Appendix A
White Paper on Attainment of Designated Uses in Onondaga Lake

ATTAINMENT OF DESIGNATED USES IN ONONDAGA LAKE

A white paper prepared for

Onondaga County Department of

Water Environment Protection

Prepared by

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0 EXECUTIVE SUMMARY

This report presents an evaluation of the extent to which Onondaga Lake is presently meeting its designated uses, including public bathing and recreation, aquatic life support, fish consumption, natural resources habitat/hydrology, and aesthetics. Water quality conditions in Onondaga Lake have improved markedly since the 1990s as a result of Onondaga County's major investments in wastewater collection and treatment. The 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation required improvements to the County's wastewater collection and treatment infrastructure. In addition, the ACJ required an extensive ambient monitoring program (the AMP) to document improvements in water quality and biological communities. This evaluation focuses on achievement of best uses designated for class "B" and "C" waters and status with respect to applicable New York State ambient water quality standards and guidelines. This assessment emphasized the following water quality parameters because they are cited specifically in the ACJ: dissolved oxygen, ammonia, turbidity, floatables, phosphorus, nitrogen, and bacteria.

Major investments in advanced wastewater treatment by Onondaga County have transformed Onondaga Lake from a highly polluted waterbody into a system that now supports a variety of recreational uses and a diverse fishery. The lake is now meeting ambient water quality standards intended to protect aquatic life and human recreation uses. Water quality conditions in the northern two-thirds of the lake are now suitable for swimming. A total of 53 species of fish have been identified in the lake since 2000, including warmwater, coolwater, and limited coldwater species. A parallel lake cleanup program being implemented by Honeywell is addressing industrial contaminants and the recovery of an edible fishery.

Treatment upgrades at the Syracuse Metropolitan Wastewater Treatment Plant (Metro) in 2004 and 2005 greatly reduced inputs of phosphorus and potentially harmful forms of nitrogen to Onondaga Lake. Loading of ammonia was reduced by 98% as a result of treatment upgrades at Metro. Water quality standards for ammonia are no longer exceeded in Onondaga Lake and the lake was delisted as impaired by ammonia in 2008. In addition, loading of nitrite, another form of nitrogen potentially toxic to aquatic biota, was reduced by 90%. Increased nitrate loading from Metro has substantially decreased the transport of phosphorus and mercury from the sediments to the water column.

Implementation of advanced treatment at Metro has resulted in an 85% decrease in total phosphorus loading to Onondaga Lake since the early 1990s and a 99% reduction since the early 1970s. Summer average total phosphorus concentrations decreased from over 50 µg/L during the 1990s to 21 µg/L during 2007–2013. Total phosphorus levels are now close to the guidance value of 20 µg/L established by New York State for protection of recreational uses of lakes. Reduced phosphorus loading has caused marked decreases in algal biomass and the occurrence of algal blooms. No major algal blooms have been observed in the lake during summer since 2005 and no minor blooms have been documented since 2007. Levels of total phosphorus and algal biomass in Onondaga Lake are now comparable to concentrations in other regional lakes.

Reductions in algal biomass have resulted in improved water clarity in both open water and nearshore regions of the lake. Water clarity now exceeds the swimming safety guidance value of 1.2 meters (4 feet) 96% of the time at South Deep and 90% of the time at nearshore locations in Class B areas of the lake. Uncontrolled inputs of clay particles from the Tully Valley mudboils continue to cause diminished water clarity in the Class C segment located at the south end of the lake proximate to the mouth of Onondaga Creek.

Treatment upgrades at Metro have also eliminated depletion of dissolved oxygen in the upper waters of the lake during fall turnover. Dissolved oxygen conditions in the lake now provide habitat for a diverse fishery, including both warmwater and coolwater fish species. Coldwater species are found in Onondaga Lake on a seasonal basis, but their habitat is restricted during summer due to a lack of cold, oxygen-rich water. The available evidence suggests that depletion of dissolved oxygen in the lower layers of Onondaga Lake is a natural condition related to the lake's morphology. This situation is not unique to Onondaga Lake. In fact, low oxygen levels were documented in the lower waters of more than 70% of the thermally stratified lakes included in a recent NYSDEC survey.

Onondaga County has completed a variety of "gray" and "green" infrastructure projects that have reduced discharges from combined sewer overflows (CSOs) and associated bacteria loading to the lake. To date, 45 CSOs have been eliminated or captured. Green infrastructure projects are reducing storm water runoff by over 108 million gallons per year and CSO discharges by approximately 51 million gallons per year. Sampling sites located in the Class B portions of the lake were in continuous compliance with the fecal coliform standard throughout the 2008–2013 interval. Water clarity and bacteria levels in the northern two-thirds of the lake now meet New York State standards for public bathing. Fecal coliform levels continue to exceed the water quality standard in Class C waters in the extreme southern portion of the lake following wet-weather events. Lower fecal coliform concentrations in the southern end of the lake are a reasonable expectation as additional gray and green infrastructure projects are implemented as part of the Save the Rain initiative.

Guidelines presented in the New York State Consolidated Assessment and Listing Methodology (CALM) served as the basis for evaluation of the extent to which Onondaga Lake is presently supporting the designated uses of public bathing and recreation, aquatic life support, fish consumption, natural resources habitat/hydrology, and aesthetics. The public bathing use is fully supported in Class B waters, which comprise the northern two-thirds of the lake. Public bathing is not a designated use in the southern third of the lake. Recreational uses of the lake are fully supported in Class B waters. Primary contact recreation is limited in the extreme southern end of the lake following runoff events due to elevated turbidity and high fecal coliform concentrations. The aquatic life use is fully supported throughout the lake as manifested in a diverse fish community and an improving macroinvertebrate community. The fish consumption use remains impaired on a lake-wide basis due to mercury, PCB, and dioxin contamination. These conclusions are generally consistent with those reached by NYSDEC in the recently updated Waterbody Inventory and Priority Waterbodies List (WI/PWL).

The water quality improvements achieved in Onondaga Lake are reflected in the recovery of lost uses, including swimming and other recreational uses, support of a robust biological community, and enhanced aesthetic appeal. Despite these improvements, water quality and biological conditions in Onondaga Lake will continue to be influenced by a variety of factors that are beyond the scope of current rehabilitation initiatives. Invasive species, such as dreissenid mussels, Alewife, and Round Goby, will continue to impact the food web and water quality conditions. Turbid inputs from the Tully Valley mudboils are presently uncontrolled and continue to cause deleterious effects on habitat conditions and aesthetics in Onondaga Creek and Onondaga Lake. Year-to-year variations in weather and long-term changes in climate will influence water quality and the biological community.

1 INTRODUCTION

1.1 Objectives of this Report

This white paper documents the extent to which Onondaga Lake is presently meeting its designated uses, including public bathing and recreation, aquatic life support, fish consumption, natural resources habitat/hydrology, and aesthetics. Water quality conditions in the lake have improved substantially over the last decade as a result of major investments in wastewater collection and treatment infrastructure. Significant progress has been made in meeting the regulatory standards and water quality goals identified for Onondaga Lake in the Amended Consent Judgment (ACJ). This report focuses on achievement of best usage designated for class “B” and “C” waters pursuant to 6 NYCRR Parts 701 and 703, and New York State ambient water quality standards and guidelines, as applicable to Onondaga Lake. Standards for the following parameters receive particular emphasis because they are cited specifically in the ACJ:

- *Dissolved oxygen (6 NYCRR § 703.3)*
- *Ammonia (6 NYCRR § 703.5)*
- *Turbidity (6 NYCRR § 703.2)*
- *Floatables (6 NYCRR § 703.2)*
- *Phosphorus (6 NYCRR § 703.2 and TOGS 1.1.1)*
- *Nitrogen (6 NYCRR § 703.2)*
- *Bacteria (6 NYCRR § 703.4)*

In most cases, the applicable water quality standards are numerical and status can be determined directly from measurements. For certain parameters (e.g., nitrogen and phosphorus), current conditions are compared to the applicable narrative water quality standard. Data and analyses from Onondaga County’s Ambient Monitoring Program (AMP) are used to support this analysis of use attainment. Annual AMP reports and supporting data sets are available on the Onondaga County Department of Water Environment Protection website (http://www.ongov.net/wep/we15.html). The scientific literature is referenced as a source of additional information on certain topics.

Our analysis of use attainment was guided by the New York State *Consolidated Assessment and Listing Methodology* (CALM), which describes how data and information are interpreted by New York State Department of Environmental Conservation (NYSDEC) to determine the level of support of designated uses to arrive at an overall assessment of water quality. Once it has been determined that a specific use is restricted, the severity of water quality impacts is evaluated as either *Precluded*, *Impaired*, *Stressed*, or *Threatened*

(Table 1-1). Additionally, the water use impacts and levels of severity are identified as *Known*, *Suspected*, or *Possible* based on the available documentation. Generally, impacts are identified as *Suspected* when the applicable monitoring data criteria is exceeded more than 10% of the time and *Known* when the data-based criteria is exceeded more than 25% of the time.

Table 1–1. Levels of severity for restricted uses.

Severity	Definition
Precluded	Frequent/persistent water quality, or quantity, conditions and/or associated habitat degradation prevents all aspects of a specific waterbody use.
Impaired	Occasional water quality, or quantity, conditions and/or habitat characteristics periodically prevent specific uses of the waterbody, or; Waterbody uses are not precluded, but some aspects of the use are limited or restricted, or; Waterbody uses are not precluded, but frequent/persistent water quality, or quantity, conditions and/or associated habitat degradation discourage the use of the waterbody, or; Support of the waterbody use requires additional/advanced measures or treatment.
Stressed	Waterbody uses are not significantly limited or restricted (i.e. uses are Fully Supported), but occasional water quality, or quantity, conditions and/or associated habitat degradation periodically discourage specific uses of the waterbody.
Threatened	Water quality supports waterbody uses and ecosystem exhibits no obvious signs of stress, however existing or changing land use patterns may result in restricted use or ecosystem disruption, or; Data reveals decreases in water quality or presence of toxics below the level of concern, or; Waterbody uses are not restricted and no water quality problems exists, but the support of a specific and distinctive use make the waterbody more susceptible to water quality threats.

1.2 Historic Conditions

Inputs of domestic and industrial waste to Onondaga Lake caused severe degradation of water quality and loss of uses, including swimming and fishing. Elevated levels of fecal coliform bacteria and low water clarity made the lake unsuitable for swimming. The lake was closed to fishing in 1970 due to mercury contamination of fish tissue and a health advisory remains in place for certain species. The Metropolitan Syracuse Wastewater

Treatment Plant (Metro) has discharged its effluent directly to Onondaga Lake since the 1920s. Loading from Metro contributed to high levels of total phosphorus and nitrogen in the lake (Effler and O'Donnell 2010, Effler et al. 2010).

The lake exhibited classical symptoms of extreme cultural eutrophication through the 1990s, including (1) high levels of phytoplankton biomass, including severe blooms of cyanobacteria (Auer et al. 1990, Effler 1996, Matthews et al. 2001); (2) low transparency (Effler et al. 2008); (3) rapid loss of dissolved oxygen from the hypolimnion (Matthews and Effler 2006); (4) large accumulations of oxygen-demanding reduced byproducts of anaerobic metabolism (e.g., hydrogen sulfide, methane) in the hypolimnion (Matthews et al. 2008); and (5) severe depletion of dissolved oxygen in the upper waters during fall mixing associated with oxidation of the reduced byproducts (Effler and Matthews 2008). Water column concentrations of two forms of nitrogen, ammonia and nitrite, exceeded applicable water quality standards by wide margins through the 1990s (Effler et al. 2010).

1.3 ACJ-Required Upgrades to Meet Water Quality Standards

The 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation required a series of improvements to the County's wastewater collection and treatment infrastructure, and an extensive ambient monitoring program (the AMP) to document the improvements achieved by these measures. Onondaga County Department of Water Environment Protection is responsible for implementing the AMP and reporting its findings.

The ACJ stipulated 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 that focus on the reduction of ammonia and phosphorus concentrations in the effluent (Table 1-2). The final limits for ammonia and phosphorus were achieved in February 2004 and November 2010, respectively.

Combined sewer overflows (CSOs), which serve portions of the City of Syracuse, carry both sewage and storm water in a single pipe. During heavy rain and snowmelt, the pipes can overflow, and a mixture of storm water and untreated sewage flows into creeks and ultimately reaches Onondaga Lake. When these overflows occur, CSOs carry bacteria, floating trash, organic material, nutrients and solid materials through the CSOs to the waterways. Improvements to the wastewater collection and treatment infrastructure are scheduled through 2018. The 4th Stipulation of the ACJ requires phased reductions of CSO volume. 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 1-3. According to simulations from the stormwater management model (SWMM) the annual combined sewage percent capture in 2014 exceeded 95% and is ahead of schedule with respect to the mandated compliance milestones.

Table 1–2. Metro compliance schedule.

(lb/d = pounds per day; mg/L = milligrams per liter)

Parameter	SPDES Limit	Effective Date	Achieved Date
Ammonia	Interim limit: 8,700 lb/d (7/1-9/30) 13,100 lb/d (10/1-6/30)	January 1998	January 1998
	Interim limit: 2 mg/L (6/1-10/31) 4 mg/L (11/1-5/31)	May 2004	February 2004
	Final limit: 1.2 mg/L (6/1-10/31) 2.4 mg/L (11/1-5/31)	March 21, 2012 to March 20, 2017	February 2004
Total Phosphorus	Interim limit: 400 lbs/day (12-month rolling average)	May 1, 2004 to March 31, 2006	January 1998
	Interim limit: 0.12 mg/L (12-month rolling average)	April 1, 2006 to November 5, 2010	April 2006
	Interim limit: 0.10 mg/L (12-month rolling average)	November 16, 2010 to June 30, 2012	November 2010
	Final limit*: 0.10 mg/L (12-month rolling average pursuant to the TMDL approved by the USEPA on June 29, 2012)	June 30, 2012	November 2010

* The permit for Metro 001 will be modified to reflect the phosphorus waste load allocation (WLA) on a 12-month rolling average basis for Metro outfall 001 set at 21,511 pounds per year and 7,602 pounds per year set for Metro outfall 002 (Bypass) to meet the TMDL allocation endpoint.

A bubble permit limit for phosphorus of 27,212 pounds per year to be applied on a 12-month rolling average basis calculated from the monthly total loads from the two outfalls is proposed in the TMDL as an option for implementation by December 31, 2018. The bubble permit allows for the natural variability inherent of combined sewer systems.

Table 1–3. CSO compliance schedule.

Project Phase	Goal	Effective Date
Stage I	Capture for treatment or eliminate **89.5%** of combined sewage* during precipitation, within the meaning of EPA's National CSO Control Policy	Dec 31, 2013
Stage II	Capture for treatment or eliminate **91.4%** of combined sewage during precipitation, within the meaning of EPA's National CSO Control Policy	Dec 31, 2015
Stage III	Capture for treatment or eliminate **93%** of combined sewage during precipitation within the meaning of EPA's National CSO Control Policy	Dec 31, 2016
Stage IV	Capture for treatment or eliminate **95%** of combined sewage during precipitation within the meaning of EPA's National CSO Control Policy	Dec 31, 2018
* on a system-wide annual average basis (per Fourth Stipulation to ACJ, Nov. 2009)		

1.4 TMDLs and SPDES Permits

New York State Department of Environmental Conservation (NYSDEC) issued a new State Pollution Discharge Elimination System (SPDES) Permit for Metro on March 21, 2012. Subsequently, 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.

2 ONONDAGA LAKE AND ITS WATERSHED

2.1 Morphometry

Onondaga Lake is relatively small, with a surface area of 12 km^2. The lake's depth averages 10.9 meters (m) with a maximum of 19.5 m. The lake's bathymetry is characterized by two minor depressions, referred to as the northern and southern basins, separated by a shallower region near the center of the longitudinal axis of the lake (Figure 2-3). The littoral zone, defined as the region of the lake where 1% of the incident light reaches the sediment surface, and consequently supports the growth of rooted plants, is narrow as illustrated by the proximity of the depth contours on the bathymetric map (Figure 2-1). Under current water clarity conditions, macrophyte growth extends to a water depth of approximately 6 meters; this is a more extensive littoral zone than existed in the late 1990s.

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.

Water residence time is defined as the average time water remains in the lake, and is dependent on the ratio of inflow volume to lake volume. A large watershed with a small lake will have a shorter water residence time. Because of the relatively large watershed and abundant rainfall, the inflowing water is sufficient to replace the entire lake volume about four times each year. Therefore, the average water residence time is about three months on a completely mixed basis.

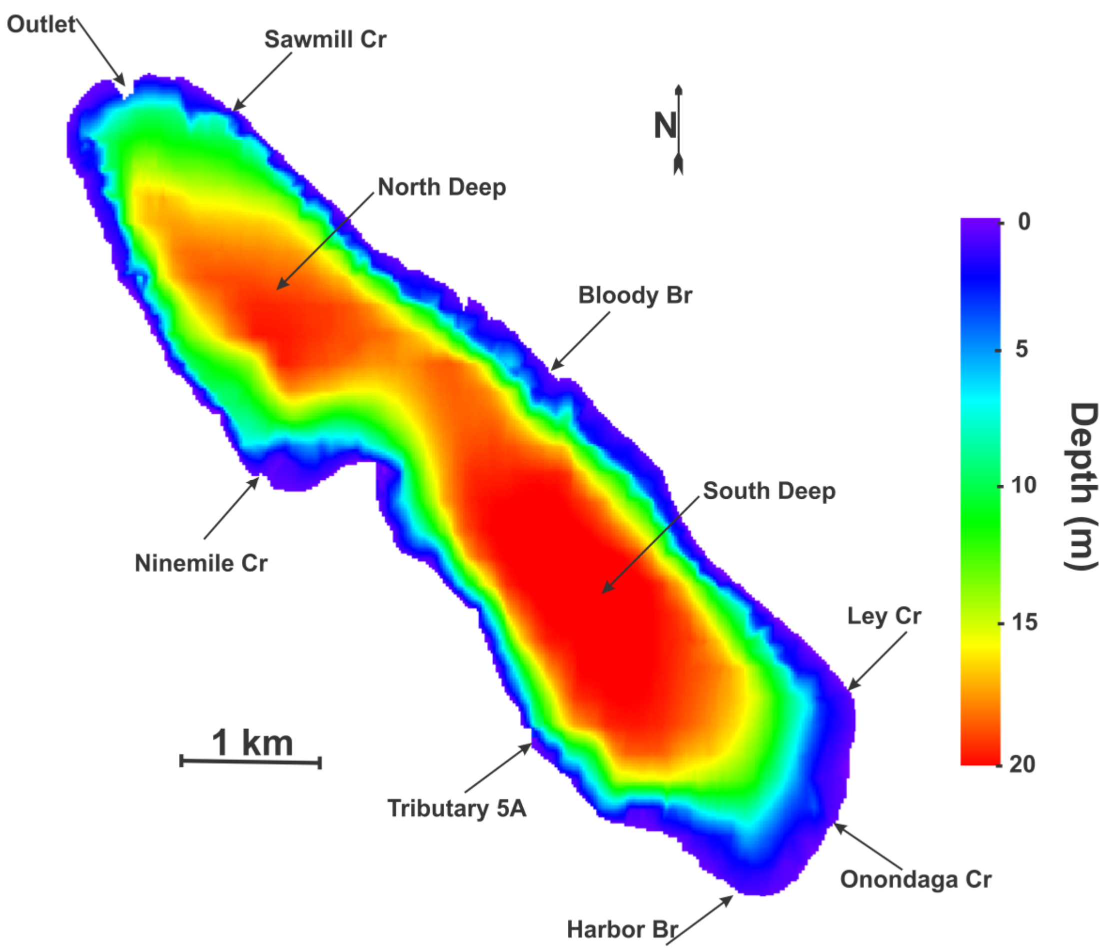


Figure 2–1. Bathymetric map of Onondaga Lake, with tributaries and primary sampling locations (South Deep, North Deep) identified.

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

2.2 Hydrology

Surface water is delivered to Onondaga Lake by a number of natural tributaries, the Metro wastewater treatment plant, industrial discharges, and direct runoff. Onondaga Creek is the largest water source to the lake, followed by Ninemile Creek, Metro, Ley Creek, and Harbor Brook (Figure 2-2). Flow in the four largest tributaries is gauged by USGS. Two minor tributaries, Bloody Brook and Sawmill Creek, drain small watersheds northeast of Onondaga Lake. Tributary 5A and the East Flume direct runoff and industrial discharges into the lake along its southwest shoreline. Much of the 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. Suburban towns and villages use Lake Ontario and Otisco Lake as water supplies. 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.

The tributaries convey surface runoff and groundwater seepage from the watershed to Onondaga Lake. The volume of runoff, and consequently stream flow, varies from year-to-year depending on the amount of rainfall and snow cover. Overflows from combined sewer systems also vary in response to the intensity and timing of runoff events. The annual volume of the Metro discharge is less variable, although the effects of extreme wet or dry years can be detected due to the portion of the service area served by combined sewers. Water quality conditions in Onondaga Lake are affected by material loading rates, which depend importantly on precipitation and stream flow.

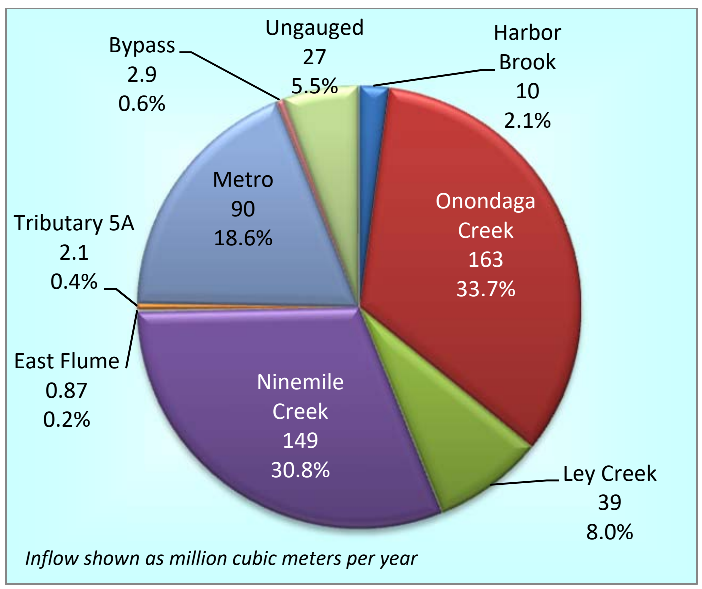


Figure 2–2. Annual average inflows (gauged and ungauged) to Onondaga Lake, 1990–2013.

2.3 Watershed and Land Use

The Onondaga Lake watershed has an area of approximately 285 square miles (740 km^2) and is located almost entirely within Onondaga County. Compared with other lakes in the region, the watershed of Onondaga Lake is relatively urbanized. According to the 2006 National Land Cover Dataset, 21% of the watershed is developed (urban/suburban), 33% is forested or scrub/shrub, and 30% is cultivated lands or pasture. Wetlands, lakes, and barren lands account for the remaining 9%. Onondaga Lake is bordered by the City of

Syracuse, two towns, and two villages. The percentage of urban land is particularly high in the Ley Creek (55%) and Harbor Brook (41%) watersheds. Agricultural lands comprise 40% of the Ninemile Creek watershed and 31% of the Onondaga Creek drainage basin. Forested areas contribute importantly to both the Onondaga Creek (50%) and Ninemile Creek (41%) watersheds.

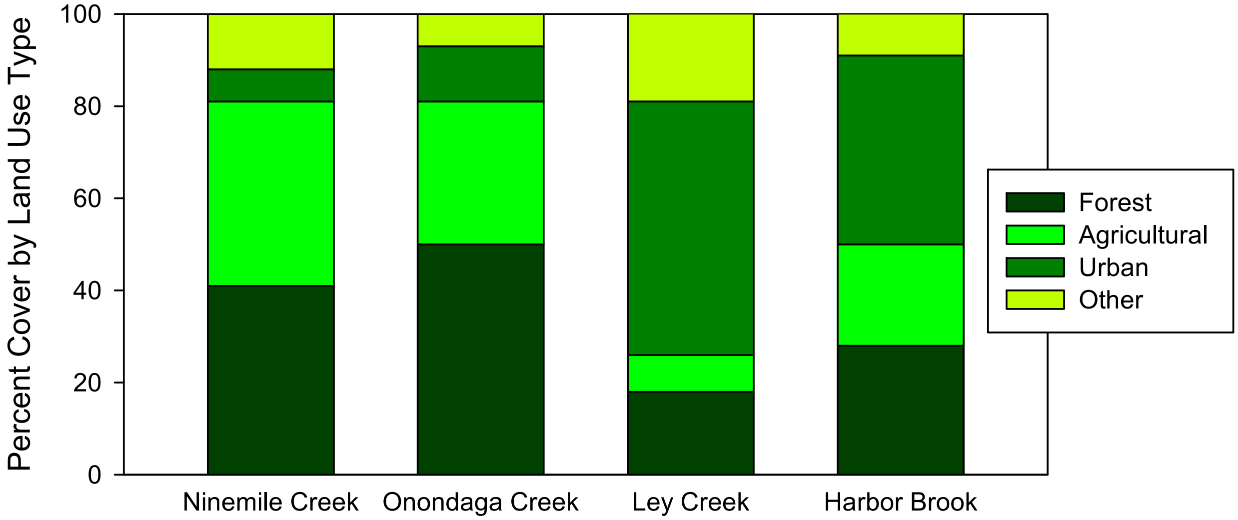


Figure 2–3. Land use in the four largest Onondaga Lake watersheds.

Aerial View of Onondaga Lake

3 AMBIENT MONITORING PROGRAM

3.1 Water Quality Monitoring

The primary objective of Onondaga County's Ambient Monitoring Program (AMP) is to evaluate the impact of alterations and improvements to Metro and the CSOs on water quality. The program was designed to assess progress towards compliance with ambient water quality standards (AWQS) and attainment of designated uses. The AMP collects and analyzes data on the physical, chemical, and biological attributes of Onondaga Lake and its tributatries. As described in the ACJ, the AMP was designed to meet the following objectives:

- Assess compliance with ambient water quality standards in the lake and tributary streams
- Estimate loading of materials to the lake, including the volume and loading of materials from the combined sewer overflows
- Evaluate physical habitat conditions in the lake and tributaries
- Evaluate the lake's trophic state (level of productivity)
- Model the assimilative capacity of the Seneca River in the region of the Onondaga Lake outlet to support a decision regarding diversion of Metro effluent
- Characterize the lake's biological community

In New York State, most of the promulgated AWQS and criteria reference maximum concentrations of chemical parameters. Chemical monitoring is consequently a significant component of the AMP. The lake and tributary monitoring programs include sample collection and analysis for a large suite of chemical parameters to support assessments of compliance with NYS AWQS and guidance values. Chemical monitoring is supplemented with assessment of indicators of the ecological integrity of the lake and its tributaries. Improved habitat for aquatic organisms is a critical element of the rehabilitation of Onondaga Lake. Both the chemical and ecological assessments are used to track progress towards achieving "swimmable and fishable" conditions.

Monitoring is conducted at two main lake stations, South Deep and North Deep, to support compliance assessment, trend analysis, and evaluation of trophic state. In addition, weekly monitoring is conducted at a network of ten near-shore locations during summer to evaluate suitability for water contact recreation.

3.2 Biological Monitoring

The objectives of the biological monitoring program for Onondaga Lake as stated in the ACJ are to "…assess the densities and species composition of phytoplankton, zooplankton, macrophytes, macrobenthos, and fish", and to "evaluate the success of walleye, bass, and sunfish propagation (quantitative lake wide nest surveys, recruitment estimates, and juvenile community structure) in the lake." Based on the more qualitative nature of the objectives, analysis and interpretation of the biological data are primarily focused on changes over time.

Phytoplankton and zooplankton samples are collected each year and analyzed for numbers, biomass, biovolume, and species composition. Long-term trends and seasonal variations are tracked. Aerial photographs and littoral zone surveys provide information on the areal coverage and community composition of macrophytes in the lake. Community composition of benthic macroinvertebrates was assessed at multiple littoral zone locations in 2000, 2005, and 2010. The next macroinvertebrate survey is scheduled for 2017. Annual monitoring of the fish community supports assessment of the densities and species composition of fish and evaluation of the success of walleye, bass, and sunfish propagation in the lake.

OCDWEP Technicians Electrofishing in Onondaga Lake

4 LOADING REDUCTIONS AND RELATED WATER QUALITY IMPROVEMENTS

4.1 Ammonia, Nitrite, and Nitrate

Major reductions in loading of ammonia (NH_3-N) to Onondaga Lake from Metro have been achieved through implementation of state-of-the-art wastewater treatment technologies. The most recent Metro upgrades were designed to meet specific water quality goals in Onondaga Lake. The loading reductions required to meet these water quality goals were established as part of a Total Maximum Daily Load (TMDL) analysis for ammonia (NYSDEC 1998). As a result of treatment upgrades the status of Onondaga Lake has improved substantially with respect to the water quality standard for ammonia toxicity (Effler et al. 2010), enabling large populations of dreissenid mussels (Spada et al. 2002) and Alewives (Wang et al. 2010).

Upgraded aeration treatment at Metro in the late 1990s and addition of a Biological Aerated Filter (BAF) system in January 2004 substantially reduced ammonia loading to Onondaga Lake (Figure 4-1a). The BAF system provides year-round nitrification of ammonia, a potentially toxic form of nitrogen (N). These treatment upgrades resulted in a 98% decrease in ammonia loading to the lake from Metro since the mid-1990s and reduced Metro's contribution to the total annual load (Metro + tributaries) from 91% during 1990–2004 to 47% during 2007–2013 (Figure 4-1a). Ammonia loading from the tributaries also decreased significantly over the 1990–2013 interval (linear least-squares regression, R^2=0.68, p<0.01). The average rate of decrease over this 24-year interval was 2.8 metric tons per year (MT/yr). Ammonia concentrations in the upper waters of Onondaga Lake decreased markedly in response to these major loading reductions (Figure 4-1b). Since 2004 ammonia-N concentrations have averaged 0.06 mg/L, a 96% reduction from the levels of the 1990s.

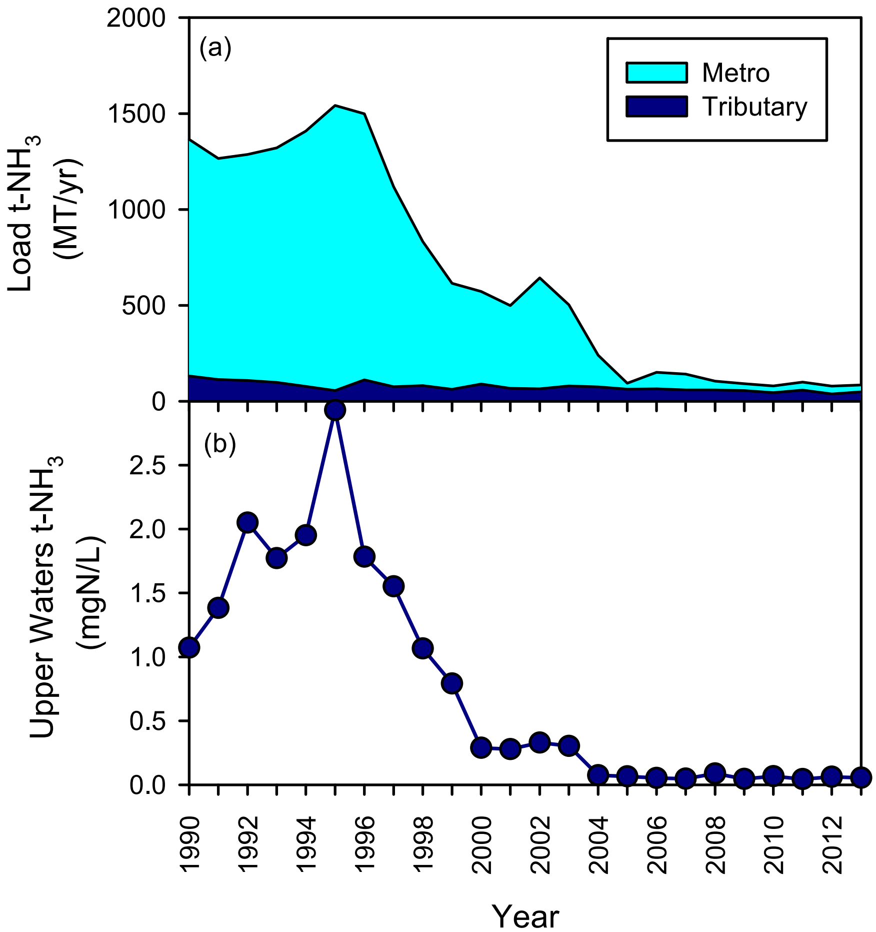


Figure 4–1. Decreases in ammonia-N (NH_3-N) loading to Onondaga Lake and lake response, 1990–2013: (a) annual loading from Metro and tributaries, and (b) summer average (June–September) concentrations in the upper waters (0-3 meters).

Nitrite (NO_2-N), another form of nitrogen that is potentially toxic to aquatic organisms, was produced at Metro as a result of incomplete nitrification (conversion of ammonia to nitrate). The loading of nitrite from Metro was greatly reduced with implementation of BAF treatment in 2004 (Figure 4-2a), which achieved more complete nitrification on a year-round basis. Nitrite loading to the lake from Metro has decreased 90% since the mid-1990s, reducing Metro's contribution to the total annual load from 79% during 1990–2004 to 25% during 2007–2013 (Figure 4-2a). The summed tributary nitrite load exhibited no consistent temporal pattern. Summer average nitrite-N levels in the upper waters of Onondaga Lake decreased from values greater than 0.13 mg/L through the mid-1990s to values consistently less than 0.05 mg/L since 2006 (Figure 4-2b).

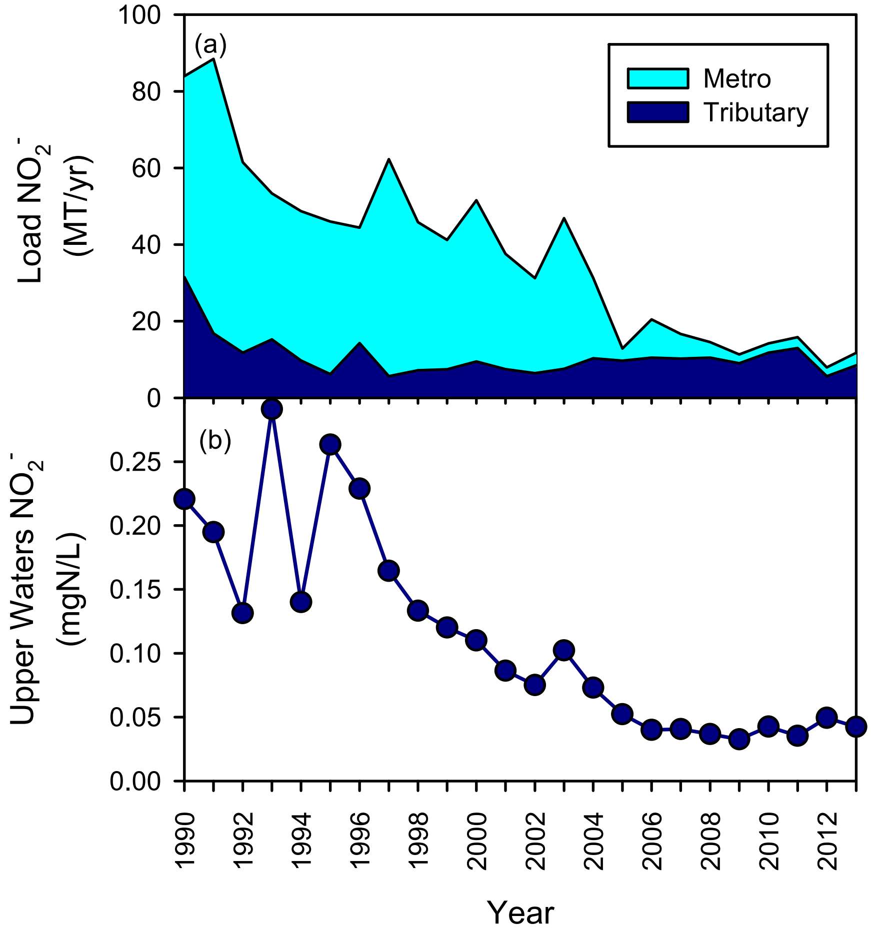


Figure 4–2. Decreases in nitrite-N (NO_2-N) loading to Onondaga Lake and lake response, 1990–2013: (a) annual loading from Metro and tributaries, and (b) summer average (June–September) concentrations in the upper waters (0-3 meters).

Loading of nitrate (NO_3-N) from Metro has increased by a factor of 3.7 as a result of the BAF treatment process (Figure 4-3a), mirroring the decreases for ammonia and nitrite (Figure 4-1a, 4-2a). Water column concentrations of nitrate-N have approximately doubled since implementation of efficient year-round nitrification in 2004 (Figure 4-3b). Nitrate can accelerate algal growth in systems where primary production is limited by the availability of nitrogen. However, this is not a concern in Onondaga Lake because algal growth is distinctly phosphorus limited. Higher nitrate levels have been beneficial to the lake by diminishing the transport of phosphorus and mercury from the bottom sediments to the water column (Matthews et al. 2013).

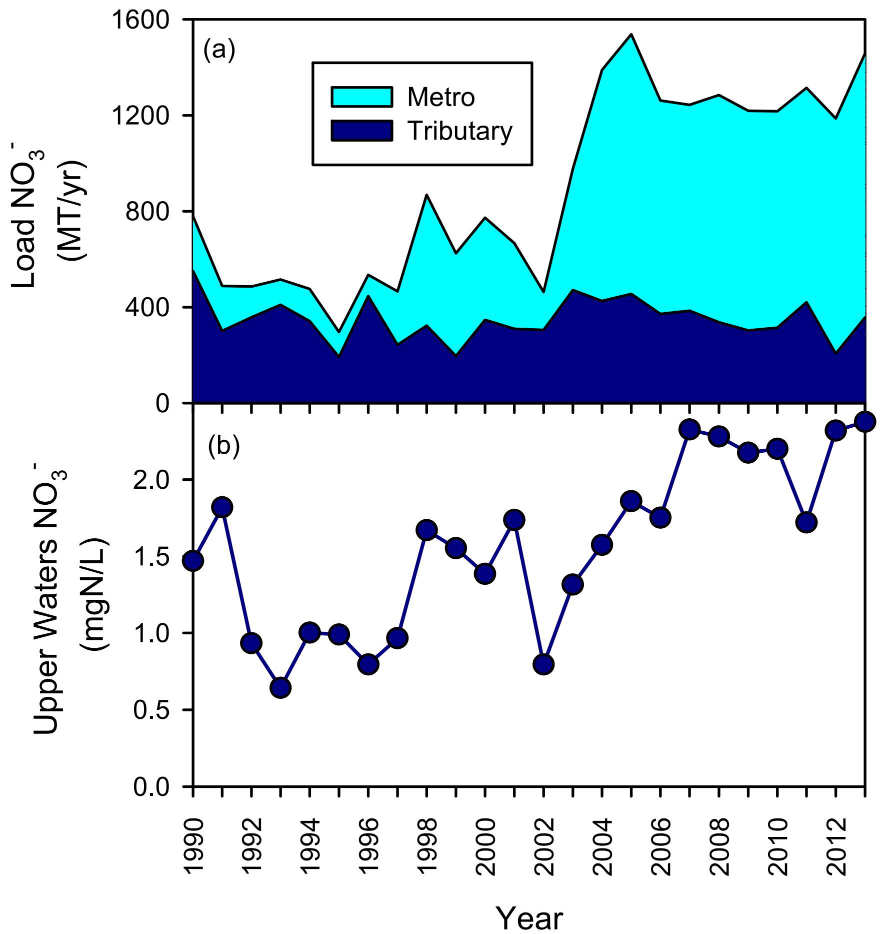


Figure 4–3. Increases in nitrate-N (NO_3-N) loading to Onondaga Lake and lake response, 1990–2013: (a) annual loading from Metro and tributaries, and (b) summer average (June–September) concentrations in the upper waters (0-3 meters).

4.2 Phosphorus

Phosphorus is an important water quality indicator because the availability this nutrient regulates algal growth in most lakes. Since the 1970s, phosphorus concentrations in the Metro effluent have decreased progressively as wastewater treatment has improved (Effler and O'Donnell 2010). The latest improvement was a physical-chemical High-Rate Flocculated Settling (HRFS) treatment technology, known as Actiflo® that came on line in February 2005. This treatment resulted in an 85% decrease in total phosphorus (TP) loading since the early 1990s (Figure 4-4a) and a 99% reduction since the early 1970s. Metro's contribution to Onondaga Lake's total annual phosphorus load decreased from 61% prior to implementation of Actiflo® (1990–2004) to 24% during 2007–2013. Loading of soluble reactive phosphorus, a form of phosphorus immediately available to support algal growth, was also reduced significantly as a result of Actiflo® treatment.

Substantial decreases in the summer average (June to September) concentration of total phosphorus in the upper waters of the lake have been achieved from the Actiflo® upgrade (Figure 4-4b). From 1990 to 2004 the total phosphorus concentration during summer ranged from 39 to 125 µg/L and averaged 67 µg/L. This level of total phosphorus is typically associated with eutrophic (i.e., highly productive) lakes and degraded water quality conditions. During the post- Actiflo® interval of 2007–2013 total phosphorus concentrations averaged 21 µg/L, slightly higher than the guidance value of 20 µg/L established by New York State for protection of recreational uses in lakes. Similar total phosphorus concentrations are observed in several nearby lakes with intermediate levels of phytoplankton production. Total phosphorus concentrations were below the 20 µg/L guidance value in 2008 and 2009, the two recent years when the absence of Alewife enabled efficient grazing of both organic and inorganic particles by *Daphnia* (Matthews et al. 2015).

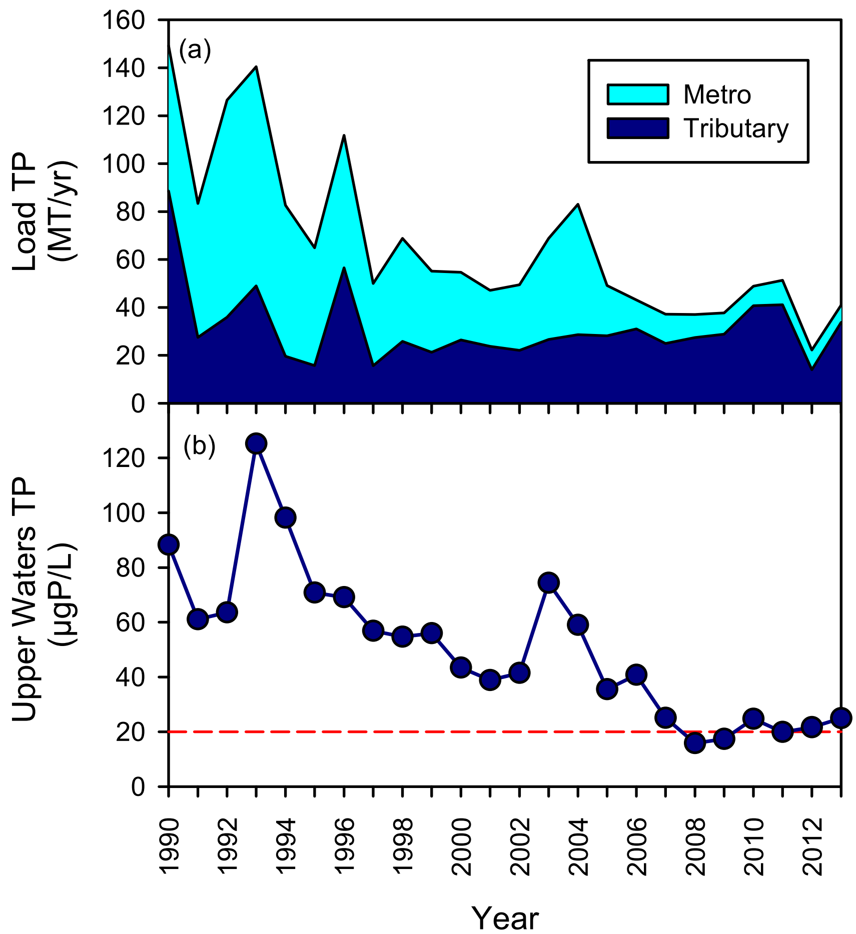


Figure 4–4. Decreases in total phosphorus (TP) loading to Onondaga Lake and lake response, 1990–2013: (a) annual loading from Metro and tributaries, and (b) summer average (June–September) concentrations in the upper waters (0-3 meters).

4.3 Algal Biomass

Reduced phosphorus loading to Onondaga Lake has caused major decreases in concentrations of chlorophyll-*a*, a photosynthetic pigment widely used as a measure of phytoplankton biomass. NYSDEC (2009) lists three levels of chlorophyll-*a* that serve as recreation use assessment criteria. Chlorophyll-*a* concentrations greater than 15 µg/L, 12 µg/L, and 8 µg/L correspond to impaired, stressed, and threatened conditions, respectively. Summer average chlorophyll-*a* concentrations, which commonly exceeded 15 µg/L during 1990–2004, have remained less than 12 µg/L since 2007 (Figure 4-5). Accordingly, recreational uses are fully supported with respect algal biomass. In addition, occurrences of algal blooms, subjectively defined as chlorophyll-*a* concentrations of 15 µg/L and 30 µg/L for minor (impaired conditions) and major blooms (nuisance conditions), respectively, have decreased dramatically since implementation of Actiflo® (Figure 4-6). According to laboratory measurements, no major blooms have occurred since the Actiflo® upgrade in 2005 and no minor blooms have occurred during summer since 2007. The composition of the phytoplankton community in the lake has also improved from one dominated by undesirable taxa such as blue-green algae (Cyanobacteria) to a more diverse assemblage of more desirable forms, including diatoms and green algae (Onondaga County 2015).

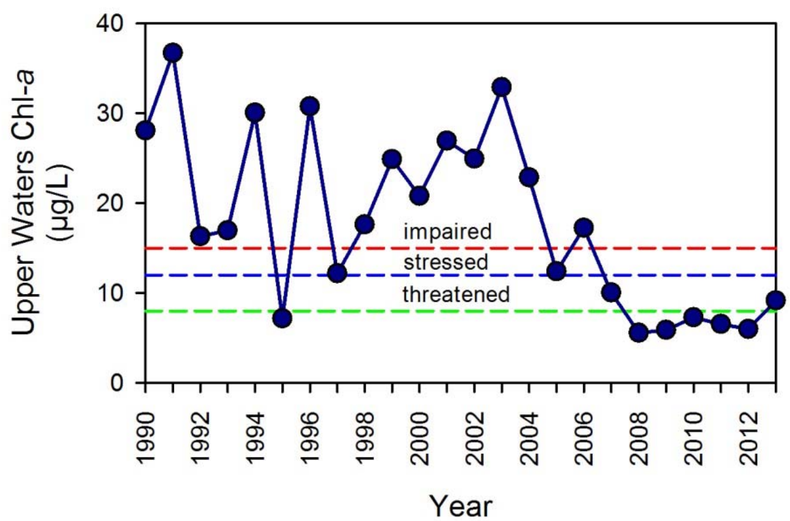


Figure 4–5. Summer average (June–September) chlorophyll-*a* concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2013.

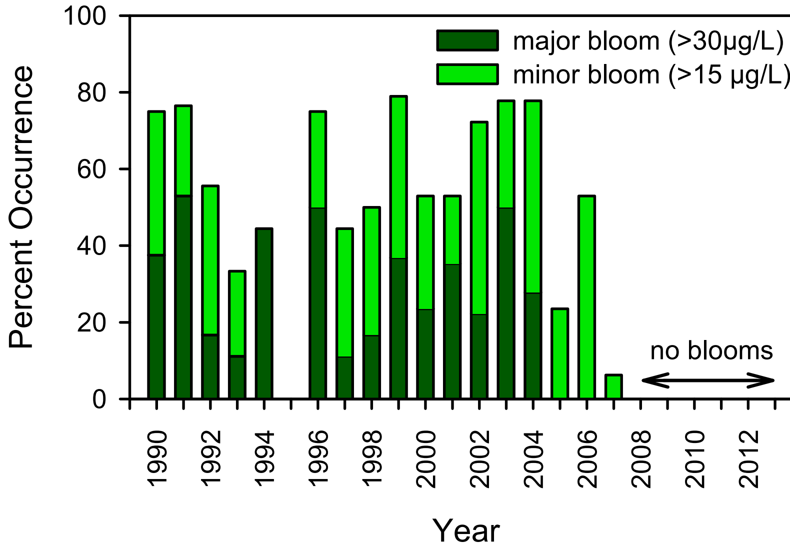


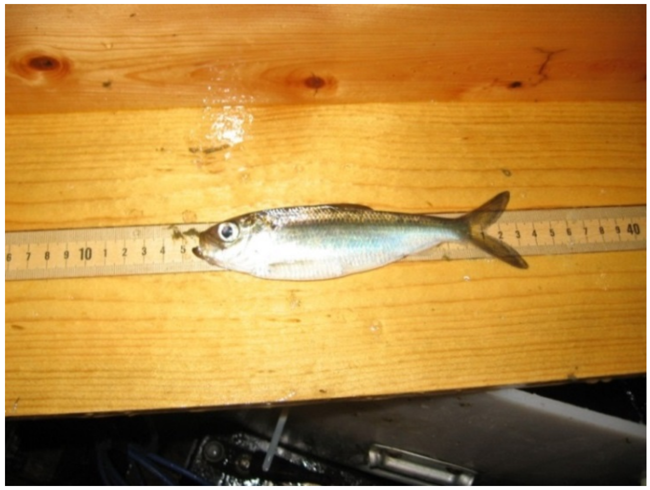
Figure 4–6. Percent occurrence of summer (June–September) algal blooms in Onondaga Lake evaluated annually for the 1990–2013 period, based on chlorophyll-*a* measurements.

4.4 Water Clarity

Water clarity has also improved in Onondaga Lake as a result of decreases in phosphorus loading and algal biomass, though food web effects have contributed to noteworthy interannual variations in this water quality metric. Visual clarity, as measured with a Secchi disk, is a commonly measured optical attribute in lakes that is closely coupled to the public's perception of water quality (Effler 1985, Smith and Davies-Colley 1992). The Secchi disk measurement is regulated importantly by both organic (i.e., phytoplankton) and inorganic particles.

Secchi disk values ranged widely over the 1990–2013 interval, from 0.5 to 7.5 meters (Figure 4-7). The higher Secchi disk observations during some years were associated with non-selective filter feeding by *Daphnia*, a large cladoceran zooplankton. Dense populations of *Daphnia* developed annually for 1 to 4 week intervals over the 1990–2002 period and caused abrupt decreases in chlorophyll-*a* and increases in Secchi disk (Effler et al. 2008). Such events are described as the "clear water phase" (Lampert et al. 1986). The increases in Secchi disk were particularly dramatic because concentrations of both phytoplankton and non-phytoplankton particles were reduced greatly by *Daphnia* during these events. Dense populations of *Daphnia* and the clear water phase were eliminated during 2003–

2007 and 2010–2013 by large populations of Alewife (Wang et al. 2010), a planktivorous fish that feeds on *Daphnia*. The potential for large Alewife populations has been linked to reductions in ammonia concentrations (Wang et al. 2010).



Alewife

Invasive dreissenid (quagga and zebra) mussels, which filter up to two liters per day as adults, also have the potential to increase water clarity. The effects of dreissenid mussels on water clarity in Onondaga Lake are likely to be most significant in the near-shore zone where they are abundant. Interestingly, the invasion of Onondaga Lake by dreissenid mussels was also likely enabled by the decreases in ammonia levels (Matthews et al. 2000, Spada et al. 2002). The macrophyte (rooted aquatic plants) community is a critical component of lake ecosystems. Macrophytes provide food for waterfowl and wildlife, serve as spawning habitats for fish, act as refuges for zooplankton and small fish, and oxygenate water. Increased light penetration has expanded macrophyte coverage in the lake by a factor of five since 2000. Presently, aquatic plants are present in approximately 400 acres of the lake's near-shore zone.

NYSDEC uses three values of Secchi disk transparency to differentiate between impaired (1.2 meters), stressed (1.5 meters), and threatened (2.0 meters) conditions. Impaired conditions correspond to the New York State Department of Health (NYSDOH) swimming safety guidance value of 4 feet or 1.2 meters. Occurrences of Secchi disk values less than 1.2 meters have been substantially reduced since the phosphorus treatment upgrade at Metro in 2005 (Figure 4-7b). This improvement in water clarity was caused by reduced algal growth (Figure 4-5) and the elimination of algal blooms (Figure 4-6). The continued, infrequent occurrences of Secchi disk values less than 1.2 meters are associated with large inputs of inorganic particles (e.g., clays) during major runoff events. The Tully Valley mudboils, located along Onondaga Creek, are an important source of this turbidity (Prestigiacomo et al. 2007, Kappel 2014).

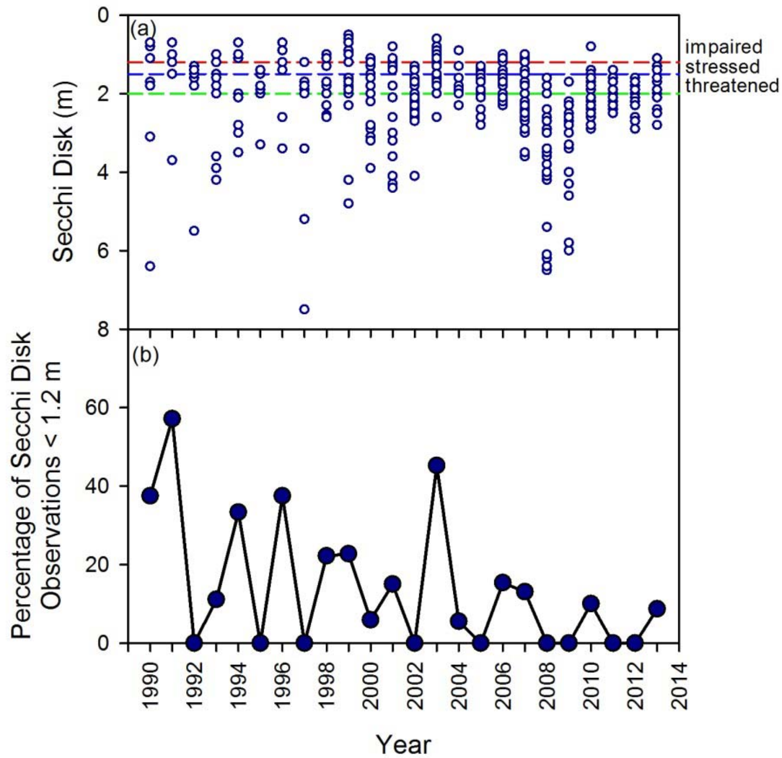


Figure 4–7. Summer (June-September) Secchi disk transparency in Onondaga Lake (South Deep), 1990–2013: (a) summer observations plotted for each year (limits for impaired, stressed, and threatened included for reference), and (b) the percentage of observations less than 1.2 meters (impaired).

4.5 Dissolved Oxygen

Adequate dissolved oxygen content is critical for sustaining aquatic life. Accordingly, NYSDEC has established water quality standards for dissolved oxygen that are protective of aquatic organisms. The applicable standard for non-trout waters, such as Onondaga Lake, is a minimum daily average of 5 mg/L and never less than 4 mg/L. Contraventions of this standard were common in the upper waters during the approach to fall turnover through the early 2000s (Figure 4-8; Matthews and Effler 2006). Low dissolved oxygen conditions during fall were associated with the entrainment of hypolimnetic waters enriched with oxygen-demanding byproducts of anaerobic metabolism (Effler and Matthews 2008). The severe depletions observed during certain years have been attributed to nitrification of ammonia (Gelda et al. 2000). Elimination of severe depletion of dissolved oxygen in the upper waters was identified as a high priority goal for rehabilitation of Onondaga Lake. This goal has been achieved through reductions in Metro loading of both ammonia (Figure 4-1) and total phosphorus (Figure 4-4).

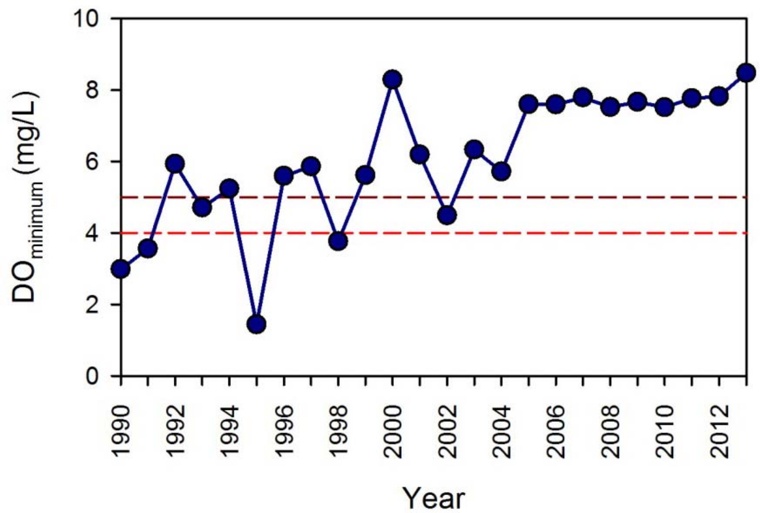


Figure 4–8. Minimum dissolved oxygen (DO_{min}) concentrations in the upper waters (0-4 meters average) of Onondaga Lake during October, annually 1990–2013. Horizontal lines represent water quality standards applicable to daily average (5 mg/L) and instantaneous (4 mg/L) measurements.

Additional improvements in dissolved oxygen status have been observed, particularly within the deeper layers (hypolimnion) of the lake. Following the onset of summer stratification in May, these layers are subject to oxygen depletion from decay of depositing algae and demand from the underlying sediments. Decreased deposition of phytoplankton from reductions in Metro phosphorus loading have resulted in lower rates of dissolved oxygen depletion and a delay in the onset of anoxic conditions from late May to mid-July (Matthews and Effler 2006). Despite these improvements, dissolved oxygen concentrations below the 4 mg/L standard continue to occur in the lower waters during the summer stratified period (Figure 4-9). Oxygen depletion is not uncommon in stratified lakes where the volume of the lower stratum (the hypolimnion) is relatively small. In New York State, an estimated 70% of assessed lakes do not meet the minimum dissolved oxygen standard in the deep waters (NYSDEC 2009).

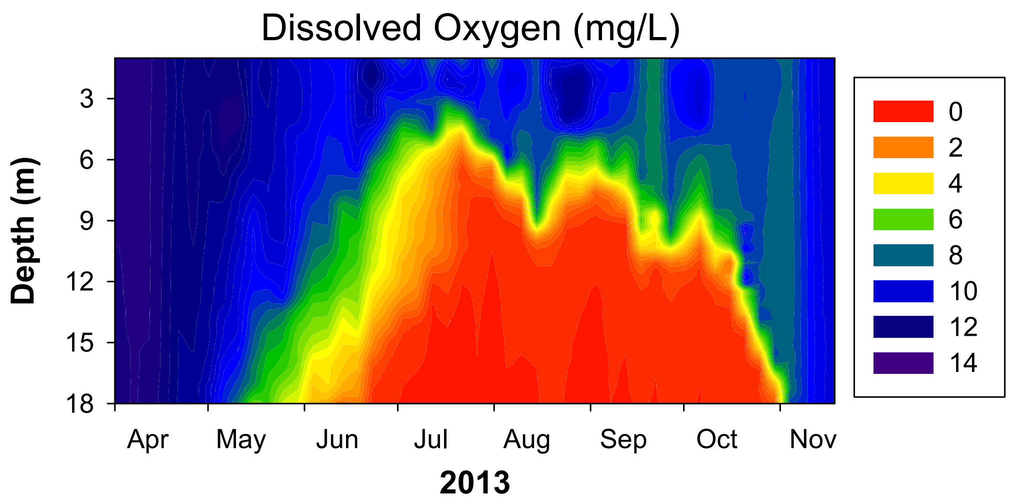


Figure 4–9. Color contour plot of dissolved oxygen concentrations in Onondaga Lake (South Deep) during 2013, based on daily vertical profiles of 1-meter depth resolution.

4.6 Fecal Coliform Bacteria

Onondaga County has completed a variety of "gray" and "green" infrastructure projects to reduce wet weather discharges from combined sewer overflows (CSOs) and associated bacteria loading. Completed gray infrastructure projects have separated storm and sanitary sewers, captured floatable materials, and maximized system storage capacity. In 1998, there were 72 active CSOs discharging to three tributaries to Onondaga Lake: Onondaga Creek, Harbor Brook, and Ley Creek. Through 2014, forty-five (45) CSOs have been closed or captured for storage by separating combined sewers where feasible, maximizing the capacity of the sewerage system, building the Hiawatha and Midland regional treatment facilities, and constructing the Clinton and Lower Harbor Brook Storage Facilities.

Green infrastructure projects increase infiltration, capture, and reuse of storm runoff before it enters the sewer system. Green infrastructure solutions are being implemented to help manage urban storm runoff before it enters the CSO system. More than 175 green infrastructure projects have been completed to date as part of Onondaga County's "Save the Rain" initiative, reducing inputs of storm water runoff and pollution to Onondaga Lake and its tributaries. These projects include replacement of traditional pavement with porous pavement, construction of vegetated roofs, installation of rain barrels and infiltration trenches, removal of pavement from some areas, and other techniques to reduce storm water runoff. By preventing storm water runoff from entering the combined sewers, more capacity is available for sanitary sewage flow to reach Metro for treatment. The completed green infrastructure projects are reducing storm water runoff by over 108 million gallons per year and providing CSO reduction of approximately 51 million gallons per year. An informational website (http://savetherain.us/) describes current initiatives and incentive programs for watershed residents to reduce impervious areas.

Green infrastructure facility at Amy Street, Delaware Avenue, and Grand Avenue

Substantial reductions in fecal coliform loading to Onondaga Lake have been achieved since the 1990s (Figure 4-10). Decreasing inputs from the Metro Bypass have been the primary driver of these loading reductions. In 2013 the largest sources of fecal coliform bacteria to the lake were Onondaga Creek (37%), Metro Bypass (21%), Ninemile Creek (19%), and Ley Creek (16%; Figure 4-11). However, bacteria loading to Onondaga Lake and the relative contributions of the sources can vary widely from year-to-year as a result of interannual variations in precipitation and runoff.

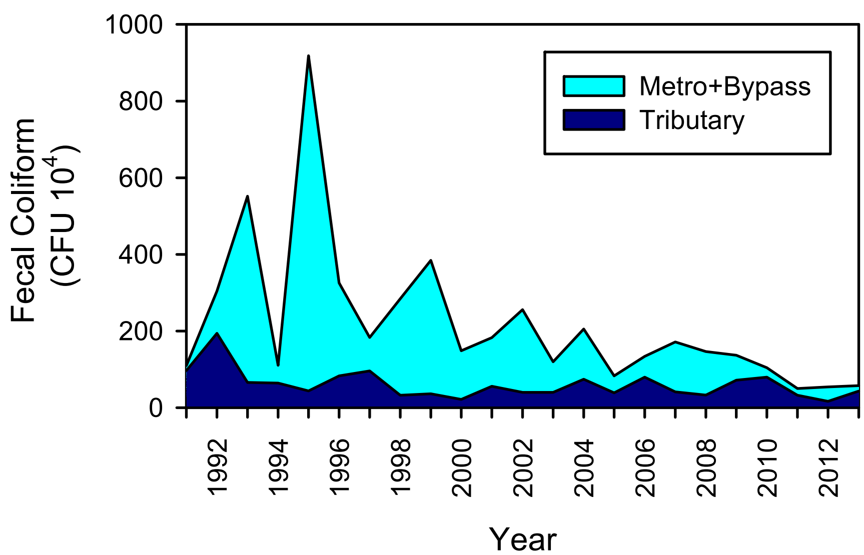


Figure 4–10. Decreases in annual loading of fecal coliform bacteria to Onondaga Lake from Metro+Bypass and tributaries, 1991–2013.

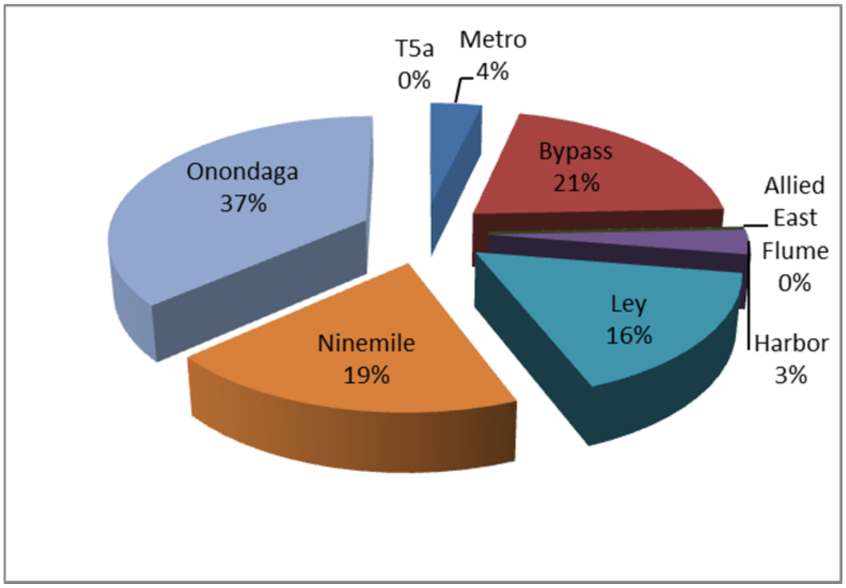


Figure 4–11. Percent contributions to fecal coliform bacteria loading to Onondaga Lake in 2013.

Sunset on Onondaga Lake

4.7 Comparisons to Regional Lakes

Major decreases in total phosphorus and chlorophyll-*a* have been achieved in Onondaga Lake through implementation of advanced wastewater treatment at Metro. A comparison of total phosphorus and chlorophyll-*a* concentrations in Onondaga Lake to conditions in other regional lakes provides context for the magnitude of the water quality improvements that have been achieved. During the 1998–2005 interval total phosphorus and chlorophyll-*a* concentrations in Onondaga Lake far exceeded those measured in some of the eastern Finger Lakes and Oneida Lake (Figure 4-12). Since 2007, levels of these important water quality indicators have been similar to those measured in Otisco Lake and Oneida Lake. Moreover, the absence of algal blooms in Onondaga Lake stands in contrast to the widespread occurrence of blue-green harmful algal blooms in lakes across New York State (see http://www.dec.ny.gov/chemical/77118.html for more information).

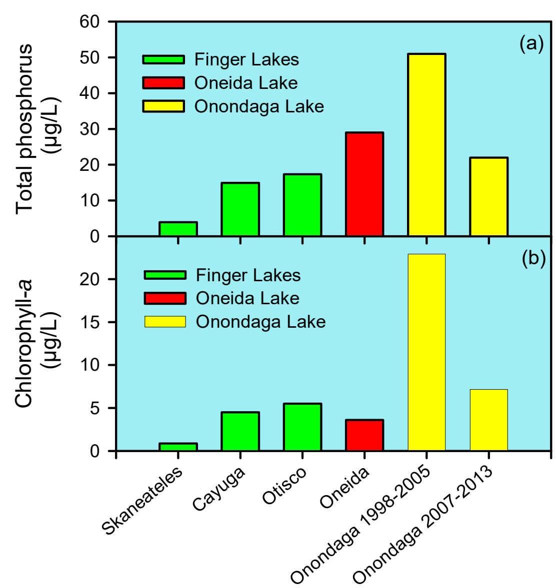


Figure 4–12. A comparison of trophic state metrics in Onondaga Lake and selected regional lakes: (a) summer average (June to September) total phosphorus concentrations and (b) summer average (June to September) chlorophyll-a concentrations.

Note: Skaneateles Lake data from 2011, courtesy of the Town of Skaneateles. Cayuga Lake data from 2013, courtesy of Cornell University. Otisco Lake data from 2010-2011, courtesy of NYSDEC. Oneida Lake data from 2013, courtesy of Dr. Lars Rudstam.

5 DESIGNATED USES OF ONONDAGA LAKE AND CURRENT LEVEL OF ATTAINMENT

5.1 Public Bathing and Recreation Uses

Although swimming and other recreational uses are evaluated using similar indicators of water quality, these uses are evaluated separately (NYSDEC 2009). The public bathing use is evaluated only in those waters classified for primary contact recreation by New York State (i.e., Class B, SB, A, AA, A/AA-Special, SA). Although primary contact recreation is specified as a designated use in Class C, D, and SC waters, these waters are generally not suitable as bathing areas because of their natural physical characteristics. The southern third of Onondaga Lake and the area near the mouth of Ninemile Creek are designated as Class C waters and the remainder of the lake is Class B (Figure 5-1). Three forms of monitoring data are used to assess the suitability of a waterbody for public bathing: bacteria levels, water clarity (Secchi disk), and total phosphorus concentrations. Recreational use assessment is based on measurements of total phosphorus, chlorophyll-*a*, and clarity (Secchi disk).

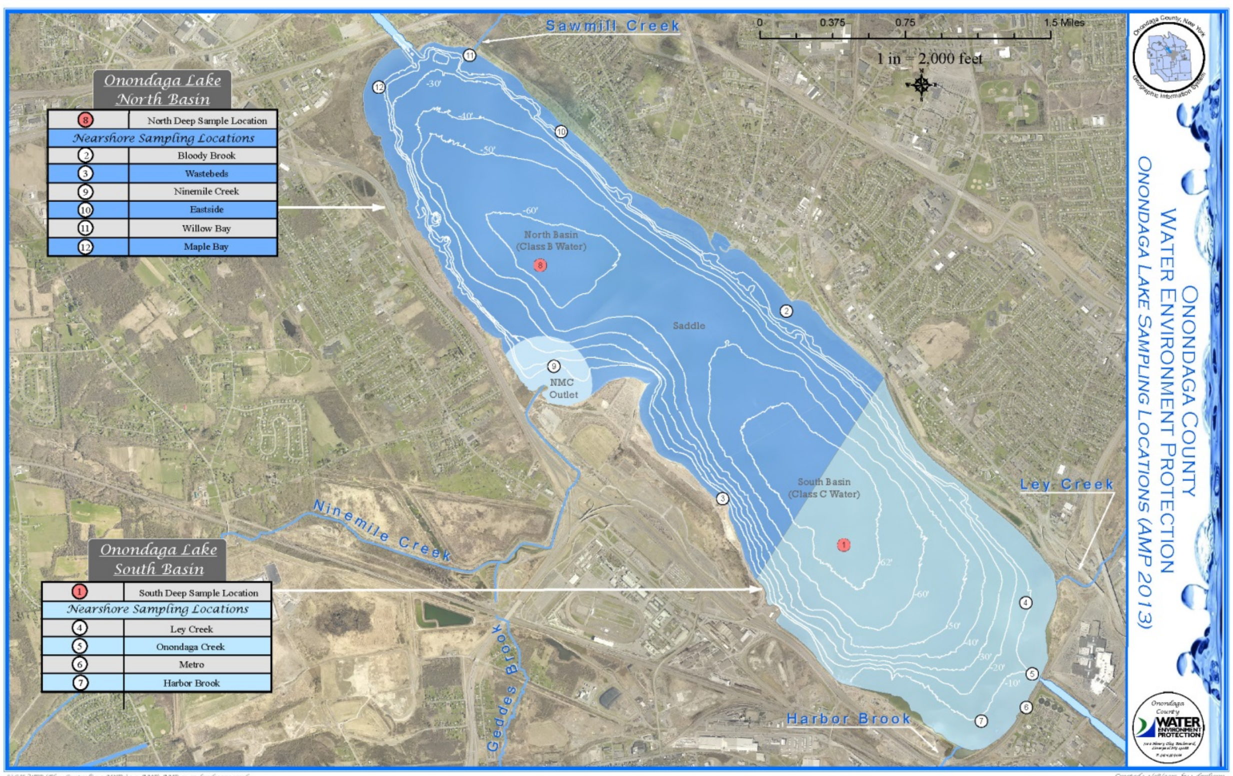


Figure 5–1. Map of AMP monitoring locations, with Class B waters shaded dark blue and Class C water shaded light blue.

5.1.1 *Indicator bacteria*

Public health concerns, including potential exposure to pathogenic bacteria, are the primary focus of evaluations regarding the level of public bathing use support. Inputs of bacteria to Onondaga Lake's tributaries occur in both urban and agricultural portions of the watershed. There are myriad sources of bacteria in the watershed, including CSOs, agricultural runoff, pets, wildlife, and faults in the sewerage system. Shoreline areas of the lake, adjacent to stream inflows, are most susceptible to elevated bacteria levels, particularly during major runoff events. In New York State, fecal coliform bacteria (a class of bacteria present in the intestinal tract of all mammals) are used to indicate the potential presence of raw or partially treated sewage in water. Although most strains of fecal coliform bacteria are not harmful, the abundance of fecal coliform bacteria in water is correlated with the risk of encountering pathogenic (disease-causing) microorganisms, including bacteria, viruses, and parasites.

The applicable New York State ambient water quality standard for fecal coliform bacteria in surface water, as set forth in 6NYCRR Part 703.4, is as follows: for classes A, B, C, D, SB, SC - the monthly geometric mean concentration of fecal coliform bacteria (colony forming units, cfu, per 100 mL), from a minimum of five examinations, shall not exceed 200 cfu per 100 mL. The fecal coliform standard for classes B, C, D, and SB shall be met during all periods: (1) when disinfection is required for SPDES permitted discharges directly into, or affecting the best usage of the water; or (2) when NYSDEC determines it necessary to protect human health. The NYS Department of Health (NYSDOH) criterion for fecal coliform in bathing beaches are ≤ 1,000 per 100 mL for a single sample and ≤ 200 per 100 mL for a 30 day geometric mean.

The fecal coliform standard was applied on a monthly basis from April to October to assess compliance at 10 locations in nearshore regions of Onondaga Lake during 2008–2013 (Figure 5-2). The five sampling sites located in the Class B portion of the lake and the site located in Class C waters proximate to the mouth of Ninemile Creek were in compliance with the fecal coliform standard throughout the 2008–2013 interval. Fecal coliform levels in southern portions of the lake often increase following significant rainfall, and concentrations can vary widely due to the event-driven nature of the sources. Contraventions of the fecal coliform standard were documented in Class C waters located in the extreme southern end of the lake during each of the six assessed years. Exceedances were most common at the two sites located near the mouth of Onondaga Creek and the Metro discharge. The Class C sites were in compliance with the standard during at least 50% of the assessed months, with one exception in 2010. Lower fecal coliform concentrations in the southern end of the lake are a reasonable expectation as additional gray an green infrastructure projects are implemented as part of the Save the Rain initiative.

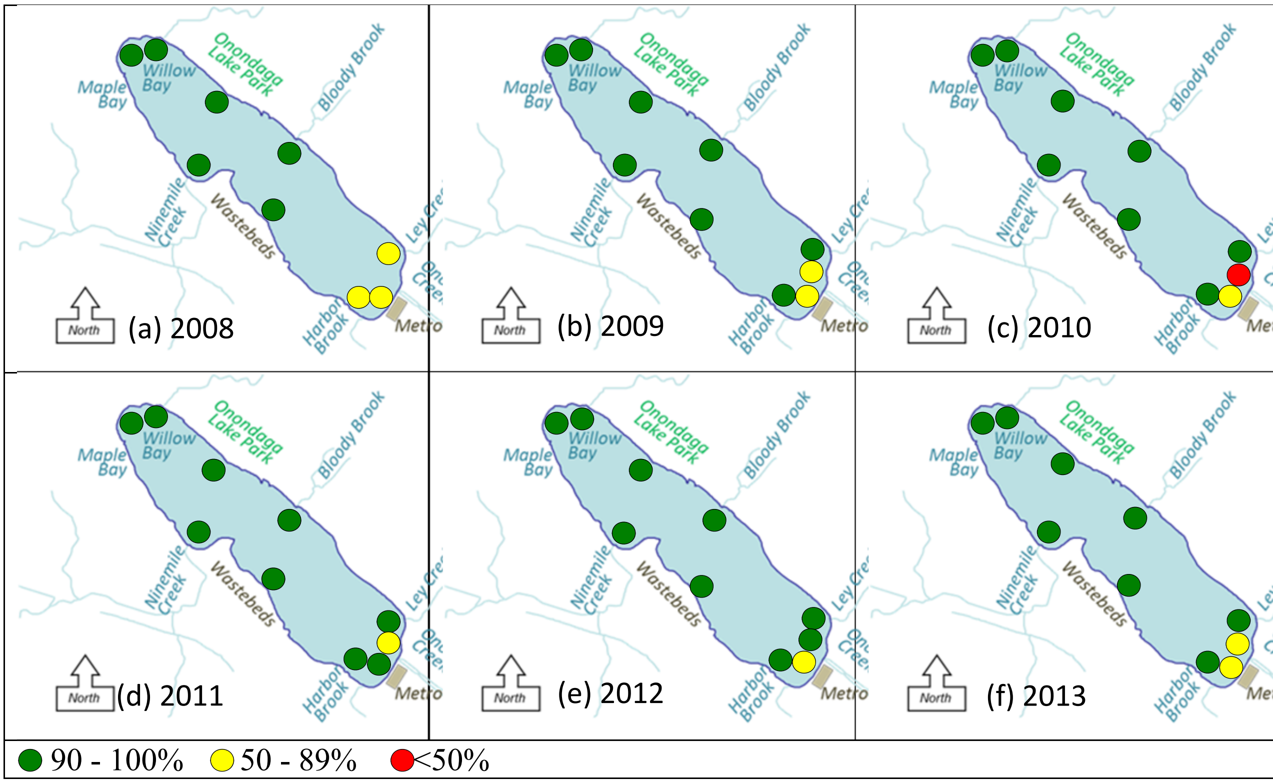


Figure 5–2. The percentage of months in compliance with the water quality standard for fecal coliform bacteria for nearshore stations in Onondaga Lake, April–October 2013.

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

5.1.2 Water clarity

Poor water clarity is a safety concern with respect to swimming and turbid water can discourage other recreational uses. Moreover, clarity is closely coupled to public perceptions of overall water quality. The narrative water quality standard for turbidity in New York State is “No increase that will cause a substantial visible contrast to natural conditions.” Public bathing and recreational uses are considered to be impaired at Secchi disk values less than 1.2 meters (4 feet). Exceedances of this value were evaluated based on summer (June–September) measurements made at 10 locations in nearshore regions of Onondaga Lake during 2008–2013 (Figure 5-3). Since 2009, clarity has exceeded the 1.2 meter standard more than 90% of the time at all sites located in Class B waters. Diminished water clarity is a persistent issue in the Class C segment located at the south end of the lake and proximate to turbid inputs from Onondaga Creek, Ley Creek, and Harbor Brook. Clarity has been particularly poor near the mouth of Onondaga Creek due to loading of clay particles from the Tully Valley mudboils (Prestigiacomo et al. 2007).

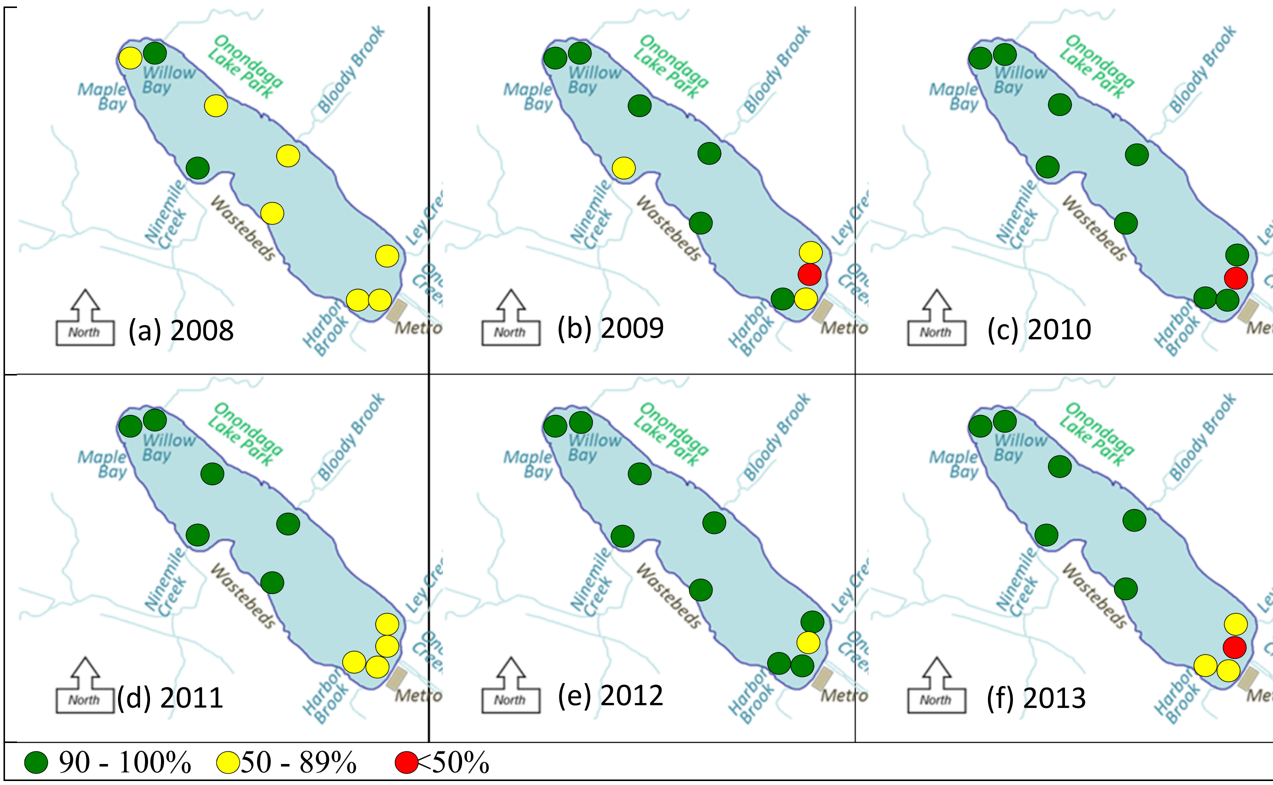


Figure 5–3. Percentage of nearshore Secchi disk transparency measurements greater than 1.2 meters (4 feet) during June–September 2013.

5.1.3 Phosphorus

Phosphorus can have deleterious impacts on public bathing and recreational uses by causing increases in algal growth. This concern is reflected in the narrative water quality standard for phosphorus in New York State: "None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages." 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 upper waters of the lake between June 1 and September 30. Since 2007, summer average total phosphorus concentrations at South Deep have ranged from 16 to 25 µg/L (Table 5-1). The guidance value for total phosphorus was met in 2008, 2009, and 2011. With the decrease in the Metro load (Figure 4-4), contemporary year-to-year variations in total phosphorus are driven importantly by loading from the tributaries and the effects of *Daphnia* grazing (Matthews et al. 2015). In addition, current phosphorus levels are not causing major algal blooms that would impact public bathing or other recreational uses (Figure 4-6).

Table 5–1. Percentage of measurements in compliance with ambient water quality standards (AWQS) and guidance values in the upper waters of Onondaga Lake at South Deep, 2007-2013.

Parameter	South Deep - Upper Waters						
	2007	2008	2009	2010	2011	2012	2013
Dissolved Oxygen (>4 mg/L)	100%	100%	100%	100%	100%	100%	100%
Dissolved Oxygen (>5 mg/L)[1]	100%	100%	100%	*99.9%*	100%	100%	100%
pH	100%	100%	100%	100%	100%	100%	100%
Total Phosphorus[2]	*0% (25 µg/L)*	100% (16 µg/L)	100% (17 µg/L)	*0% (25 µg/L)*	100% (20 µg/L)	*0% (22 µg/L)*	*0% (25 µg/L)*
Ammonia	100%	100%	100%	100%	100%	100%	100%
Nitrite	100%	100%	100%	100%	100%	100%	100%
Total Dissolved Solids	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Dissolved Mercury	--	--	--	--	--	100%	*67%*
Fecal Coliform Bacteria[3]	100%	100%	100%	100%	100%	100%	100%

Notes:

Dashed lines indicate that compliance was not evaluated; parameters listed in bold are cited in the ACJ; occurrences of less than 100% compliance are highlighted in italic red text.

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

[2] Total phosphorus compliance based on the average for the June 1–September 30 period.

[3] The AWQS for fecal coliform bacteria is specified as the monthly geometric mean 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).

5.1.4 *Chlorophyll-a*

High levels of algal biomass in lakes can cause turbid conditions that are unsafe for swimming and may deter other recreational uses. A chlorophyll-*a* concentration of 15 µg/L has been established as the threshold for impairment of recreational uses in New York State. This value has not been exceeded in Onondaga Lake on a summer average basis since 2006 (Figure 4-5) or on weekly basis since 2007 (Figure 4-6). Blooms of blue-green algae (cyanobacteria) can reduce the recreational value of lakes by causing unpleasant appearances and odors. Contact with harmful (toxic) blue-green algae blooms can cause health effects in humans and animals. Blue-green algae, which used to dominate the summertime phytoplankton community of Onondaga Lake, are no longer an important component of the ecosystem (Onondaga County 2015).

5.2 Aquatic Life Use Support

5.2.1 *Biological data*

Different types of monitoring data may be used to determine if the aquatic life use is supported, including biological, physical/chemical, and toxicity monitoring data. The ***NYSDEC Statewide Waters Monitoring Program*** relies on biological sampling to provide an integrated assessment of aquatic life support. The assemblage most frequently used is macroinvertebrates; however, periphyton and fish community assessments have been incorporated to a lesser degree. Aquatic Life use support is generally determined according to an assessment of macroinvertebrate community data, when such information is available and considered definitive. In cases where the assessment of the macroinvertebrate community is inconclusive, determination of aquatic life use support may be informed by comparison of monitoring data with applicable water quality standards and criteria for the protection of aquatic life.

5.2.1.1 Macroinvertebrate community

Onondaga County conducted surveys of the macroinvertebrate community in the littoral zone of Onondaga Lake in 2000, 2005, and 2010. The next survey is scheduled for 2017. According to biological assessment profiles conducted at five sites, the macroinvertebrate community of the littoral zone showed considerable improvement over the 2000-2010 interval (EcoLogic 2011). Improvements were most pronounced at Site 3 – Metro and Site 4 – Ley Creek, which were in the poorest condition in 2000 (Figure 5-4). Although the macroinvertebrate community at Site 3 continued to be categorized as severely impacted in 2010, conditions at this site have improved steadily since 2000 and are approaching a moderately impacted state. Three (Sites 2, 4, and 5) of the five sites were categorized as slightly impacted in 2010. These changes have been attributed to improved water quality, decreased organic loading, improved dissolved oxygen conditions in littoral sediments, and increased macrophyte abundance and coverage.

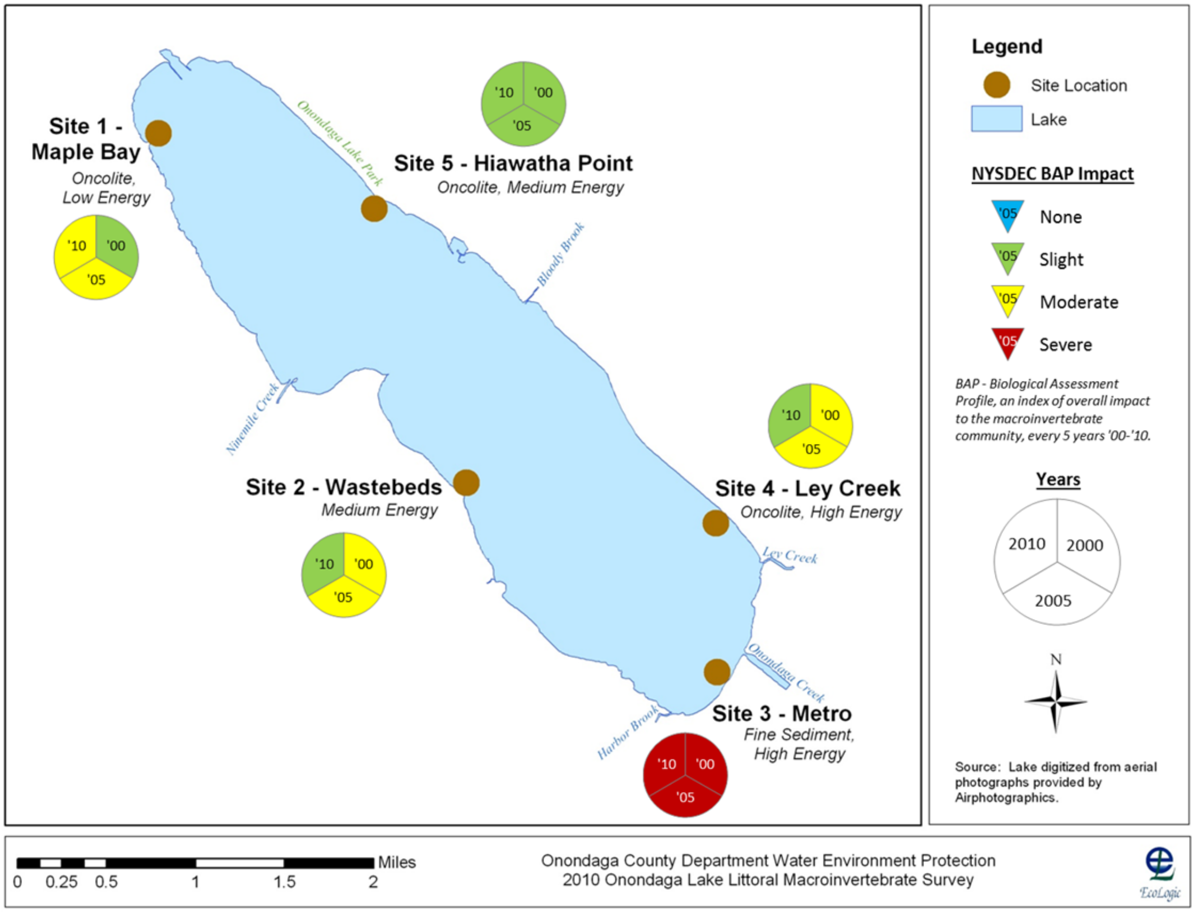


Figure 5–4. Summary of aquatic life use support assessments for 2000, 2005, and 2010, based on macroinvertebrate surveys conducted at five littoral zone sites in Onondaga Lake.

Although noteworthy improvements in the macroinvertebrate community of Onondaga Lake have occurred over time, Site 3 in the south end of the lake remains severely impaired. Because the sediment habitat was particularly poor in this area of the lake, it will likely take longer to recover from decades of impacts from municipal and industrial inputs. Diversity and richness of the macroinvertebrate community at this location may never equal that seen in other areas of the lake due to the poorer habitat quality of the predominantly fine sediments at the south end of the lake. Inputs of clay particles from the

Tully Valley mudboils undoubtedly contribute to the poor habitat conditions of the littoral sediments in this area of the lake.

5.2.1.2 Fish community

Fish communities are good indicators of aquatic ecosystem conditions because they integrate physical, chemical, and biological factors and express them in terms of species composition, age and growth characteristics, and reproductive success. Since 2000, the Onondaga County AMP has conducted an extensive fisheries monitoring program to track various life stages of the fish community. Improved water quality and habitat conditions in Onondaga Lake have been reflected in a changing fish community. The major reductions in ammonia and phosphorus loading from Metro have resulted in expanded habitat for fish in both the littoral and pelagic zones. Since 2000 more than 166,000 individual fish have been captured or observed from Onondaga Lake by Onondaga County's sampling program, representing 53 species (Table 5-2).

Table 5–2. Fish species identified in Onondaga Lake, 2000–2013.

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

Annual nesting surveys have been conducted in the littoral zone of the lake to estimate the number and spatial distribution of the nests of Largemouth Bass, Smallmouth Bass, Pumpkinseed, Bluegill, Rock Bass, and Brown Bullhead. The number of nests observed in the south basin of Onondaga Lake has increased since 2008, resulting in a more even distribution of nests between the north and south basins (Figure 5-5). The increased nesting activity observed in the southern basin of the lake may be influenced by increased macrophyte coverage, which shelters nesting areas. Pumpkinseed nests have been most common, accounting for 38% of the 3,492 nests observed in 2013. Larval, young-of-year, and juvenile fish are common in Onondaga Lake, with particularly large numbers of Pumpkinseed, Bluegill, and Largemouth Bass observed.

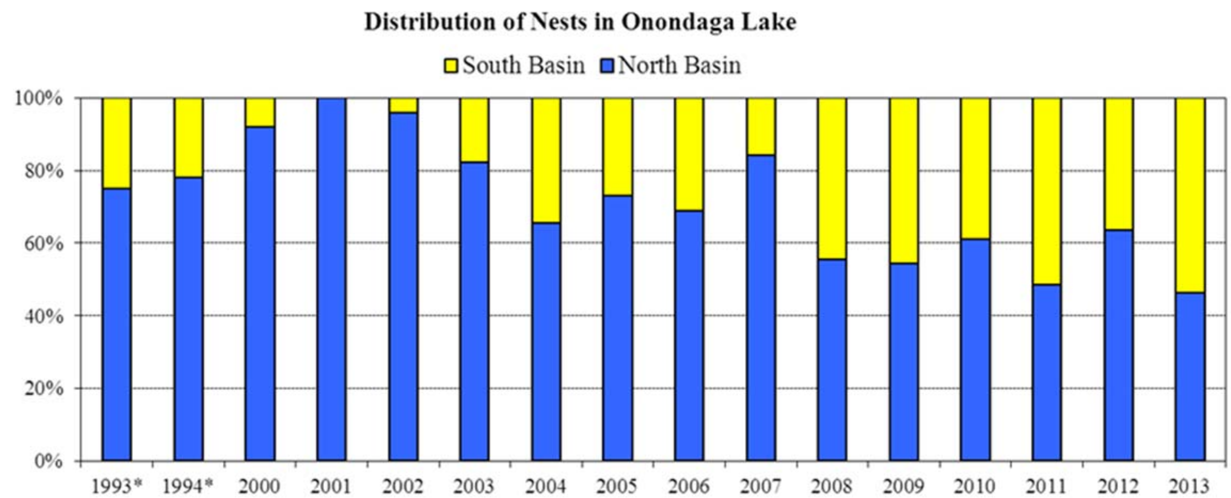


Figure 5–5. Distribution of fish nests between the south and north basins of Onondaga Lake, 1993–2013.

Centrarchid Nests

The relative abundance of adult fish in Onondaga Lake has shifted substantially with improvements in water quality. Populations of Largemouth Bass, Pumpkinseed, Bluegill, Yellow Perch, Walleye, and Brown Bullhead have increased in recent years. In contrast, populations of Smallmouth Bass, Channel Catfish, and White Perch have decreased. The divergent population trends for Largemouth and Smallmouth Bass are particularly striking

(Figure 5-6) and likely reflect the expansion of macrophytes in the littoral zone, which has created habitat more suitable for Largemouth Bass.

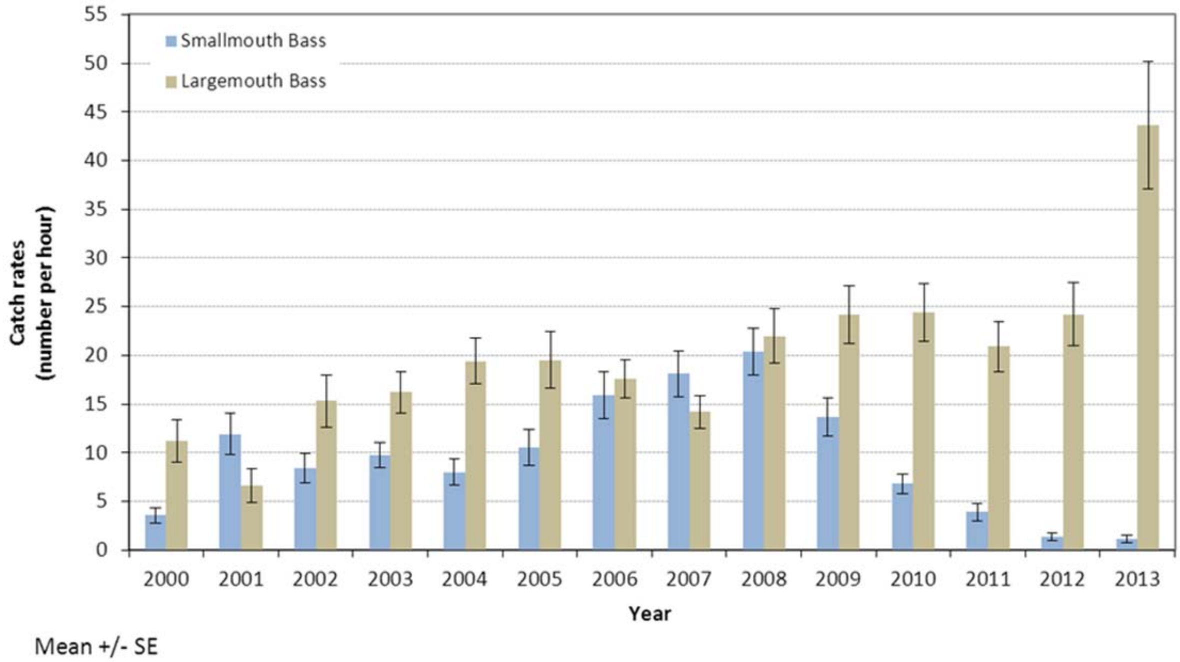


Figure 5–6. Trend in annual average catch rates (number per hour) of Largemouth and Smallmouth Bass combined in Onondaga Lake from 2000 to 2013.

The occurrence of physical abnormalities in adult fish from Onondaga Lake has been monitored by Onondaga County using a standardized protocol of identifying Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies (DELTFM). Fish abnormalities can result from chemical contamination; biological agents such as bacteria, viruses, or fungi; or interactions among multiple stressors. Overall, DELTFM abnormalities increased from 2003 to 2009 and decreased from 2009 to 2013 (Figure 5-7). A definitive cause for the increase is not known, but it may have been related to several pathogens that affected Brown Bullhead in 2008. The incidence of lesions and tumors in Brown Bullhead in Onondaga Lake in 2013 was 10% and is again approaching the range associated with regional reference sites. Additional information on the fish community of Onondaga Lake can be found in the 2013 AMP Report (Onondaga County 2015).

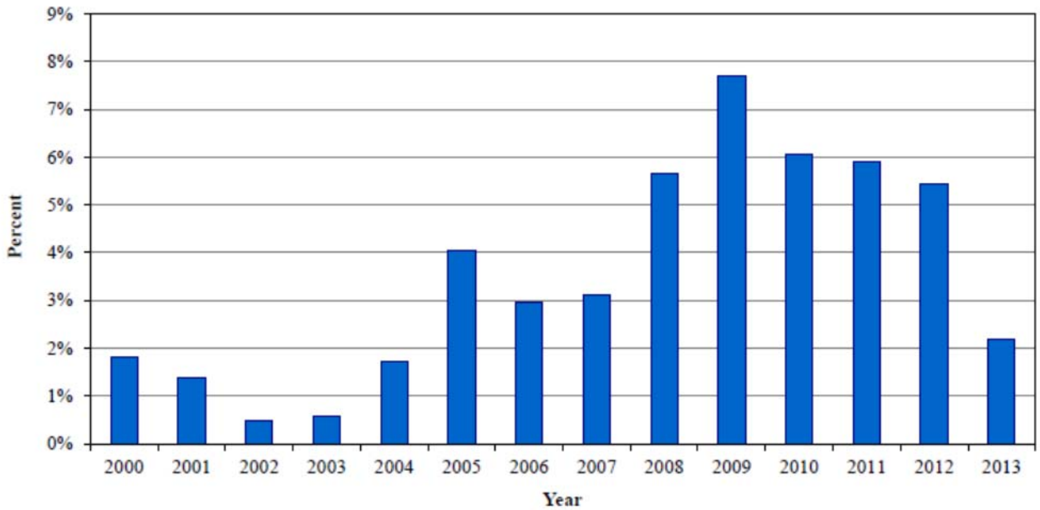


Figure 5–7. Percent of adult fish captured during AMP sampling with DELTFM abnormalities.

5.2.2 Physical/Chemical data

The vertical distributions of dissolved oxygen and water temperature in stratifying lakes largely determine the amount of habitat available for different fish species. Adequate dissolved oxygen levels are necessary for most forms of aquatic life, and coldwater fish require a combination of high dissolved oxygen concentrations and low temperatures to maintain a population. Establishment of low dissolved oxygen levels or warm temperatures during summer can exclude a major volume of the lake to habitation by certain species of fish. Dissolved oxygen can become depleted in the deeper, colder layers of stratifying lakes during summer. The upper layers, which typically remain oxygen enriched, may become too warm for coolwater and coldwater fish species during summer. As a result, the habitat available for certain fish may be diminished or eliminated.

The habitat available for coldwater and coldwater fish communities in Onondaga Lake has been tracked from 2000 to 2013 using high frequency measurements of dissolved oxygen and temperature taken at multiple depths. The 6-month period from May 15 through November 15 (185 days) has been used for this analysis because it encompasses the summer season when the upper waters of the lake can reach temperatures that are potentially stressful to the coldwater fish community. The percentage of the total lake volume available to coldwater fish increased significantly (t-test, p<0.01) from 32% during 2000-2005 to 41% during 2006-2013 (Figure 5-8a). Similarly, the habitat available to coolwater fish increased from 43% to 50% (p<0.01). The percentage of days with at least 1 meter of vertical habitat available for coldwater fish averaged 72% during 2000-2013 and ranged from 51% in 2002 to 87% in 2004 (Figure 5-8b). Conditions were better suited for coolwater fish species, with 95% of the days meeting habitat requirements during an average year.

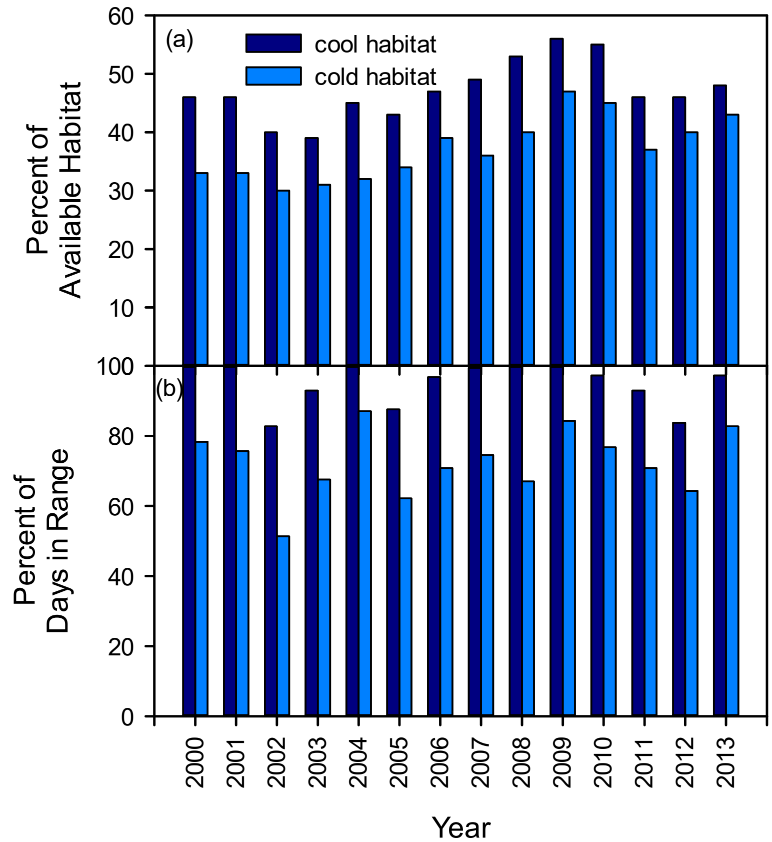


Figure 5–8. Coolwater and coldwater fish habitat, 1990–2013: (a) the percentage of the lake volume with dissolved oxygen and temperature conditions suitable for coolwater and coldwater fish, and (b) the percentage of days in the May 15 through November 15 interval with habitat available for coolwater and coldwater fish.

The New York State Consolidate Assessment and Listing Methodology (NYSDEC 2009) notes that low dissolved oxygen is likely to occur at lower depths of lakes as a result of natural conditions. In fact, more than 70% of the thermally stratified assessed in a recent NYSDEC survey experienced hypoxia in the hypolimnion (NYSDEC 2010). Lakes with small hypolimnetic volumes, such as Onondaga Lake, are particularly susceptible to oxygen depletion during summer stratification. The suite of water quality models used to support development of the TMDL for phosphorus in Onondaga Lake was applied to hindcast dissolved oxygen in the hypolimnion for pastoral (pre-1800) conditions (NYSDEC 2012). Model simulations indicated that oxygen depletion in deep water during summer was likely an annual occurrence.

Additional chemical factors that could impair aquatic life use support include harmful levels of ammonia or nitrite and pH values outside the 6.5 to 8.5 range. Exceedances of the ambient water quality standards for ammonia and nitrite were eliminated in 2004 by implementation of the BAF treatment process. The reductions in ammonia concentrations in the upper waters of the lake have enabled a more diverse biota. In 2008, New York State Department of Environmental Conservation (NYSDEC) delisted Onondaga Lake as impaired by ammonia in the 303(d) list of impaired waterbodies. Onondaga Lake is a well-buffered system with moderate pH values that typically remain within the 7 to 8 range.

The available biological and physical/chemical data indicate that Onondaga Lake is meeting its designated use of aquatic life support. The macroinvertebrate community has improved since 2000, with three of the five sampling sites categorized as slightly impacted in 2010. Although the macroinvertebrate community remains severely impacted at the extreme southern end of the lake, conditions at this site have improved steadily since 2000. The lake supports a diverse and productive warm and cool water fish community, and is popular with recreational anglers.

5.3 Fish Consumption Use

Advisories issued by the New York State Department of Health (NYSDOH) form the primary basis for assessment of the fish consumption use. The general NYSDOH advisory is that people can eat up to four, one-half pound meals a month (which should be spaced out to about a meal a week) of fish from New York State fresh waters. An additional NYSDOH advisory is in place for Onondaga Lake due to mercury, PCB, and dioxin contamination. The current advisory recommends that women under age 50 and children under age 15 consume no fish from Onondaga Lake. In addition, the following species specific consumption guidelines are provided for men over age 15 and women over age 50:

- Largemouth & Smallmouth Bass over 15 inches – Don’t Eat; less than 15 inches – one meal per month
- Walleye, Carp, Channel Catfish and White Perch – Don’t Eat
- Brown Bullhead and Pumpkinseed – four meals per month
- All fish not listed – one meal per month

Accordingly, the fish consumption use is precluded for women under age 50 and children under age 15 and impaired for men over age 15 and women over age 50. Honeywell International is proceeding with a number of projects to address industrial contamination issues, with oversight by the federal Environmental Protection Agency (EPA) and NYSDEC. About 2 million cubic yards of contaminated sediment has been removed from the lake and about 450 acres of the lake bottom are being capped to provide a new habitat layer, prevent erosion, and isolate remaining contaminants. Capping and habitat restoration are scheduled for completion in 2016.

5.4 Natural Resources Habitat/Hydrology Uses

Natural resources habitat/hydrology uses are included in New York State's assessment methodology to better incorporate wetlands and other natural resources concerns in water quality assessments. Although water quality conditions may support designated uses, various other conditions, including habitat, invasive species, and hydrology, can result in degradation of natural resources. Various anthropogenic and natural perturbations have affected the natural resources, habitat, and hydrology uses of Onondaga Lake and its watershed.

5.4.1 Wetland and riparian habitat

Wetlands and riparian zones provide a variety of ecosystem services, including wildlife habitat, flood mitigation, nutrient removal, and aesthetic value (Mitsch and Gosselink 1993). These habitats and their related services have been greatly diminished or eliminated through various alterations to the Onondaga Lake ecosystem that accompanied urbanization of the area. In 1822, a channel was cut to connect the lake with the Seneca River. As a result, the lake level was reduced by four feet and wetlands at the south end of the lake were drained. In addition, the lake's tributaries have been channelized and riparian zones have been lost to development. For example, the channel of Onondaga Creek was altered substantially (deepened and straightened) to promote rapid removal of flood water and sewage and Ninemile Creek was rerouted to accommodate disposal of ionic waste from soda ash production.

Honeywell recently completed a habitat restoration project along Geddes Brook and Ninemile Creek, transforming 44 acres of the Onondaga Lake watershed into a diverse new habitat for wildlife. Additional work is under way to improve wetlands on the shores of Onondaga Lake and along the lake's tributaries. About 1.1 million plants, shrubs, and trees are being planted to enhance habitat for fish and wildlife in the Onondaga Lake watershed. Additional details can be found on Honeywell's website (http://www.lakecleanup.com).

5.4.2 Tully Valley mudboils

The Tully Valley mudboils are created by fine-grained sediment and water brought to the land surface by artesian discharge (Kappel 2014). Sediment from the mudboils, which is composed mostly of clay minerals, is loaded directly to Onondaga Creek and transported to Onondaga Lake. The high sediment load and extensive in-stream deposition have negatively impacted the stream's biota and the aesthetics of the Inner Harbor (Prestigiacomo et al. 2007). Onondaga Creek is the dominant source of inorganic particulate material to Onondaga Lake and an important source of particulate phosphorus. Through the early 1990s the mudboils were loading sediment to Onondaga Creek at a rate of approximately 30 tons per day. Sediment loading from the mudboils was reduced to about 1 ton per day in the mid-1990s through an array of remedial measures. A new "rogue" mudboil area developed in 2010 that increased sediment loading to more than 20 tons per day. Kappel (2014) has outlined the technical and practical issues related to potential remedial strategies to reduce mudboil discharges and improve water quality and habitat conditions in Onondaga Creek.

5.4.3 Invasive species

Because Onondaga Lake is an open system, connected to Lake Ontario, Oneida Lake, and certain Finger Lakes by the Three Rivers System, it is particularly susceptible to invasion by aquatic invasive species. Many invasive species have colonized the Great Lakes as a result of ballast water transfers from international ships. A variety of invasive species have entered the Great Lakes since the early 1800s, including include fishes, mollusks, crustaceans, other invertebrates and plants. In the past 200 years more than 145 different plants and animals have invaded the Great Lakes. In the absence of natural predators, many of these exotic invaders have spread throughout aquatic ecosystems, limiting food and habitat and competing with or even displacing native species. Some of the more noteworthy invasive species present in Onondaga Lake include dreissenid (zebra and quagga) mussels, fishhook waterfleas (*Cercopagis pengoi*), Alewife (*Alosa pseudoharengus*), Common Carp (*Cyprinus carpio*), and the Round Goby (*Neogobius melanostomus*).

Zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*) were first recorded in Onondaga Lake in 1992, although they did not become abundant until 2000 and 2008, respectively (Mills et al. 1993, Spada et al. 2002). By 2009, quagga mussels largely replaced zebra mussels in water depths of 3 to 6 meters (Rudstam and Gandino 2014). However, zebra mussels remained co-dominant with quagga mussels in shallower water. Both zebra and quagga mussels can alter ecosystems through filter feeding and alteration of benthic habitat. They filter particulate matter (e.g., algae) from the water column, producing dissolved nutrients (phosphorus and nitrogen) and consuming oxygen. Dreissenid mussels likely have a significant positive impact on water clarity in nearshore areas of Onondaga Lake; however, the ecological impacts associated with these filter feeders are not fully understood.

The Alewife is a planktivorous fish that feeds preferentially on large zooplankton, which are more efficient grazers of algae than smaller zooplankton. The development of large populations of Alewife in Onondaga Lake during 2003–2007 and 2010–2013 nearly eliminated large-bodied zooplankton such as *Daphnia* (Wang et al. 2010, Onondaga County 2013). In years when Alewife were abundant, the absence of *Daphnia* caused higher levels of phosphorus and chlorophyll-*a* and diminished water clarity (Matthews et al. 2015). The potential for large alewife populations has been linked to reductions in ammonia concentrations (Wang et al. 2010).

A Rock Colonized by Dreissenid Mussels

5.4.4 *Weather variations and climate change*

Water quality conditions in Onondaga Lake are subject to substantial year-to-year variations as a result of interannual differences in meteorological conditions. Air temperature and wind speed influence the stratification regime and, therefore, dissolved oxygen concentrations in the hypolimnion. Precipitation, as the primary driver of stream flow, is the single most important meteorological attribute affecting material loading from the tributaries. Increased nutrient loading during high runoff years can enhance algal growth, and large inputs of inorganic particles can cause poor clarity. In contrast to random year-to-year variations, climate change is forecast to cause major systematic shifts in climate. In the Northeast, climate change is expected to result in warmer temperatures and an increase in the occurrence of high intensity storms. Model simulations of the response of Onondaga Lake to climate change indicate increases in the magnitude of peak flows and nutrient loading, water temperatures increases of 5 °C during the 2040–2069 time period, and a prolonged summer stratification interval (Taner et al. 2011).

5.5 Aesthetics

Evaluation of the extent to which a waterbody supports the aesthetics use is necessarily more subjective than for the other uses assessed in this report. NYSDEC (2009) recommends the use of available objective information for assessment of aesthetic use support, such as lake perception surveys and preponderance of citizen complaints. Although this type of information is generally lacking for Onondaga Lake, a reasonable evaluation of the aesthetics use can be performed on the basis of available data related to water clarity, the frequency of algal blooms, macrophyte coverage, and floatables control.

5.5.1 Water clarity

Public perceptions of the overall health of a waterbody are influenced importantly by water clarity. Water clarity, as measured by Secchi disk transparency, has improved in both open water and nearshore areas of the lake. Impaired water clarity conditions, which correspond to the New York State Department of Health (NYSDOH) swimming safety guidance value of 4 feet or 1.2 meters, have been substantially reduced since the phosphorus treatment upgrade at Metro in 2005 (Figure 4-7b). Since 2005, just 12 of the 194 (6%) Secchi disk measurements made at South Deep were less than 1.2 meters. These infrequent occurrences of low transparency were primarily associated with inputs of inorganic particles during major runoff events and not with excessive algal growth. Since 2009, water clarity at nearshore sites has exceeded the 1.2 meter standard more than 90% of the time in Class B waters (Figure 5-3). Turbid inputs from Onondaga Creek, Ley Creek, and Harbor Brook continue to cause diminished water clarity in the Class C segment located at the south end of the lake. Uncontrolled loading of clay particles that originate from the Tully Valley mudboils is the primary cause of poor clarity at the mouth of Onondaga Creek during runoff events.

5.5.2 Algal blooms

Excessive algal growth is one of the most common complaints reported by residents and users of New York's lakes (NYSFOLA 2009). Algal blooms discolor the water and may cause odor problems, resulting in conditions unsuitable for swimming and other forms of recreation. Toxins emitted by blue-green algae during harmful algal blooms (HABs) can cause health effects when consumed by dogs, cats, cattle, and humans. While the occurrence of HABs has increased in New York State in recent years (http://www.dec.ny.gov/chemical/77118.html), the frequency and severity of algal blooms in Onondaga Lake has diminished (Figure 4-6). In fact, no major algal blooms have occurred in the lake since the upgrade in phosphorus treatment in 2005 and minor blooms have been absent since 2007. Blue-green algae are no longer important in Onondaga Lake, and there have been no problems with toxic forms.

5.5.3 Macrophytes

In a survey of lake residents in New York State, the most frequently reported problem was nuisance macrophytes or weeds (NYSFOLA 2009). Although macrophytes serve a variety of beneficial ecological functions in lakes, dense populations of invasive plants can cause nuisance conditions that inhibit lake uses. Macrophyte coverage in Onondaga Lake increased from less than 20% in the early 2000s to approximately 50% in recent years (Figure 5-9). The current level of macrophyte coverage is in the optimum range for Largemouth Bass, which may explain recent high catch rates. Dense plant growth, which is limited to shallow, nearshore areas where light can reach the lake bottom, isn't a significant impediment to swimming and boating in most areas of the lake. Water stargrass (*Zosterella dubia*), stonewort (*Chara vulgaris*), and coontail (*Ceratophyllum demersum*) were the most abundant species in the lake in 2013 (Onondaga County 2015). Although invasive species such as Eurasian water milfoil (*Myriophyllum spicatum*) and water chestnut (*Trapa natans*) are present in Onondaga Lake, they have not become dominant.

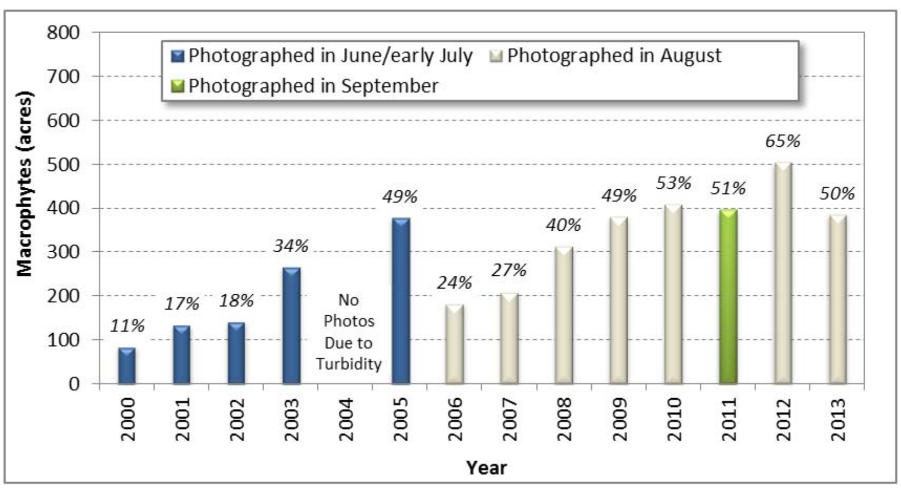


Figure 5–9. Macrophyte coverage in Onondaga Lake, 2000–2013. Percentage represents coverage of the littoral zone (to depth of 6 meters).

5.5.4 *Floatables*

The occurrence of floating debris in lakes and streams can negatively affect public perceptions of water quality. Floatable debris consists of a wide variety of plastic, wood, paper, glass, rubber, metal, and organic waste materials that float or are suspended in the water column and may eventually be deposited along shorelines. Common sources of floatable debris include street litter, storm water discharges, decaying shoreline structures, pleasure boaters, anglers, and CSO discharges. Onondaga Lake is particularly susceptible to floating debris because of its urban setting. The ACJ requires "elimination or minimization of floating substances in Onondaga Lake attributed to the County's CSOs."

Onondaga County has implemented a number of programs that are reducing the amount of floating debris in Onondaga Lake and its tributaries. The County contracts the services of a skimmer boat for collection and disposal of floatable debris in the Inner Harbor of Syracuse, along the mouth of Onondaga Creek, and in near shore portions of Onondaga Lake near the mouth of Onondaga Creek. The skimmer boat is typically operated eight hours per week during April, May, September, October and November, and 16 hours per week during June, July, and August. The debris collected typically consists of the following elements (listed in the order of frequency): leaves and grass, tree limbs, plastic and Styrofoam food packaging, plastic containers, glass bottles, cigarette butts, dead fish, Rx bottles, playground equipment, construction barricades, syringes, condoms, and feminine hygiene products. From 2002 to 2013 more than 195 tons of debris was collected by the skimmer boat.

The County currently operates four Floatable Control Facilities (FCF) on Onondaga Creek and Harbor Brook. Onondaga County Department of Water Environmental Protection (OCDWEP) personnel inspect the FCFs weekly and after wet-weather events. In 2012 more than 25 tons of debris were collected at FCFs and disposed of – this value increased to more than 29 tons in 2013. When the FCF and skimmer boat operations are considered together, the amount of floating debris removed from Onondaga Lake and its tributaries was 37.3 and 49.6 tons in 2012 and 2013, respectively. In addition, the County performs a number of maintenance tasks at its green infrastructure projects, including general trash clean up, catch basin filter insert cleaning, and porous pavement vacuuming.

In 2012 Onondaga County completed a characterization study of eighteen (18) CSOs to assess the need for creating the most effective strategy for controlling floatables from these CSOs (ARCADIS 2013). This assessment found that material presumed to originate predominantly from sanitary sewage (textiles, colloidal and health/hygiene) generally represented a small fraction of the floatables contained in discharges from these CSOs. Composition results obtained from sampling of floatables from the individual CSOs indicated 52-98% of material sampled was natural debris unrelated to sanitary sewage. This finding is consistent with the high percentage of natural materials captured at both the Harbor Brook FCF (88%) and Inner Harbor (92%). Debris derived from street litter (i.e., paper, plastics, foam) accounted for 68 to 100% of the floatables from the individual CSOs.

The control of floatables into Onondaga Lake and its tributaries remains an important water quality objective. The available data indicate that the majority of floatable material discharging from CSOs is natural and/or street derived debris associated with storm water. Accordingly, source control such as street sweeping, catch-basin modifications, and cleaning programs would likely be an effective method for floatables control. In addition, an aggressive public education program focused on appropriate disposal of hygienic and other personal care products could further reduce floatables associated with sanitary sewage.

6 CONCLUSIONS

The water quality improvements achieved at Onondaga Lake have been striking in the context of lake rehabilitation examples from North America and beyond. Lakes usually respond positively to reductions in nutrient loading; however, responses are often slower and less evident than anticipated (Cooke et al. 2005). In contrast, the water quality improvements at Onondaga Lake were both tangible and immediate following wastewater treatment upgrades at Metro. The lake has been transformed from a highly eutrophic system that failed to support a number of designated uses through the early 2000s to a mesotrophic system that now supports a variety of recreational uses and a diverse fishery. Noteworthy examples of water quality improvements include:

- Loading of ammonia and nitrite, two potentially toxic forms of nitrogen, was reduced by 98% and 90%, respectively, as a result of treatment upgrades at Metro. Water quality standards for ammonia are no longer exceeded in Onondaga Lake and the lake was delisted as impaired by ammonia in 2008.

- Increased loading of nitrate from Metro has substantially decreased the transport of phosphorus and mercury from the sediments to the water column.

- Upgraded phosphorus treatment at Metro has resulted in an 85% decrease in total phosphorus loading to Onondaga Lake since the early 1990s and a 99% reduction since the early 1970s.

- Summer average total phosphorus concentrations averaged 21 µg/L during 2007–2013, close to the guidance value of 20 µg/L established for protection of recreational uses of lakes.

- Reduced phosphorus loading has caused marked decreases in algal biomass and the occurrence of algal blooms. No major algal blooms have been observed since 2005 and no minor blooms have been documented since 2007.

- Reductions in algal biomass have resulted in improved water clarity in both open water and nearshore regions of the lake. Water clarity now exceeds the swimming safety guidance value of 1.2 meters (4 feet) 96% of the time at South Deep and 90% of the time at Class B nearshore locations.

- Depletion of dissolved oxygen in the upper waters of the lake during fall turnover has been eliminated. The lake's dissolved oxygen resources now provide habitat for a diverse fishery, including both warmwater and coolwater fish species. Coldwater species are found in Onondaga Lake, but their habitat is restricted during summer due to a lack of cold, oxygen-rich water.

- Onondaga County has completed a variety of "gray" and "green" infrastructure projects that have reduced CSO discharges and bacteria loading to the lake. Forty-five (45) CSOs have been eliminated or captured. Green infrastructure projects are reducing storm water runoff by over 108 million gallons per year and CSO discharges by approximately 51 million gallons per year.

- Although Onondaga Lake currently has no public bathing beach, water quality conditions in the northern two-thirds of Onondaga Lake are now fully supportive of the public bathing use.

Using the New York State *Consolidated Assessment and Listing Methodology* (CALM) as a guide, we have documented the extent to which Onondaga Lake is presently supporting the designated uses of public bathing and recreation, aquatic life support, fish consumption, natural resources habitat/hydrology, and aesthetics. The public bathing use is fully supported in the northern two-thirds of the lake. Public bathing is not a designated use in the southern third of the lake. Recreational uses of the lake are fully supported with the exception of the extreme southern end of the lake following runoff events. Levels of turbidity and indicator bacteria become elevated in this portion of the lake following significant rainfall. The aquatic life use is fully supported throughout the lake as manifested in a diverse fish community and an improving macroinvertebrate community. The fish consumption use remains impaired on a lake-wide basis due to mercury, PCB, and dioxin contamination.

Improved water quality has resulted in a more balanced ecosystem, with increased habitat for aquatic organisms and enhanced aesthetic appeal. However, Onondaga Lake is subject to a variety of effects that are beyond the scope of current rehabilitation initiatives. Invasive species, such as dreissenid mussels, Alewife, and Round Goby, will continue to impact the food web and water quality conditions. The impact of Alewife on water clarity and phosphorus levels has been particularly conspicuous. Turbid inputs from the Tully Valley mudboils continue to affect habitat conditions and aesthetics in Onondaga Creek and Onondaga Lake. Finally, lake water quality and biota will continue to be influenced by both interannual variations in weather and long-term changes in climate.

The conclusions reached in this report regarding the attainment of designated uses in Onondaga Lake are generally consistent with those provided by NYSDEC in the recently updated **Waterbody Inventory and Priority Waterbodies List** (WI/PWL). The WI/PWL entry for Onondaga Lake, which was updated on October 20, 2014, documents the marked improvements in water quality and concludes that the lake now supports most uses (see http://www.dec.ny.gov/chemical/36737.html). Specifically, the WI/PWL reports that the public bathing, recreation, and aquatic life uses are fully supported in the northern two-thirds of the lake. The aquatic life use is also fully supported in the southern end of the lake. Recreational uses are stressed in the southern end due to elevated bacteria levels following wet-weather events. The WI/PWL considers fish consumption to be impaired throughout the lake.

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