitan Syracuse Wastewater Treatment Plant	**Metro**	The wastewater treatment plant that treats the municipal waste from the City of Syracuse and large portions of Onondaga County, located in Syracuse, NY near Onondaga Lake.
New York State Department of Environmental Conservation	**NYSDEC**	The state agency responsible for the conservation, improvement, and protection of natural resources within the state of New York.
New York State Department of Health	**NYSDOH**	
nanograms per liter	**ng/L**	A concentration unit. One billionth of a gram per liter or 10^{-9} g per liter
nitrate-N	**NO_3-N**	A form of nitrogen used by phytoplankton for growth; the end product of nitrification. In addition, the final stages of wastewater treatment at Metro produces large quantities of nitrate-N that is discharged to Onondaga Lake.
nitrite-N	**NO_2-N**	A form of nitrogen formed in the intermediate step of nitrification. Accumulation of nitrite-N can be toxic to aquatic organisms.
nitrogen	**N**	A common element required by algae for growth. In aquatic ecosystems, nitrogen is usually in abundance and does not limit algal growth in most freshwater systems.
oligotrophic	**--**	Systems with low levels of productivity.
Onondaga Lake Technical Advisory Committee	**OLTAC**	
organic nitrogen	**--**	The total amount of nitrogen in a water sample, associated with total (particulate and dissolved) organic matter.
oxidation-reduction potential	**Redox or ORP**	A measure (in volts) of the affinity of a substance for electrons. The value is compared to that for hydrogen, which is set at zero. Substances that are more strongly oxidizing than hydrogen have positive redox potentials (oxidizing agents); substances more reducing than hydrogen have negative redox potentials (reducing agents). In Onondaga Lake's hypolimnion, ORP declines as organic material is decomposed.
particulate	**PP**	The non-dissolved fraction of total phosphorus.

Term	Abbreviation	Definition
phosphorus		
pelagic zone	**--**	Any water in the sea of a lake that is not near the bottom or the shore.
pH	**pH**	The negative log of the hydrogen ion concentration commonly used to quantify the acidity of a waterbody. pH is an important regulator of chemical reactions in ecosystems.
phosphorus	**P**	A common element required by algae for growth. In freshwater aquatic ecosystems, phosphorus is usually the nutrient limiting phytoplankton production. Increases in phosphorus can result in accelerated eutrophication.
photic zone	**--**	Upper layer of the water column where light penetration is sufficient for photosynthesis (algal growth).
phytoplankton	**--**	The community of algae and cyanobacteria present in a water body.
percent model affinity	**PMA**	A measure of similarity of a sampled community to a model non-impacted community, using percent abundance of 7 major groups to quantify the community structure. The closer the similarity of the sampled community structure is to the model non-impacted community structure, the more likely that the sampled community is non-impacted.
potassium	**K**	A common alkali metal element necessary for proper growth and functioning of aquatic organisms.
profundal	**--**	The deep zone in an inland lake below the range of effective light penetration, typically below the thermocline.
Secchi disk	**SD**	A round disk, 25 cm in diameter, with alternating quadrants of black and white commonly used in limnology to quantify the clarity of surface waters. The disk is lowered through the water column on a calibrated line, and the depth at which it is no longer visible is recorded; thus indicating water clarity.
silica	**Si**	A metallic element used by phytoplankton for construction of cellular structures.
soluble reactive phosphorus	**SRP**	A dissolved form of phosphorus that is most readily used by algae for growth.
sodium	**Na**	A common metallic element in aquatic ecosystems usually associated with chloride, NaCl a common form of salt.
sonde	**--**	A compact monitoring device that includes one or more sensors or probes to measure water quality parameters, such as temperature, pH, salinity, oxygen content, and turbidity directly, eliminating the need to collect samples and transport them to a laboratory for analysis.
specific conductance	**SC**	Conductivity normalized to 25°C.

Term	Abbreviation	Definition
species diversity	**--**	A common ecological measure of the abundance and relative frequency of species in an ecosystem.
species evenness	**--**	A measure of the relative abundance of different species in an ecological community.
species richness	**--**	The number of different species represented in an ecological community.
stoichiometric	**--**	The ratio of required elements needed for a chemical reaction; in this context, refers to the ratio of N and P required by phytoplankton for metabolism.
sulfate	**SO_4^{2-}**	A compound in abundance in Onondaga Lake due to the large quantities of gypsum (naturally occurring geological formation) in the lake's watershed. SO_4^{2-} can be converted to hydrogen sulfide when oxygen is depleted.
total dissolved phosphorus	**TDP**	A dissolved form of phosphorus that is used by algae for growth. TDP is not as readily available as SRP.
total dissolved solids	**TDS**	A common measure of the amount of salts in a water body.
total inorganic carbon	**TIC**	The total amount of carbon in a water sample, not associated with organic matter.
total Kjehldahl nitrogen	**TKN**	A measure of the concentration of organic nitrogen and ammonia-N in a water sample.
Total Maximum Daily Load	**TMDL**	An allocation of the mass of a pollutant that can be added to a water body without deleterious effects to its designated use.
total organic carbon	**TOC**	The total amount of carbon in a water sample, associated with total (particulate and dissolved) organic matter.
total nitrogen	**TN**	The total amount of nitrogen in a water sample, associated with particulate and dissolved organic and inorganic matter.
total organic carbon filtered	**TOC_f**	The total amount of carbon in a water sample, associated with dissolved organic matter.
total phosphorus	**TP**	The total amount (dissolved plus particulate) of phosphorus in a water sample. Summer average TP in the upper waters of lakes is a common metric of water quality.
total suspended solids	**TSS**	The amount of particulate material in a water sample.
trophic state	**--**	The status of a water body with regard to its level of primary production (production of organic matter through photosynthesis)
micrograms per liter	**µg/L**	A concentration unit. One millionth of a gram per liter or 10^{-6} g per liter.
milligram per liter	**mg/L**	A concentration unit. One thousandths of a gram per liter or 10^{-3} g per liter
volatile suspended solids	**VSS**	The total amount of organic particulate matter in a water sample (a fraction of TSS).

Term	Abbreviation	Definition
volume days of anoxia	**--**	A metric that integrates the volume of the lake water affected by low dissolved oxygen (DO) conditions over the duration of the low DO.
water year	**--**	The continuous 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending September 30, 2010 is referred to as the 2010 water year.
watershed	**--**	An area of land that drains rainfall and streams to a common outlet.
Water Environment Protection	**WEP**	The agency in Onondaga County, NY responsible for wastewater and stormwater treatment as well as the monitoring and protection of all water resources in the county.