Onondaga County Department of WATER ENVIRONMENT PROTECTION

Onondaga Lake

Ambient Monitoring Program: 2012

2012 Annual Report

Final, February 2014

Onondaga County, New York

Joanne M. Mahoney, County Executive

ONONDAGA COUNTY DEPARTMENT OF WATER ENVIRONMENT PROTECTION

VISION

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

MISSION

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

CORE VALUES

Excellence
Teamwork
Honesty
Innovation
Cost-Effectiveness
Safety

Onondaga County Department of WATER ENVIRONMENT PROTECTION

Save the Rain

http://www.savetherain.us

Cover photos by C. Strait

ONONDAGA LAKE AMBIENT MONITORING PROGRAM
2012 ANNUAL REPORT

ONONDAGA COUNTY, NEW YORK

Final, February 2014

Prepared for

ONONDAGA COUNTY, NEW YORK

Prepared by

Upstate Freshwater Institute
Syracuse, NY

Anchor QEA, LLC
Liverpool, NY

Onondaga County Department of Water Environment Protection
Syracuse, NY

Lars Rudstam, Ph.D.
Cornell Biological Field Station
Bridgeport, NY

William W. Walker, Ph.D.
Environmental Engineer
Concord, MA

Key Features of this Report

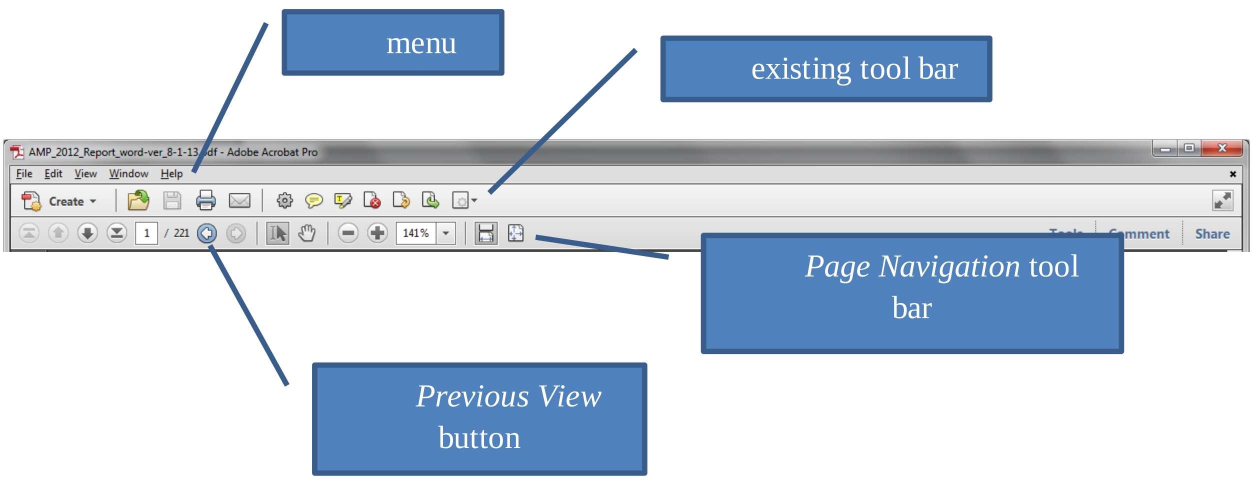
The 2012 report is distributed as an electronic file in portable document format (PDF), which can be opened using Adobe Reader. Key results and supporting tables and graphics are included in the main document, with links to additional tables, technical reports, and graphics in electronic appendices. The report and supporting files are available on CD upon request and on the Onondaga County web site http://www.ongov.net/wep. Throughout the document the reader will find hyperlinks marked in bright blue, which provide easy access to other sections of the report (e.g., figures, tables) as well as external links to web pages and email addresses.

Users navigate to external resources by simply left-clicking on the hyperlink. For web links, the users default web browser will load and navigate to the selected web site. When finished viewing the web site, the user simply closes the web browser leaving the report open at the previous location. When the user first selects a web link, a security warning menu will appear: "*Do you trust* (domain name here)? *If you trust the site choose Allow. If you do not trust the site choose Block*". The user will need to select the *Allow* button if they wish to display the web page. Left-clicking on email addresses will cause the users email program to open. After composing an email message, click the *Send* button and the email will be sent and the report will remain open at the previous location. For links to appendices, Adobe Reader will launch and open a copy of the selected appendix in PDF format. When finished viewing the appendix, simply close the PDF window, leaving the main report open at the previous location.

Navigation to and from internal links in the main Report PDF is very simple. The user simply clicks on the hyperlink marked in bright blue to move to the bookmarked position in the document. The user can return to their previous position in the report by selecting the *Previous View* on the *Page Navigation* toolbar, or by pressing the *Alt* key and *left arrow* key at the same time. Users can follow the instructions below to activate the *Page Navigation* toolbar in Adobe Reader.

To turn on the *Page Navigation* toolbar simply select the *Show/Hide* option on the *View* menu in Adobe Reader. Select the *Toolbar Items* option of the *Show/Hide* menu. Next select the *Page Navigation* option from the *Toolbar Item* menu. Finally, select *Show All Page Navigation Tools* from the *Page Navigation* menu. These steps are captured below in the picture of the report opened in Adobe Reader.

The following Page Navigation tool bar will appear at the top of the Adobe reader directly under the menu bar and existing tool bars.



The *Previous View* button on the *Page Navigation* toolbar is shown above. Alternatively, users can return to their previous location in the report by pressing the *Alt* key and *left arrow* key at the same time.

While each hyperlink has been checked, it is possible that some features will not be enabled on every computer's operating system. Feedback on the functionality of the electronic features of the document is welcome. Please contact JeannePowers@ongov.net with comments.

Acknowledgements

In addition to the authors of the Annual Report, several other individuals and professional service firms contributed their expertise to the data collection and interpretation effort. We wish to acknowledge the contribution of the following specialists for their ongoing commitment to investigating the Onondaga Lake ecosystem.

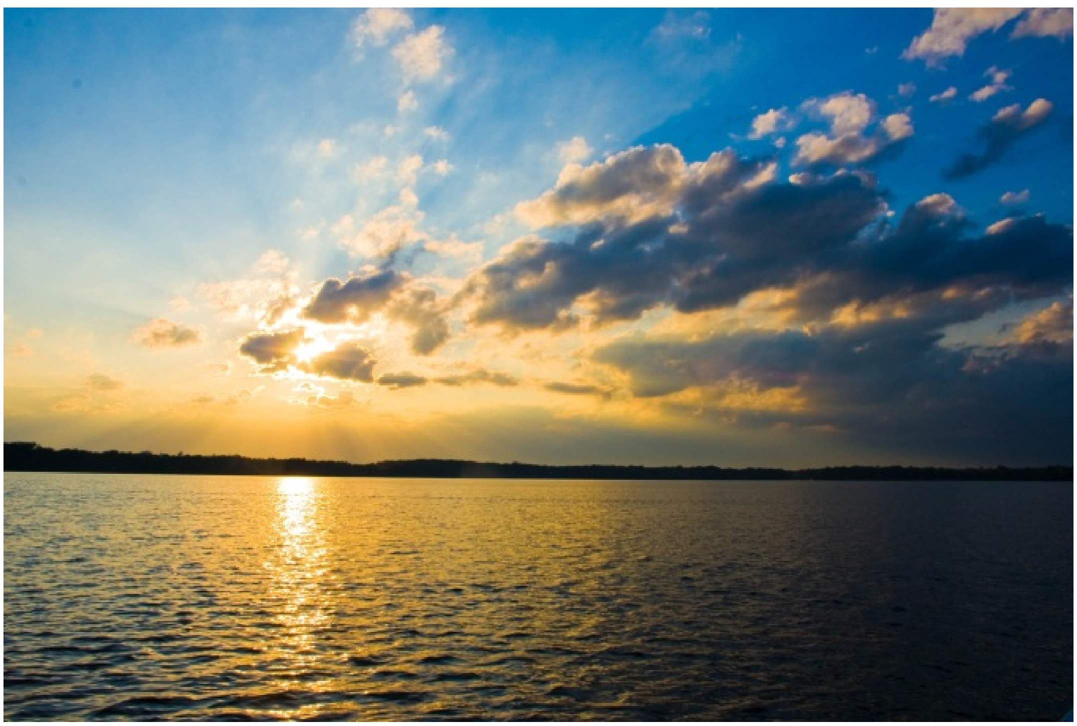
1. AirPhotographics Inc. of Martinsburg WV. This firm obtains the aerial photographs of the lake's nearshore zone each summer and provides high-quality images for interpretation of the amount of the littoral zone covered with macrophytes. They have been working with the AMP team since 2000.

2. PhycoTech Inc. of St. Josephs MI. Dr. Ann L. St. Amand has been identifying the Onondaga Lake phytoplankton community since 1990. Each year, Dr. St. Amand and her staff at PhycoTech provide the detailed taxonomic information needed to characterize this ecosystem in flux.

3. Ecologic, LLC digitized the aerial photographs of macrophytes in the littoral zone.

Table of Contents

Appendices



Sunset on Onondaga Lake

LIST OF TABLES

LIST OF FIGURES

This page intentionally left blank

Executive Summary

Introduction

This Annual Report of Onondaga County's Ambient Monitoring Program (AMP) describes the state of Onondaga Lake, its tributaries, and adjoining portions of the Three Rivers System in 2012. Conducted annually since 1970, the County's monitoring program provides water resource managers, public officials, state and federal regulators, and the entire community a window into the significant changes evident in Onondaga Lake – both in the lake's water quality conditions and in its biological community.

Changes in the lake ecosystem are the result of multiple factors. Some of these factors reflect human intervention, notably, the significant investment in improved wastewater treatment technology and the ongoing efforts to remediate legacy industrial wastes. Other changes in the Onondaga Lake ecosystem reflect biological factors such as the fluctuating population of the alewife and its cascading effects on the lake's food web. The 2012 Annual Report documents the input of water and materials (bacteria, sediment, nutrients, and salts) to Onondaga Lake from the watershed and the Metropolitan Syracuse Wastewater Treatment Plant (Metro). The response of the lake to these inputs is a focus of the annual program. The AMP examines water quality conditions, compliance with New York State ambient water quality standards (AWQS), and long-term trends. The AMP also tracks the species composition and abundance of fish, phytoplankton, zooplankton, benthic invertebrates, aquatic macrophytes, and dreissenid (zebra and quagga) mussels.

Report Format

This report is a scientific summary of the major findings of the AMP in 2012, supported by graphs and tables of current and historic data. This paperless format was developed to advance two objectives: first, to reach a broader audience, and second, to continue to find ways to reduce our environmental footprint, through a commitment to green initiatives (for more information on Onondaga County's green initiatives visit http://www.savetherain.us). This format was envisioned as a means to enable Onondaga County leaders and citizens to learn about the condition of Onondaga Lake and its watershed. Additional program information is available on the County web site http://www.ongov.net/wep/we15.html. Annual reports from prior years are posted at http://www.ongov.net/wep/we1510.html. While the *Executive Summary* focuses on noteworthy features of the 2012 AMP results, the following section (*Highlighting Improvements in Onondaga Lake*) reports on the long-term water quality and biological improvements that have been achieved in Onondaga Lake.

Regulatory Framework

The 2012 AMP annual report has been prepared to comply with a judicial requirement set forth in the 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation (ASLF). The ACJ requires upgrades to the County's wastewater collection and treatment infrastructure, and an extensive monitoring program (the AMP) to document related environmental improvements. Onondaga County Department of Water Environment Protection (WEP) is responsible for implementing the AMP and reporting its findings. Links to the ACJ and its modifications are posted on the Onondaga County web site http://www.ongov.net/wep/we15.html.

Two important regulatory milestones were reached in 2012. First, New York State Department of Environmental Conservation (NYSDEC) issued a new State Pollution Discharge Elimination System (SPDES) Permit for Metro on March 21, 2012. Second, a total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake was 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 municipal separate storm sewer systems (MS4) areas by 12/31/2025.

Onondaga County Actions and Progress with Related Initiatives

The County completed a number of "gray" and "green" infrastructure projects in 2012 that will reduce wet weather discharges from combined sewer overflows (CSOs) into Onondaga Lake and its tributaries. Gray infrastructure projects include sewer separation, capture of floatable materials, and maximization of system storage capacity. In 1998, there were 72 active CSOs (outfall points with the potential to discharge combined sewage) in the collection system, discharging to Onondaga Creek, Harbor Brook, and Ley Creek. Through 2012, 26 CSOs have been abandoned (completely eliminated or converted to a storm discharge point only) as a result of ACJ projects. In addition, green infrastructure projects are capturing hundreds of millions of gallons of stormwater runoff before it can enter the combined sewer system.

Construction was completed on multiple gray infrastructure projects in 2012 that will significantly reduce CSO discharge. The CSO 044 Conveyances Project, designed to capture 6 million gallons of CSO volume, was completed in 2012. Construction of the Harbor Brook Interceptor Sewer Replacement Project, which will result in the capture of a CSO volume of 36 million gallons, was also completed in 2012. In 2012, construction was completed on the CSO 022 and CSO 045 Sewer Separation Projects, which will capture a combined 1 million gallons of CSO volume per year. Work on the Clinton and Harbor Brook Storage Facilities continued in 2012. These facilities will provide a combined 147 million gallons of CSO capture annually.

Green infrastructure solutions are being implemented at County facilities and in other urban areas to help capture and reuse urban storm runoff before it enters the CSO system. Since 2010, over 120 green infrastructure projects have been completed as part of the "Save the Rain" initiative (http://savetherain.us/), reducing inputs of stormwater runoff and pollution to Onondaga Lake and its tributaries. The "Save the Rain" program experienced another impressive year in 2012 with over 50 green infrastructure projects completed. These projects included 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 stormwater runoff.

The Onondaga Environmental Institute (OEI) has conducted a series of studies to locate and identify dry weather sources of bacteria to both Onondaga Creek and Harbor Brook. The emphasis of the Phase I Microbial Trackdown Study, conducted in 2008 and 2009, was to monitor spatial and temporal trends of bacteria and to locate and characterize potential dry weather sources. The updated version of the Microbial Trackdown Phase II workplan, dated April 5, 2012, outlined a comprehensive study implemented in 2012 and 2013 to monitor presence of fecal coliform in Harbor Brook and Onondaga Creek, as a follow-up to the findings of the Phase I study.

In 2012, OEI conducted a detailed examination of the physical, chemical, and biological conditions of sites located in Upper Onondaga Creek. The study report (***An Investigation of Ecological Condition in the Upper Onondaga Creek Watershed: An examination of water and habitat quality, biotic integrity, and contaminant burdens in biota – 2012***) was issued in July 2013.

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. Dredging and capping of Onondaga Lake sediments began in summer 2012. About 2 million cubic yards of contaminated sediment will be removed from the lake by hydraulic dredging, which is expected to be about halfway complete by the end of 2013. About 450 acres of the lake bottom are being capped to provide a new habitat layer, prevent erosion, and isolate remaining contaminants. Additional work is under way to remediate and transform 17 acres at Geddes Brook and 30 acres at Ninemile Creek into diverse new habitats for wildlife. Contaminated soil has been removed and 100,000 native shrubs, flowers, and trees are being planted. In 2012, the second-year of a three year pilot test, nitrate was added to the deep waters of Onondaga Lake with the objective of limiting release of methylmercury from the profundal sediments to the hypolimnion.

Tributary Water Quality

Precipitation is the primary driver of stream flow and the single most important meteorological attribute affecting material loading from the tributaries to Onondaga Lake. Annual precipitation totaled 35.1 inches in 2012, lower than the 30-year (1982-2011) historic average of 38.7 inches and substantially lower than the 49.5 inches received in 2011. Lower than average precipitation during most of 2012 resulted in an annual average flow for Onondaga Creek in the lower 20th percentile of the 42-year record. Stream flow in 2012 was 32% lower than the long-term average and one-half of the average flow in 2011.

The 2012 tributary data continued to indicate that the major tributaries were generally in compliance with ambient water quality standards (AWQS). The primary exceptions in meeting AWQS in the tributaries were total dissolved solids (TDS) and fecal coliform bacteria (FC). Contravention of the AWQS for TDS is primarily associated with the natural hydrogeology of the watershed and not with anthropogenic effects. The primary sources of fecal coliform bacteria to Onondaga Lake in 2012 were the Metro bypass (002) and Onondaga Creek. However, the Metro effluent (001) and the other primary tributaries made noteworthy contributions as well. The following tributary locations were 100% compliant with the fecal coliform standard: Harbor Brook at Bellevue, Ninemile Creek at I-695, Tributary 5A, and the Onondaga Lake Outlet. Compliance with the AWQS for fecal coliform bacteria was achieved for less than 50% of the monthly means at Bloody Brook at Onondaga Lake Parkway (45%), Harbor Brook at Hiawatha (0%), Ley Creek at Park (33%), Onondaga Creek at Kirkpatrick (18%), and Sawmill Creek at the Onondaga Lake Park (25%).

A detailed analysis of fecal coliform data collected from Onondaga Lake tributaries over the 1998-2012 interval generated a number of important findings. There is strong evidence of increasing fecal coliform concentrations at a rate of about 10% per year under both dry and wet weather conditions at the Dorwin Ave. station on Onondaga Creek. There is also evidence of increasing trends in long-term fecal coliform concentrations at Ninemile Creek (6.3% per year) and Harbor Brook (4.6% per year). Compliance with the AWQS for fecal coliforms was observed in 70% of the months at the upstream sites, as compared with 15-25% at the downstream sites. Achieving compliance with the standard in 90% of the months would require >60% reductions at the upstream sites and >90% reductions at downstream sites. Achieving higher compliance rates would require significantly higher reductions.

The largest total phosphorus (TP) loads to Onondaga Lake in 2012 were delivered by the Metro effluent (001) and the two largest tributaries, Onondaga Creek and Ninemile Creek. Total phosphorus loads were much lower in 2012 than in 2011, consistent with decreases in precipitation and stream flow. The total Metro load decreased 20% while loads from Onondaga and Ninemile Creeks decreased by 68% and 69%, respectively. The highest total dissolved phosphorus (TDP) loads in 2012 were delivered by Metro, Onondaga Creek and Ninemile Creek.

The Metro effluent was also the leading source of total nitrogen and ammonia nitrogen (NH_3-N) to the lake in 2012. The total suspended solids (TSS) load from Onondaga Creek exceeded the next largest source, Ninemile Creek, by a factor of 3, and the Metro input by a factor of 13. The particularly high load of TSS in Onondaga Creek is at least in part attributable to inputs from the mud boils in upstream portions of its watershed. Annual loading of TSS from the tributaries decreased 62% from 2011 to 2012, associated with relatively high runoff in 2011 and low runoff in 2012.

Metro continued to perform at a high level in 2012, meeting permit limits for total phosphorus and ammonia throughout 2012, and often by a wide margin. Beginning in March 2012, the Metro plant began to experience higher levels of total phosphorus in the effluent. By the end of July, TP concentrations had returned to pre-March levels. The recovery in performance was attributed to two operational enhancements: (1) maximizing the TP removal in the secondary process through increased chemical dosing, and (2) relocation of the outlying treatment plant sludge disposal to the blend tank for the solids handling end of the treatment process. Monthly average effluent total phosphorus concentrations have been exceptionally low (<0.07 mg/L) since September 2012. Bypasses of the full treatment process are sometimes required during intense runoff events. Headworks bypasses receive little or no treatment prior to discharge. There were no headworks bypasses during 2012. Discharges through Bypass Outfall 002 totaled 213.8 million gallons, and another 12.2 million gallons were discharged through Outfall 001 as a result of tertiary bypasses.

Onondaga Lake Water Quality

Trained County technicians collect samples from Onondaga Lake throughout the year to characterize water quality and biological conditions. Most sampling occurs between April and November when the lake is free of ice. The 2012 monitoring results indicate that the open waters of Onondaga Lake were in compliance with most AWQS. The lake is now in full compliance with the AWQS for ammonia, and in 2008 was officially removed from the New York State’s 303(d) list of impaired waterbodies for this water quality parameter. Exceedances of the AWQS for nitrite now only occur in the lower layers of the lake when hypoxia prevails. These conditions reflect incomplete nitrification of ammonia within those lower lake depths.

Long-term trends in total phosphorus (TP) concentrations in the lake’s upper waters continue to depict major decreases since the early 1990s. The 2012 summer (June-September) average TP concentration in the lake’s upper waters was 22 (micrograms per liter) µg/L, slightly higher than the state’s guidance value of 20 µg/L. Dissolved oxygen (DO) concentrations met the AWQS in the upper waters of Onondaga Lake throughout the 2012 sampling period. Anoxic conditions prevailed in the lower waters during most of the summer stratified period. However, this situation is not uncommon in stratified lakes where the volume of the lower stratum (the hypolimnion) is relatively small. In New York, an estimated 70% of assessed lakes do not meet AWQS for DO in the deep waters.

The summer average chlorophyll-*a* (Chl-*a*) concentration in the upper waters of the lake was 6.3 µg/L in 2012, similar to values observed in recent years. The average and peak concentrations of this plant pigment have declined substantially, particularly since the phosphorus treatment upgrade at Metro in 2005. According to the Chl-*a* thresholds of 15 µg/L to represent minor blooms (impaired conditions) and 30 µg/L to represent major blooms (nuisance conditions), there were no algal blooms in Onondaga Lake during the summer recreational period (June–September) of 2012. A minimum summer average Secchi disk transparency of 1.5 meters at South Deep has been established for Onondaga Lake as a target for improved aesthetic appeal. During the summer of 2012, Secchi disk values ranged from 1.6 to 2.9 meters and averaged 2.1 meters. Water clarity conditions in 2012 were comparable to those observed in 2010 and 2011.

In 2012, the measured fecal coliform bacteria counts at the Onondaga Lake monitoring stations were in compliance with the AWQS (monthly geometric mean concentrations of 200 cfu/100 mL) at offshore and nearshore locations within the Class B portion of the lake. Fecal coliform counts exceeded the standard at a single site located adjacent to the Metro outfall within the Class C water segment in April. This location was in compliance with the fecal coliform standard during May–October. All other locations within the Class C water segment met the ambient water quality standard for all monitored months.

The concentration of total dissolved solids (TDS), which primarily reflects concentrations of major cations and anions, exceeded the AWQS of 500 mg/L by a wide margin. Exceedance of this standard is associated with the lake's natural hydrogeology and not with anthropogenic effects. The bedrock in Onondaga County is comprised of Paleozoic sedimentary rocks with high concentrations of calcium and sulfate, which contribute to the high TDS levels in Onondaga Lake and its tributaries.

The mass of phosphorus accumulated in the hypolimnion during the summer stratification interval has decreased by 90% since the 1990s as a result of lower primary production following the Metro phosphorus treatment upgrade and the increase in nitrate from year-round nitrification. The supply of nitrate to the lower waters in summer is being augmented by Honeywell during a three year (2011–2013) pilot test intended to control sediment release of mercury. This also affects phosphorus accumulation because phosphorus release from the sediments is blocked by maintenance of high nitrate concentrations in the hypolimnion. The complete absence of sediment phosphorus release under the high nitrate concentrations of 2012 clearly demonstrates the positive effect of nitrate.

Biology and Food Web

As phosphorus concentrations in Onondaga Lake have declined to mesotrophic levels, biological conditions have responded. Improved light penetration, a consequence of lower algal abundance, has resulted in expansion of macrophyte beds. This expanded coverage of macrophytes throughout the littoral zone has improved habitat and shelter for many fish and other aquatic organisms.

The biomass of phytoplankton in Onondaga Lake has declined rapidly since the 1990s, from a standing crop around 8 mg/L in 1998–99 to less than 1.5 mg/L after 2007. Phytoplankton abundance in 2012 was similar to values measured since 2007, with average algal biomass within the range expected for a mesotrophic lake (Chl-*a* of 3.5-9.0 µg/L). The composition of the phytoplankton community has changed from one dominated by undesirable blue-green algae (cyanobacteria) and dinoflagellates to one dominated by more desirable diatoms and green algae.

Macrophyte coverage in 2012 was the highest observed since monitoring began in 2000, with over 500 acres of plants covering 65 percent of the littoral zone. Macrophyte coverage has expanded to cover approximately five times more of the littoral zone in 2012 compared to a decade ago, providing more complex habitat for many aquatic organisms. Overall relative abundance was dominated by water stargrass (35%) and sago pondweed (18%).

The size structure of the zooplankton community is regulated by the selective feeding of fish on zooplankton. The average dry weight biomass of zooplankton samples collected in Onondaga Lake in 2012 was slightly higher than in 2011, the lowest recorded in the AMP. Zooplankton biomass has been low since 2010, and there is an overall long-term decline. Zooplankton species and size composition indicate high planktivory continuing in 2012, similar to 2010–2011. The low biomass of *Daphnia* from 2003 through 2007 and 2010 through 2012 is attributed to predation pressure by abundant alewife during these periods.

Zebra mussels were first recorded in Onondaga Lake in 1992, although they did not become abundant until 2000. A second related species, the quagga mussel, was first detected in Onondaga Lake in 2005. Abundance of quagga mussels has been similar to abundance of zebra mussels since 2010. The average density of dreissenid mussels declined slightly in 2012 following a large increase in 2011. Quagga mussels dominated mussel biomass in 2012 (90%) due to their larger average size.

Changes in the fish community of Onondaga Lake have occurred as water quality and habitat conditions have improved. Centrarchid species (largemouth and smallmouth bass, pumpkinseed, bluegill, and rock bass) and bullhead construct nests in the littoral zone of the lake. In 2012, 2,416 nests were observed, with approximately two-thirds in the North basin and one-third in the South basin. The occurrence of nests in the north and south basins has been more evenly distributed during the past several years, primarily due to increased numbers of nests in the south basin since 2008. The majority of the nests observed in 2012 were sunfish (pumpkinseed, bluegill, and green sunfish) accounting for 70% of the total nests identified. Lesser amounts of largemouth bass (3.5%) and bullhead (0.41%) were also observed. The remaining 26% of the nests were described as unknown (nest observed without an adult fish present).

Nine fish species were captured during the 2012 larval seine events, including pumpkinseed, bluegill, banded killifish, brook silverside, logperch, bluntnose minnow, golden shiner, round goby, and yellow perch. Overall catch per unit effort (CPUE) was higher in 2012, compared to other years when larval seines were used (2000 through 2003), although the number of species was lower. Young-of-year bluegill and pumpkinseed, common carp, largemouth and smallmouth bass, rock bass, and round goby were captured by littoral zone seining in 2012. The number of young-of-year fish species has steadily declined since 2008 when 13 species were caught. The overall number of species represented in the 2012 juvenile catch (15) was approximately double the number of young-of-year species. Alewife, pumpkinseed, largemouth bass, and gizzard shad juveniles each represented approximately 20% of the overall catch.

In 2012, 21 species of pelagic adults were collected using experimental gill nets during late spring and fall. White perch was dominant lakewide, with yellow perch and largemouth bass making significant contributions. Overall CPUE for pelagic adults was higher than rates seen in previous years. The number of littoral adult species (28) captured in 2012 by electrofishing tied the record high (2009 and 2010) observed since the program began. Alewife and gizzard shad were the dominant littoral species. Yellow perch and pumpkinseed were the next most abundant. Overall CPUE for littoral adults in 2012 was lower than in 2011, but was one of the higher rates observed over the entire program. The black bass population is increasingly dominated by largemouth bass in both adult and young-of-year life stages. Smallmouth bass catch rates continue to decline, likely indicative of the changing conditions in the littoral zone with increased macrophyte coverage more suitable for largemouth bass.

Overall trends in catch rates have varied by fish species since 2000. Several species have increased recently, including largemouth bass, gizzard shad, brown bullhead, and yellow perch; while catch rates of smallmouth bass, bluegill, pumpkinseed, white perch, and carp have declined. These patterns likely reflect the changing habitats in the lake including increased macrophyte coverage, increased mussel abundance, and changes in the fish community associated with alewife. In Onondaga Lake, adult fish species richness has gradually increased since 2000. In 2012, a total of 37 adult species were captured during electrofishing, gill netting, and seining surveys. Since the monitoring program started in 2000, fifty adult fish species have been identified in the lake.

DELTFM (Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies) abnormalities showed an overall increase from 2003 to 2009, but have decreased since then.

DELTFM abnormalities began declining in 2010 and have steadily decreased to 5.4% in 2012. The majority of abnormalities in the Onondaga Lake fish community in 2012 were lesions (69%), followed by deformities (24%). Erosions, tumors, malignancies, and fungal infections were rare (7% combined). Eighteen species of adult fish were found with DELTFM abnormalities in 2012, similar to 2011 and recent previous years.

Water Quality in the Three Rivers System

Water quality conditions in lotic ecosystems are highly dependent on the magnitude and timing of flow. Flow rates in the Seneca and Oneida Rivers were near or below long-term median flows for much of 2012. The summer average (July–September) flow in the Seneca River was 735 cfs, less than one-half the long-term summer average of 1,634 cfs. Summer average flow in the Oneida River was 356 cfs in 2012, 72% lower than the long-term summer average of 1,261 cfs. The lowest 7-day average flow that occurs on average once every 10 years (7Q10) is a commonly used statistic for identifying critical low flow conditions in rivers and streams. Flows in the Seneca River were below the 7Q10 of 374 cfs on 10 days during the summer of 2012. Only on July 1 did flow in the Oneida River fall below the 7Q10 of 237 cfs.

Dreissenid mussels were first observed in the Seneca River in 1991, and dense populations had developed by 1993. These invasive, filter-feeding bivalves have had a considerable impact on water quality in the Three Rivers System since their introduction in the early 1990s. The dreissenid mussel invasion has converted the Seneca River at Baldwinsville from a low clarity, phytoplankton rich, nutrient depleted system, with nearly saturated oxygen concentrations, to a system with increased clarity, low phytoplankton levels, highly enriched in dissolved nutrients, with substantially undersaturated oxygen concentrations. Increased water clarity has led to a major expansion in macrophyte coverage in many areas of the Three Rivers System. Conspicuous signatures of dreissenid mussels were observed in the 2012 survey data, including decreases in turbidity, dissolved oxygen, and chlorophyll-*a*, and increases in ammonia and soluble reactive phosphorus concentrations from Cross Lake to the Onondaga Lake outlet.

Dissolved oxygen concentrations were below the instantaneous minimum AWQS of 4 mg/L at all six locations monitored during the 2012 synoptic survey conducted on July 19. At five of the six locations dissolved oxygen concentrations were extremely low (<0.3 mg/L) in the lower portion of the water column, suggesting widespread anoxic conditions. High frequency measurements of dissolved oxygen made during the June to November period of 2012 documented low dissolved oxygen conditions in the Seneca River at Buoy 316, downstream of Baldwinsville. Based on measurements made 1 meter above the bottom, dissolved oxygen concentrations were below the daily average standard of 5 mg/L on 42% of the days for which measurements were available. Concentrations lower than the 4 mg/L standard were measured on 35% of the days in the monitoring period. In 2011, the frequency of contravention of the 5 mg/L and 4 mg/L standards at Buoy 316 was 17% and 8%, respectively. The apparent worsening of dissolved oxygen conditions in 2012 was likely a result of much lower summertime flows in 2012 (average = 735 cfs) compared to 2011 (average = 2,528 cfs).

Emerging Issues and Recommendations

The AMP continues to evolve in response to new information and emerging issues affecting Onondaga Lake, its tributaries, and the Three Rivers System. On February 28, 2013, OCDWEP submitted the 2013 Annual AMP sampling workplan to NYSDEC. A number of revisions were proposed for the Onondaga Lake, Tributary, and River sampling programs. With the completion of advanced wastewater treatment at Metro, which became operational in 2005, several notable water quality improvements have been realized in the lake. In addition several major milestones have recently been achieved, including successful completion of the Onondaga Lake Water Quality Modeling Project related efforts in 2012 and the NYSDEC's issuance of the Final Onondaga Lake TMDL for Phosphorus, dated May 2012. The proposed scope of the 2013 AMP reflects these important accomplishments.

A detailed re-evaluation of the sampling program was undertaken, based on defining program objectives in relation to the collection of meaningful data. This evaluation was completed taking into consideration future data collection needs, effort to reduce data redundancy and completion of additional data analysis used in supporting these modifications. The proposed modifications support a focused sampling program that will produce the data needed to continue assessment of compliance with AWQS, track progress toward use attainment, and support future management decisions. The program will continue to incorporate flexibility and allocate resources in response to assessing additional chemicals or potential sources as needed during the course of the year. It is OCDWEP's goal to ensure that all elements of the AMP provide meaningful data in a scientifically defensible and cost-effective manner.

Highlighting Improvements in Onondaga Lake

Introduction

This section highlights selected water quality and biological improvements that have been documented in the lake, and reports on long-term changes brought about by rehabilitation efforts. Following this brief summary is the main body of the 2012 Annual AMP Report, where the results are discussed in more detail and supporting documentation is provided.

Dramatic Reductions in Ammonia and Phosphorus Loading to Onondaga Lake from Improved Wastewater Treatment

Major reductions in the loading of ammonia (NH_3-N) and phosphorus (P) to Onondaga Lake from Metro have been achieved through implementation of state-of-the-art wastewater treatment technologies. Progressive improvements in treatment have been made since the 1970s. The most recent Metro upgrades were designed to meet specific water quality goals in Onondaga Lake. Total Maximum Daily Load (TMDL) analyses established the loading reductions required to meet these water quality goals.

The Biological Aerated Filter (BAF) system, which came on line in January 2004, provides year-round nitrification of ammonia, a potentially toxic form of nitrogen (N). This treatment resulted in a 98% decrease in the ammonia loading to the lake from Metro since the mid-1990s (Figure HI-1) and reduced Metro's contribution to the total annual load (Metro + tributaries) from 91% to 53% (Figure HI-2). Implementation of BAF treatment also reduced the loading of nitrite (NO_2-N), another form of nitrogen that is a potentially toxic to aquatic organisms. Loading of nitrate (NO_3-N), yet another form of nitrogen, has increased as a result of the BAF treatment process. However, this form of nitrogen is not a water quality concern in Onondaga Lake. In fact, the increases in nitrate are having beneficial effects on the lake by diminishing the cycling of phosphorus and mercury in the lower waters and bottom sediments.

A physical-chemical High-Rate Flocculated Settling (HRFS) treatment technology, known as Actiflo®, came on line in February 2005 to provide additional phosphorus removal. This treatment resulted in an 85% decrease in total phosphorus (TP) loading since the early 1990s (Figure HI-3) 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 37% in 2012 (Figure HI-4).

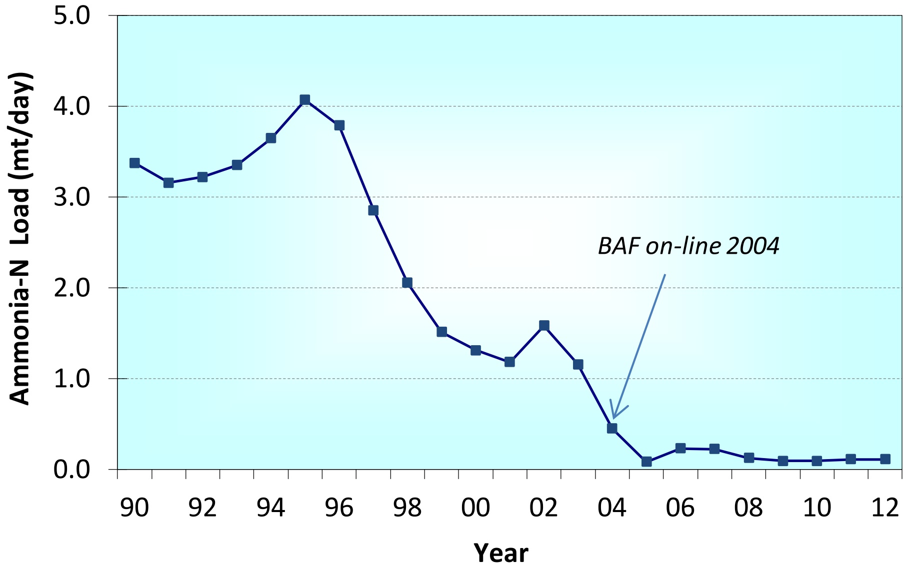


Figure HI-1. Time plot of the annual daily average Metro (outfalls 001+002) ammonia-N loading (metric tons/day) to Onondaga Lake, 1990–2012.

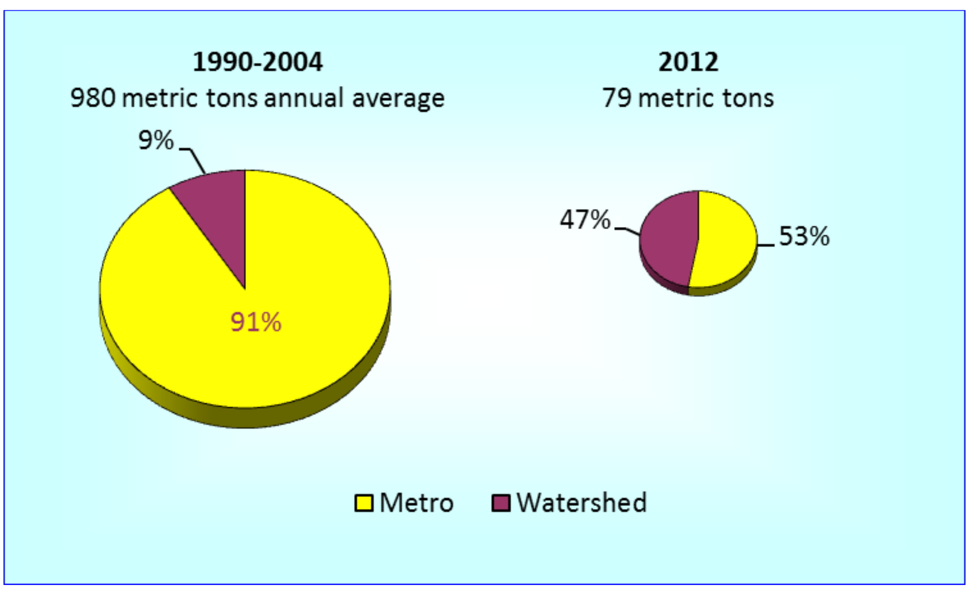


Figure HI-2. Contributions of Metro (outfalls 001+002) and the watershed to the total annual input of ammonia to Onondaga Lake, average for 1990–2004 compared to 2012.

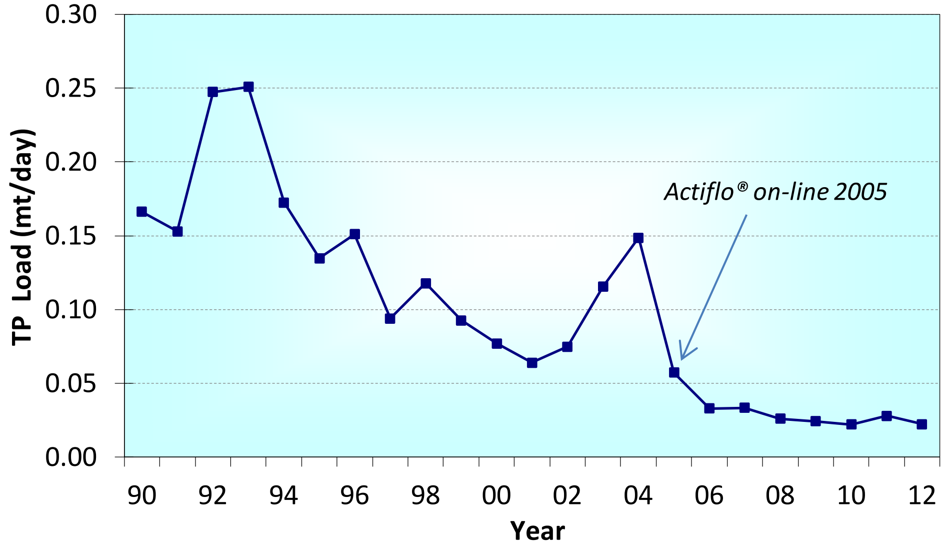


Figure HI-3. Time plot of the annual daily average Metro (outfalls 001+002) total phosphorus (TP) loading (metric tons/day) to Onondaga Lake, 1990–2012.

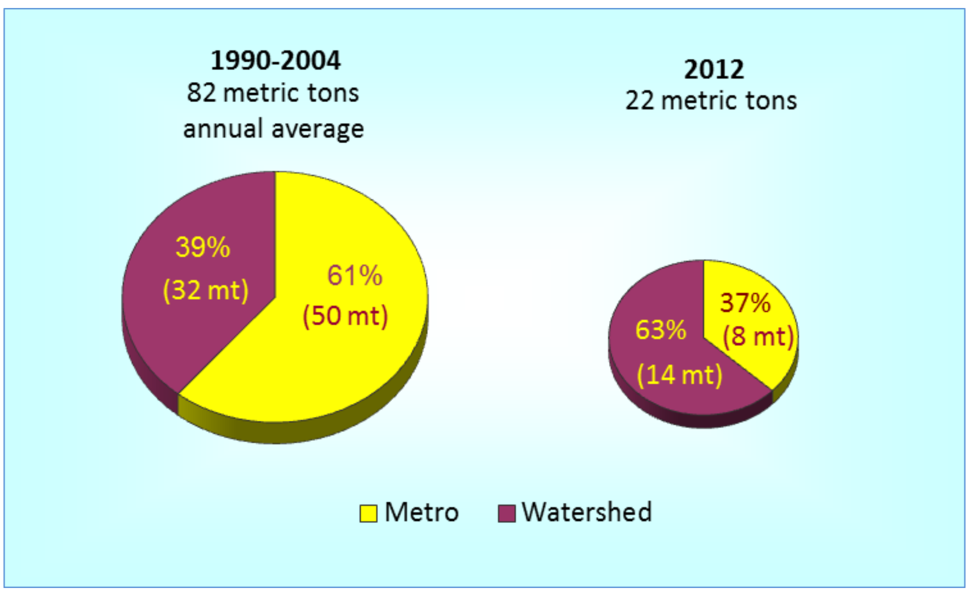


Figure HI-4. Contributions of Metro (outfalls 001+002) and the watershed to the annual input of total phosphorus to Onondaga Lake, average for 1990–2004 compared to 2012.

Remarkable Improvements in Onondaga Lake from Metro Upgrades

The inputs of ammonia, nitrite, and phosphorus from Metro caused severely degraded conditions in Onondaga Lake during earlier portions of the monitored record. Exceedence of water quality standards to protect against the toxic effects of ammonia and nitrite occurred frequently in the upper waters of the lake. The high phosphorus loads caused a severe case of cultural eutrophication (major increases in the production of microscopic plants – phytoplankton). Associated features of degraded water quality included: (1) high concentrations of phytoplankton, including nuisance conditions described as blooms; (2) low water clarity, as measured by a Secchi disk (SD); (3) high rates of deposition of oxygen-demanding organic material into the lower layers of the lake; (4) rapid loss of oxygen from the lower layers of the lake; and (5) depletion of oxygen in the upper layers of the lake during the fall mixing period.

In the context of lake rehabilitation examples from North America and beyond, the water quality improvements in Onondaga Lake have been extraordinary. While lakes usually respond to reductions in nutrient inputs, the response is often slow and the degree of improvement less than expected (Cooke et al. 2005). In contrast, water quality improvements in Onondaga Lake were both substantial and rapid following Metro upgrades. Exceedance of the ammonia and nitrite standards were eliminated by implementation of the BAF treatment process. The reductions in ammonia concentrations in the upper waters of the lake (Figure HI-5) have enabled a more diverse biota. In 2008, New York State Department of Environmental Conservation (NYSDEC) removed Onondaga Lake from the state's 303(d) list for impairment by excessive ammonia concentrations.

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 HI-6). The summer average concentration in 2012 was 22 micrograms per liter (µg/L), slightly higher than the guidance value of 20 µg/L established by New York State. This is a modest increase from the 2011 value of 20 µg/L. The summer average total phosphorus concentration was less than 20 µg/L in 2008 and 2009. Similar total phosphorus concentrations are observed in several nearby lakes with intermediate levels of phytoplankton production. 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.

Occurrences of phytoplankton 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 HI-7). No major blooms have occurred since the upgrade, and no minor blooms have occurred during summer since 2008. Chlorophyll-*a* concentrations approached the 15 µg/L threshold in May and July of 2012. Water clarity has also improved, though biological (food web) effects also cause noteworthy variations in this water quality metric.

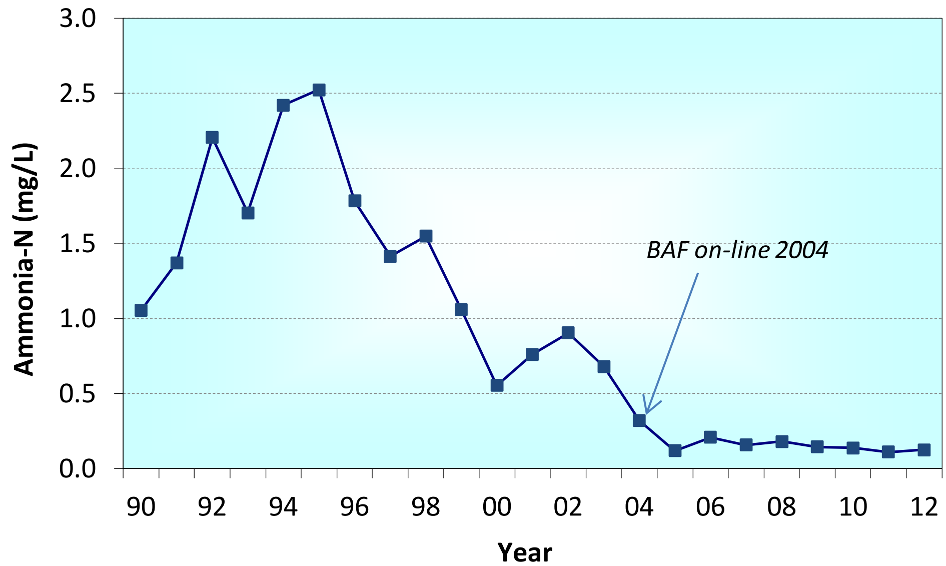


Figure HI-5. Annual average ammonia-N concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2012.

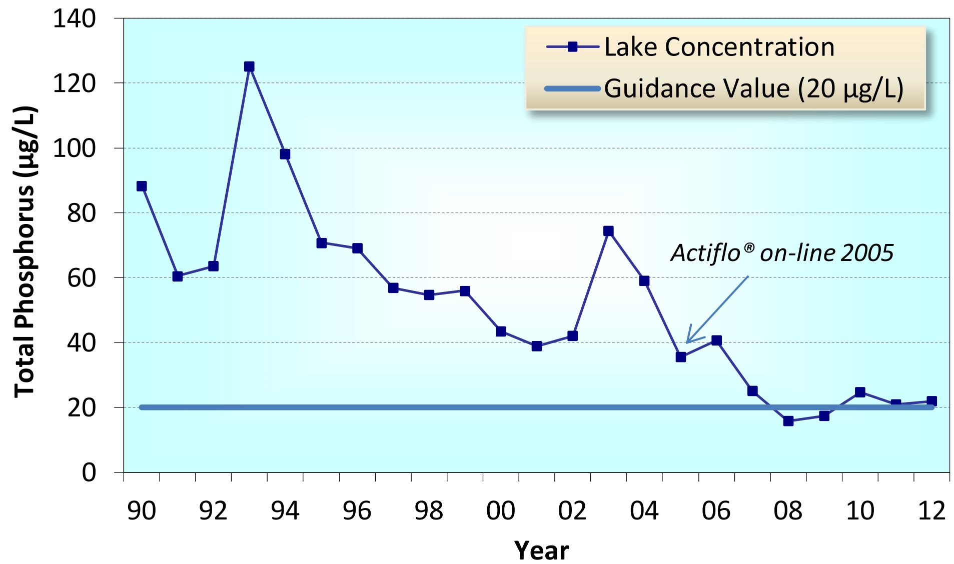


Figure HI-6. Summer (June to September) average total phosphorus concentration in the upper waters (0-3 meters) of Onondaga Lake, 1990–2012.

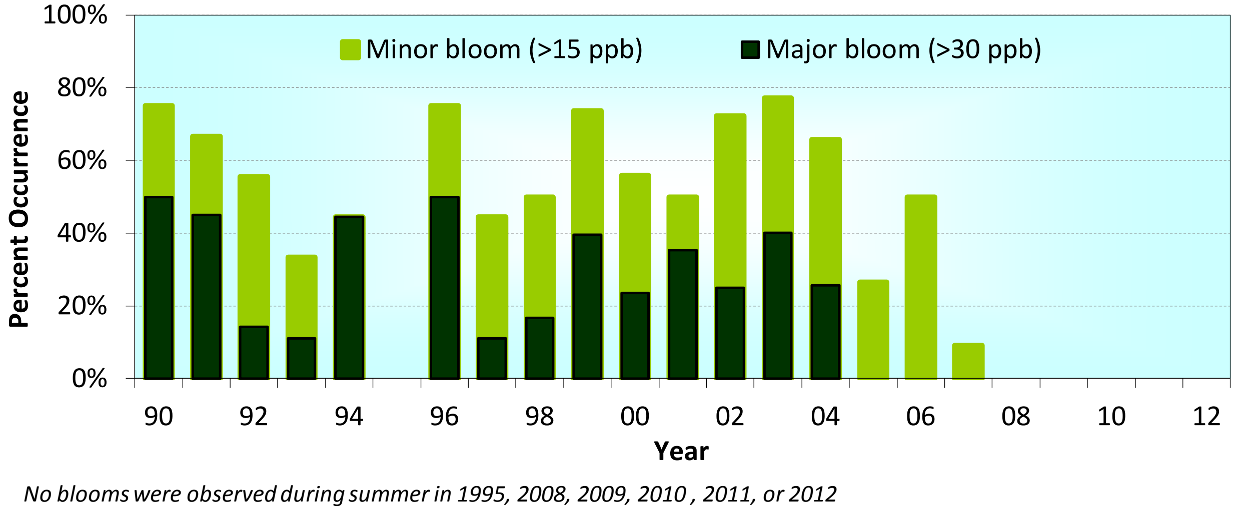


Figure HI-7. Summer (June to September) algal bloom percent occurrences in Onondaga Lake evaluated annually for the 1990–2012 period, based on chlorophyll-*a* measurements.

Reductions in phytoplankton growth have led to decreased deposition of organic matter (settling phytoplankton) and thereby reduced oxygen demand in the lower layers of the lake. As a result, the oxygen resources of the lower layers have improved, according to a metric termed "volume-days of anoxia" (Figure HI-8), which takes into account both the volume of the lake affected by low dissolved oxygen concentrations and the duration of these conditions. Two different low oxygen thresholds are presented (Figure HI-8), corresponding to hypoxia (less than 2 milligrams per liter (mg/L) and anoxia (less than 0.5 mg/L). Decreasing (improving) trends are shown for both thresholds. The oxygen status of the upper waters through the fall mixing period has also improved substantially, as indicated by consistently higher annual minima in oxygen concentration since 2005 (Figure HI-9). Oxygen concentrations in the upper waters have remained well above the standard to protect aquatic organisms since Actiflo® was implemented.

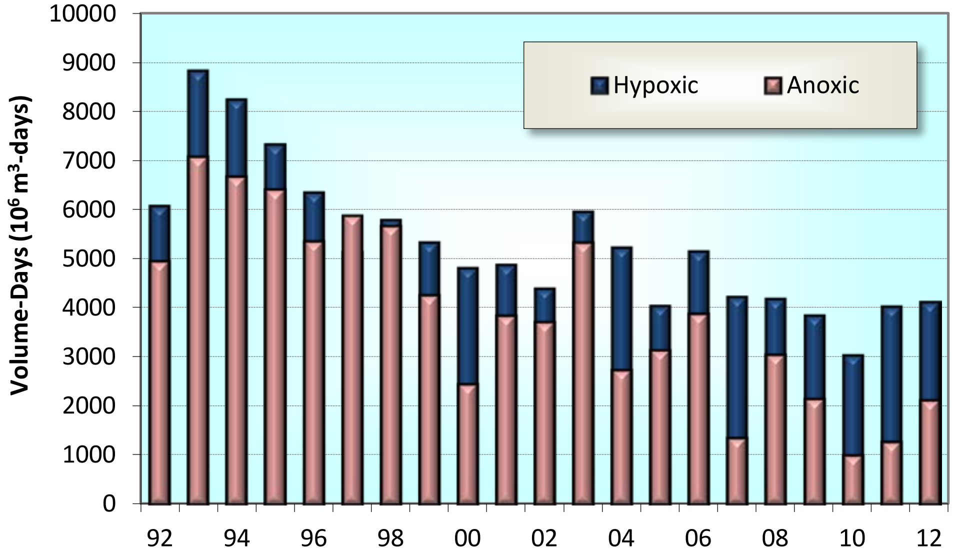


Figure HI-8. Volume-days of anoxia (dissolved oxygen less than 0.5 mg/L) and hypoxia (dissolved oxygen less than 2 mg/L), in Onondaga Lake during the summer, 1992–2012.

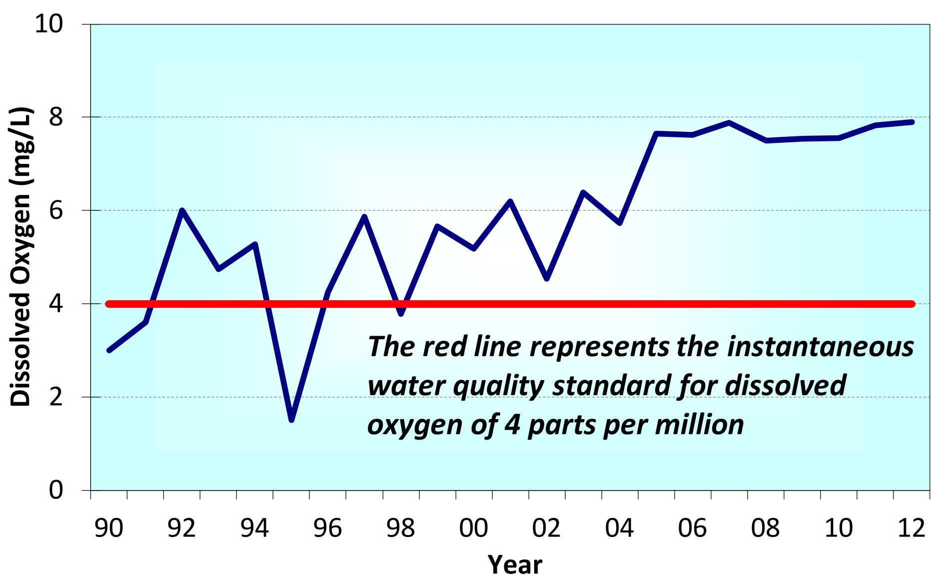


Figure HI-9. Minimum dissolved oxygen (DO) concentration in the upper waters (0-3 meters) of Onondaga Lake during fall turnover (October), annually 1990–2012.

Food Web Effects and Impacts on Water Clarity

Because the AMP includes monitoring of water quality and biological parameters, it is possible to analyze the relative effects of “bottom-up” (nutrient management) and “top-down” (food web) controls on the lake’s trophic state. Clearly, treatment upgrades at Metro have affected the lake’s algal abundance, water clarity, DO concentrations, and ammonia-N concentrations. Food web effects also are important, however, and now that Onondaga Lake is in the mesotrophic range (i.e., total phosphorus between 10 and 35 µg/L and algal biomass 3 to 5 mg/L), the impact of fluctuations in the abundance of alewife and dreissenid (zebra, quagga) mussels has become increasingly apparent.

Alewife and dreissenid mussels have a major impact on food web dynamics in Onondaga Lake. Analysis of the 2012 data showed higher alewife abundance in the spring of 2012 than in the spring of 2011 (Appendix F-05), although catches in electrofishing gear were lower in 2012 compared to 2011. Alewife abundance was high enough to continue to impact the larger zooplankton, with *Daphnia* essentially non-existent since the fall of 2009. The average zooplankton size in 2012 increased slightly compared to 2010 and 2011, but was still at the lower end of observed values (Figure HI-10). Phytoplankon biomass has declined as a result of reduced phosphorus loading by Metro and is dominated by diatoms; however, annual variation also is affected by the changes in the zooplankton size structure. Smaller zooplankton are less efficient grazers of phytoplankton than larger ones, and phytoplankton abundance typically increases as a result. More abundant phytoplankton results in decreased water clarity, typically measured as Secchi disk transparency. The relationship between zooplankton size and water clarity is illustrated in Figure HI-11.

The impact of zebra and quagga mussel populations on Onondaga Lake currently is not fully understood, but unquestionably plays a role in the food web dynamics. Both quagga and zebra mussels filter large amounts of water (up to two liters per day as an adult) in order to draw in phytoplankton, small zooplankton, and bacteria they use as food. The removal of phytoplankton through this filtering action potentially could increase water clarity and reduce food availability for fish and other organisms. Additionally, waste produced by mussels could potentially affect the nitrogen and phosphorous budgets of Onondaga Lake.

Improved Water Quality Reflected in a Changed Biological Community

The reduction in phosphorus also has led to changes in the phytoplankton community with no undesirable blue-green algal blooms reported again in 2012 and diatoms dominating the community. Aquatic plants have continued to expand within Onondaga Lake, with over 500 acres covering 65 percent of the littoral zone in 2012. This increased coverage has notably improved largemouth bass habitat with catch rates remaining high again in 2012.

Electrofishing catch rates of largemouth bass generally increased from 2000 to 2009, with an apparent leveling more recently, while the catch of smallmouth bass has declined since a peak in 2008 (Figure HI-12). In Onondaga Lake, fish species richness (number of species) has fluctuated annually since the start of the AMP. The highest number of species was again captured in 2012, with 28 adult species captured during spring and fall electrofishing surveys (similar to 2009 and 2010). Since the start of the AMP fisheries program in 2000, 50 adult species have been captured and identified from Onondaga Lake. The lake is an open system, allowing migration of fish between the Lake, its tributaries, and the adjoining Seneca River. These community interactions are largely responsible for the fish diversity of Onondaga Lake.

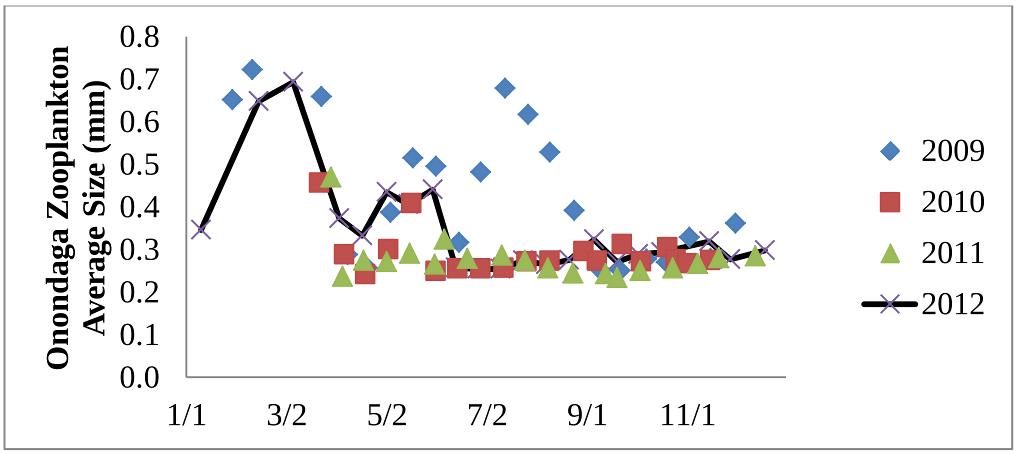


Figure HI-10. Seasonal development of average crustacean zooplankton length (mm), 2009 through 2012. Lines connect the values from 2012.

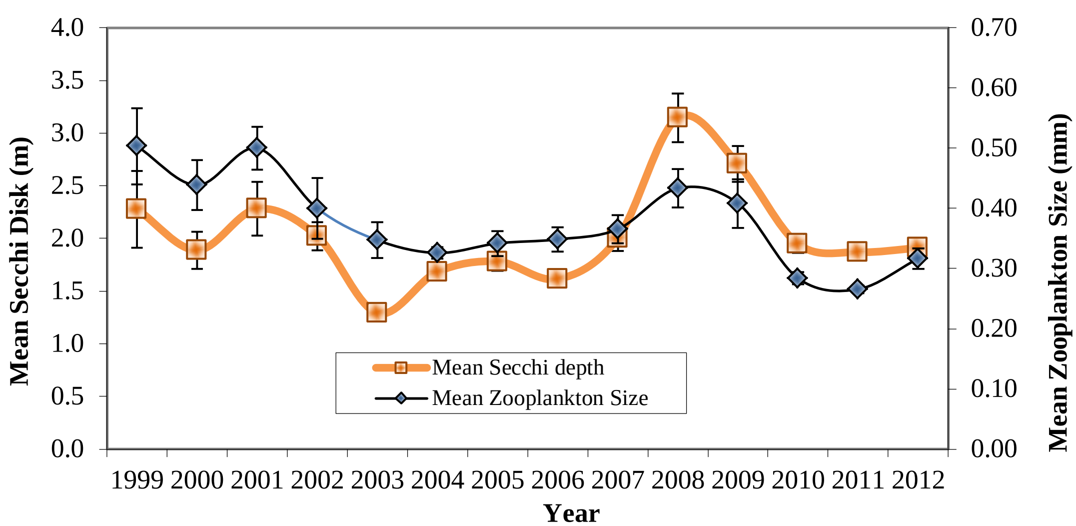


Figure HI-11. Growing season (April-October) mean (± standard error) Secchi disk depth and zooplankton size for Onondaga Lake, 1999–2012.

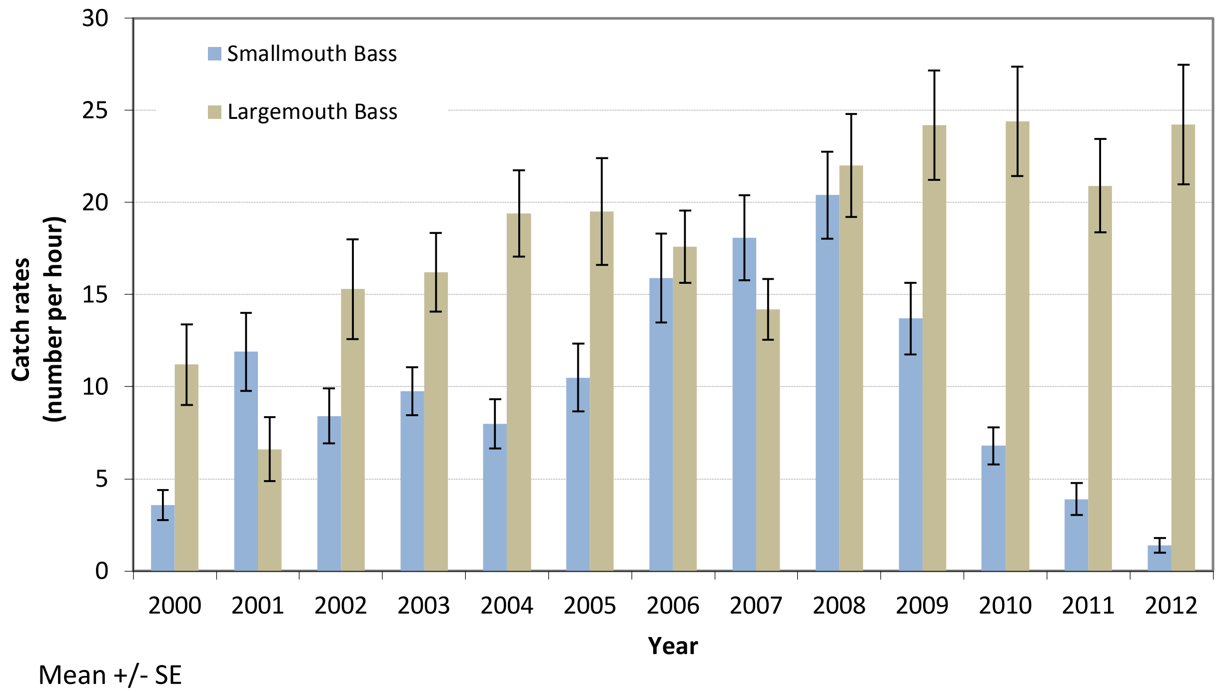


Figure HI-12. Trend in annual average catch rates (number per hour) from two electrofishing events (spring and fall) of largemouth and smallmouth bass combined in Onondaga Lake from 2000 to 2012.

Diversity of the fish community also fluctuates in response to the periodic peaks and crashes of two species of clupeid: alewife and gizzard shad. Abundance of these two species of the herring family is highly variable, as Onondaga Lake is near the northern edge of their geographic range, and both species periodically exhibit significant winter mortality. Extremes in recruitment are common; both species periodically produce very strong year classes that dominate the catch for years, as alewife can live to 10 years and gizzard shad even longer. In 2012, alewife catch per unit effort (CPUE) was approximately two thirds lower than in 2011 (588 versus 1,898, respectively) while gizzard shad CPUE was slightly higher in 2012 (1,344) than in 2011 (1,081).

Onondaga Lake's aquatic food web continues to include shifting dominance of fish species, both native and exotic, with increasingly complex pathways of material and energy transfer among the different life stages. Yellow perch continued to increase in 2012. Largemouth bass have increased since 2000, likely reflecting the increasing complexity of the littoral zone and increased macrophyte coverage. In 2012, macrophytes expanded further with over 500 acres covering 65 percent of the littoral zone. This increasing complexity with regard to energy sources and energy flow results in an ecosystem that may be more resilient to environmental stress. As lake water quality continues to improve, resulting in more diverse and higher quality habitat conditions, increases in aquatic species diversity, abundance, and interrelatedness also can be expected.

Suitability of Nearshore Areas for Contact Recreation

Two parameters are used to assess the suitability of a waterbody for contact recreation: fecal coliform bacteria (FC) and water clarity. The fecal coliform bacteria standard is used by NYSDEC to evaluate water quality and by New York State Department of Health (NYSDOH) to evaluate suitability for swimming at designated beaches. During the April to October interval of 2012, bacteria levels in Class B areas of Onondaga Lake did not exceed the standard established for contact recreation. One site, located within the Class C segment at the lake's southeastern shoreline, exceeded the bacteria standard only during the month of April. While there is no NYSDEC standard for water clarity, NYSDOH has a swimming safety guidance value for designated bathing beaches of 4 feet or 1.2 meters. The NYSDOH swimming safety guidance value was met in Class B waters throughout the summer recreational period of 2012. Monitoring locations near the mouths of Onondaga Creek and Harbor Brook failed to meet the guidance value on 15% and 5% of the monitored days, respectively. Sediment inputs from the mud boils on upper Onondaga Creek likely contributed to the diminished water clarity in nearshore areas of the Class C segment in the southern portion of the lake. Presently, Onondaga Lake has no designated bathing beaches.

Bald Eagle with fish from Onondaga Lake

Onondaga County Initiatives and AMP Modifications

In 2012, Onondaga County continued work on both "gray" and "green" infrastructure projects to reduce wet weather discharges from combined sewer overflows (CSOs). Gray infrastructure projects include sewer separation, capture of floatable materials, and maximization of system storage capacity. In 1998, there were 72 active CSOs in the collection system (outfall points with the potential to discharge combined sewage). These CSOs discharged to three tributaries to Onondaga Lake: Onondaga Creek, Harbor Brook, and Ley Creek. Through 2012, the Amended Consent Judgment (ACJ) projects have led to the abandonment (completely eliminated or converted to a storm discharge point only) of 26 of these collection system overflow points by separating combined sewers where feasible, maximizing the capacity of the sewerage system, and building the Hiawatha and Midland regional treatment facilities.

Substantial progress was made on a number of gray infrastructure projects in 2012. The CSO 044 Conveyances Project, designed to capture 6 million gallons of CSO volume that was discharged to Onondaga Creek annually, was completed in 2012. Construction of the Harbor Brook Interceptor Sewer Replacement Project was finished in 2012. This project will capture a CSO volume of 36 million gallons through upgrades to the existing Harbor Brook Interceptor. In 2012, construction was completed on the CSO 022 and CSO 045 Sewer Separation Projects, which will capture a combined 1 million gallons of CSO volume per year. Work on two CSO storage facilities advanced in 2012. The Clinton and Harbor Brook Storage Facilities will provide 55 and 92 million gallons of annual CSO capture, respectively. Construction of the Clinton Storage Facility was approximately 60% complete by 12/31/12, while construction of the Harbor Brook Storage Facility was about 50% complete. Construction is scheduled to be completed at both sites by 12/31/13. Green infrastructure components have been incorporated in many of these gray infrastructure projects, including bioretention basins, tree plantings, green roofs, and rain gardens.

CSO 045 – Completed Project – September 2012

Arbor Day—Bellevue Tree Planting

OnCenter Green Roof

Rain Barrel Program

Green infrastructure projects increase infiltration, capture, and reuse of storm runoff before it enters the sewer system. County facilities and other urban areas are implementing "green infrastructure" solutions to help manage urban storm runoff before it enters the CSO system. Since 2010, over 120 green infrastructure projects have been completed as part of the "Save the Rain" initiative, reducing inputs of stormwater runoff and pollution to Onondaga Lake and its tributaries. Building on the success of the 2011 "Project 50" campaign, the STR program had another impressive year in 2012 with over 50 GI projects completed. These projects included 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. A "Save the Rain" initiative is underway to educate watershed residents about ways to capture and use rainwater. An informational website (http://savetherain.us/) describes current initiatives and incentive programs for watershed residents to reduce impervious areas.

Onondaga County worked with NYSDEC and ASLF during 2011 to modify the tributary monitoring program to address the requirements of the Fourth Stipulation Amending the ACJ, which directs the County to evaluate the effectiveness of the green and gray infrastructure improvements. Enhanced tributary monitoring includes additional storm event sampling on Onondaga Creek and Harbor Brook, following completion of the Clinton and lower Harbor Brook storage facilities. The enhanced tributary monitoring program also includes limited testing for the presence and concentration of priority pollutants, such as heavy metals, pesticides, and other compounds. The additional monitoring was initiated in 2012, following NYSDEC approval of the work plan in 2011. Detailed results of this sampling effort are reported in Section 4.2.1.

The 2012 monitoring results indicate that Onondaga Lake tributaries were generally in compliance with ambient water quality standards; however, contraventions of the standard for fecal coliform bacteria were widespread. The highest concentrations of fecal coliform bacteria were measured near the mouths of Onondaga Creek, Ley Creek, and Harbor Brook. The enhanced tributary monitoring program will support further evaluation of fecal coliform levels, including assessment of long-term trends and potential improvements related to both gray and green infrastructure projects. A rigorous statistical evaluation of fecal coliform data from Onondaga Lake tributaries is presented in Section 4.3.5 of this report.

Canada Geese near the Onondaga Lake Outlet

Section 1. Introduction to the AMP

1.1 Regulatory Requirements

The 2012 Annual Ambient Monitoring Program (AMP) report has been prepared and submitted to the New York State Department of Environmental Conservation (NYSDEC) to comply with a judicial requirement set forth in the 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation. The parties have modified the ACJ four times since 1998, most recently by stipulation in November 2009. The ACJ requires a series of improvements to the County's wastewater collection and treatment infrastructure, and an extensive monitoring program (the AMP) to document the improvements achieved by these measures. Onondaga County Department of Water Environment Protection (WEP) is responsible for implementing the AMP and reporting its findings. Links to the ACJ and the Fourth Stipulation are posted on the Onondaga County web site http://www.ongov.net/wep/we15.html.

1.2 Classification and Best Use

NYSDEC classifies surface waters, including lakes, rivers, streams, embayments, estuaries and groundwater with respect to their best use. Onondaga Lake and its tributaries are currently classified as Class B and Class C waters (Table 1-1; Figure 1-1). The best usages of Class B waters are primary and secondary water contact recreation and fishing (New York Codes, Rules and Regulations (NYCRR) Part 701.7). Primary water contact recreation includes activities that immerse the body in the water, such as swimming; secondary water contact recreation includes activities without full immersion, such as boating. In addition, Class B waters shall be suitable for fish, shellfish, and wildlife propagation and survival (NYCRR Part 701.7). The best usage of Class C waters is fishing. These waters shall also be suitable for fish, shellfish and wildlife propagation and survival. Class C waters shall be suitable for primary and secondary water contact recreation, although other factors may limit the use for these purposes (NYCRR Part 701.8). A listing of water quality impairments in Onondaga Lake and its watershed is provided in Table 1-2.

1.3 AMP Objectives and Design

Onondaga County WEP designed the AMP to meet several specific objectives related to the effectiveness of the required improvements to the wastewater collection and treatment infrastructure. Trained field technicians collect representative samples from a network of permanent sampling locations along the lake tributaries, nearshore and deep stations in Onondaga Lake (Figure 1-2), and along the Three Rivers System (see Figure 7-1, in Section 7), and evaluate water quality conditions and the nature of the biological community. These data are interpreted to determine whether designated uses are, in fact, supported in these waters.

Table 1-1. Summary of regulatory classification of Onondaga Lake and streams within the Onondaga Lake watershed.

Lake/Stream	Description of Lake/Stream segment	Regulatory Classification	Standards
Onondaga Lake	northern 2/3 of lake, excluding the area adjacent to Ninemile Creek	B	B
	southern 1/3 of lake and waters adjacent to the mouth of Ninemile Creek	C	C
Onondaga Creek	enters Onondaga Lake at southeastern end. Mouth to upper end of Barge Canal terminal (0.85 miles)	C	C
	upper end of Barge Canal terminal to Temple Street (1.7 miles)	C	C
	from Temple Street, Syracuse to Tributary 5B (4.4 miles)	B	B
	from Tributary 5B to Commissary Creek (1.9 miles)	C	C
	from Commissary Creek to source	C	C(T)
Ninemile Creek	enters Onondaga Lake from south approximately 2.25 miles from lake outlet along west shore of lake. From mouth to Allied Chemical Corp. water intake located on creek 0.6 mile upstream of Airport Rd and 0.6 mile downstream of Rt. 173 bridge at Amboy	C	C
	from water intake between Airport Rd and Rt. 173 to outlet of Otisco Lake	C	C(T)
Harbor Brook	enters Onondaga Lake at the southernmost point of the lake and within the City of Syracuse. From mouth to upper end of underground section, at Gifford Street (approx. 1.9 miles)	C	C
	from upper end of underground section to City of Syracuse line (1.3 miles)	B	B
	from City of Syracuse City line to source	C	C(T)
Ley Creek	enters Onondaga Lake 0.2 mile southeast of point where City of Syracuse line intersects east shore of lake. From mouth to Ley Creek sewage treatment plant outfall sewer	C	C
	from Ley Creek sewage treatment plant outfall sewer to South Branch. Tribs. 3-1A and 3-1B enter from north approximately 3.0 and 3.1 miles above mouth respectively	B	B
Bloody Brook	enters Onondaga Lake 2.25 miles southeast of outlet. From mouth to trib. 1 of Bloody Brook (approximately 0.37 miles from mouth)	B	B
	from trib. 1 of Bloody Brook to source	C	C

Source:
6 NYCRR Part 895 Onondaga Lake Drainage Basin, on-line at http://www.dec.ny.gov/regs/4539.html

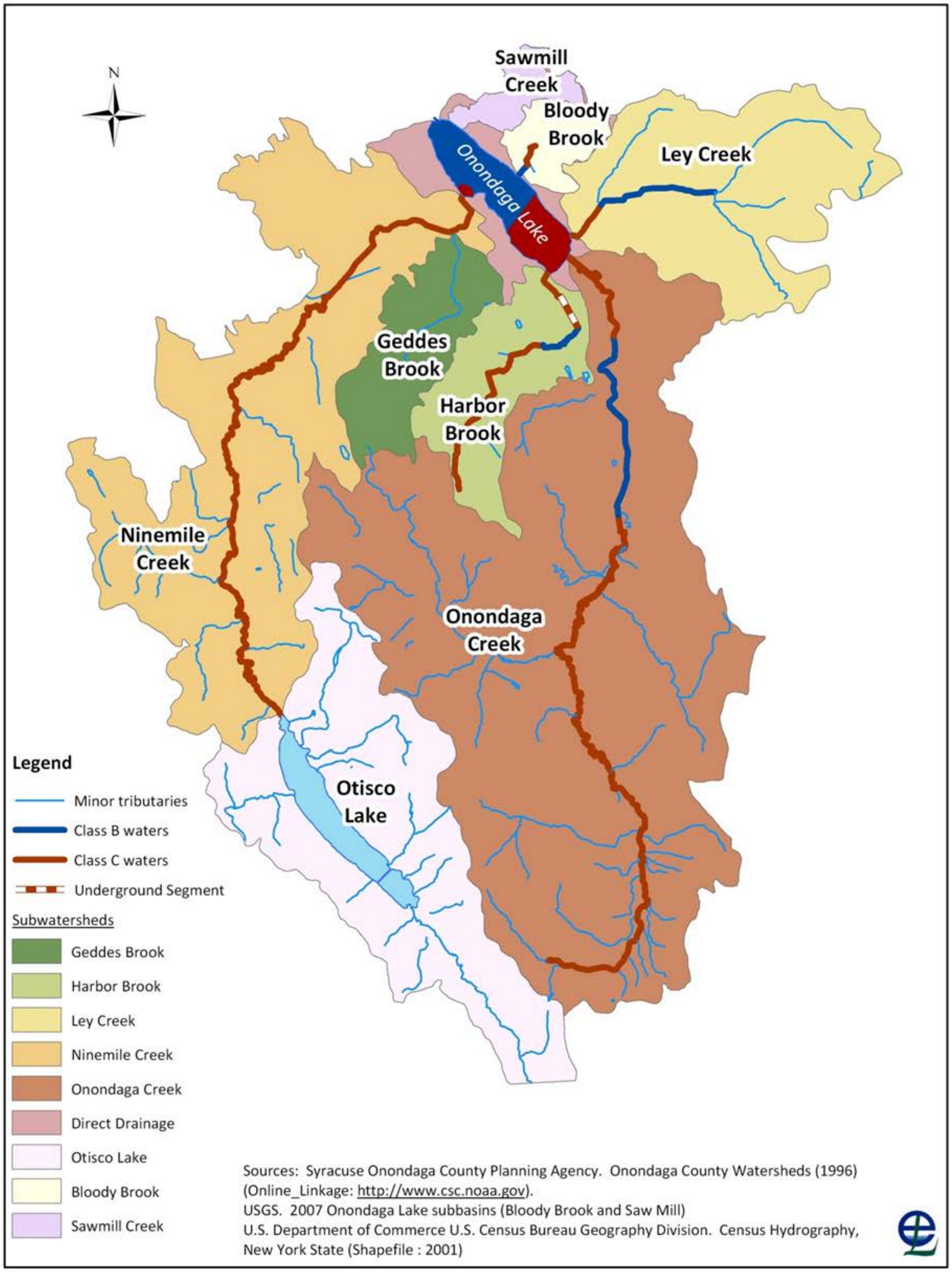


Figure 1-1. Tributary and lake regulatory classifications (6 NYCRR) and subwatershed boundaries.

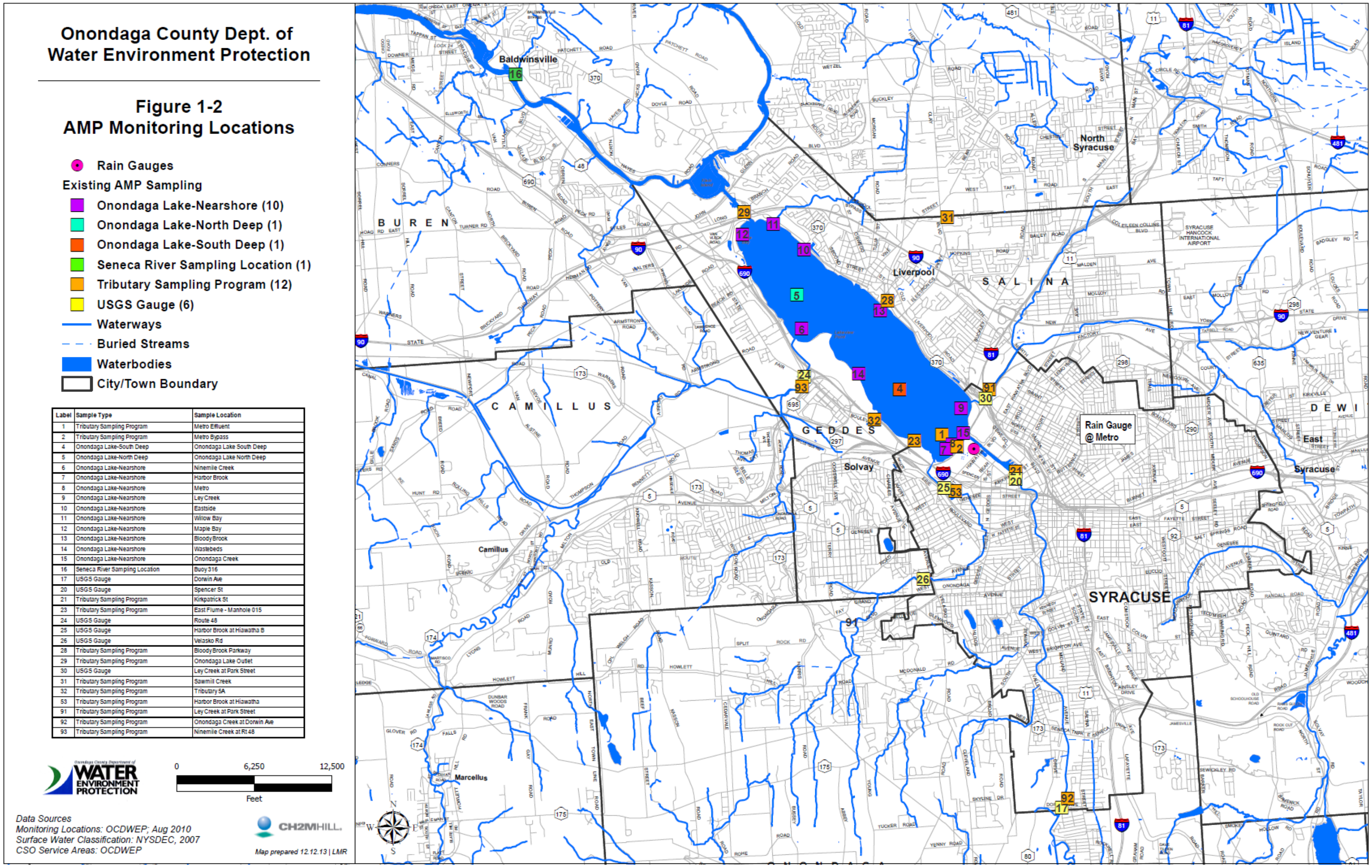
Table 1-2. Listing of water quality impairments in Onondaga Lake and its watershed.

Waterbody Name	Category of Impairment	Cause/Pollutant	Source	Year Listed
Onondaga Lake, northern end	fish consumption advisory	PCBs, dioxin, mercury, other toxics	contaminated sediments	1998
Onondaga Lake, southern end (including Ley Creek)	fish consumption advisory	PCBs, dioxin, mercury, other toxics	contaminated sediments	1998
Onondaga Lake, southern end	pending implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Onondaga Lake, northern end	pending verification of use impairments/pollutants/sources	dissolved oxygen	–	2012
Onondaga Lake, southern end	pending verification of use impairments/pollutants/sources	dissolved oxygen	–	2012
Bloody Brook and tribs	requires verification of cause/pollutant	aquatic toxicity	unknown	2010
Bloody Brook and tribs	pending implementation/evaluation of other restoration measures	pathogens	municipal, urban runoff	2008
Geddes Brook and tribs	pending implementation/evaluation of other restoration measures	ammonia	municipal, urban runoff	1998
Harbor Brook, lower, and tribs	pending implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Harbor Brook, lower, and tribs	pending implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	1998
Harbor Brook, lower, and tribs	pending implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	1998
Ley Creek and tribs	pending implementation/evaluation of other restoration measures	pathogens	municipal, urban runoff	2008
Ley Creek and tribs	pending implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	1998
Ley Creek and tribs	pending implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	1998
Ley Creek and tribs	pending implementation/evaluation of other restoration measures	cyanide	CSOs, municipal, urban runoff	2008
Minor tribs to Onondaga Lake	pending implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Minor tribs to Onondaga Lake	pending implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	2008
Minor tribs to Onondaga Lake	pending implementation/evaluation of other restoration measures	nitrogen (ammonia, nitrite)	CSOs, municipal, urban runoff	2008

Table 1-2. Listing of water quality impairments in Onondaga Lake and its watershed.

Waterbody Name	Category of Impairment	Cause/Pollutant	Source	Year Listed
Minor tribs to Onondaga Lake	pending implementation/evaluation of other restoration measures	cyanide	CSOs, municipal, urban runoff	2008
Ninemile Creek	pending implementation/evaluation of other restoration measures	pathogens	municipal, urban runoff	2008
Ninemile Creek	pending implementation/evaluation of other restoration measures	nutrients (phosphorus)	municipal, urban runoff	1998
Onondaga Creek, lower, and tribs	requires verification of impairment	turbidity	streambank erosion	2010
Onondaga Creek, lower	pending implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Onondaga Creek, lower	pending implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	1998
Onondaga Creek, lower	pending implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	1998
Onondaga Creek, middle, and tribs	requires verification of impairment	turbidity	streambank erosion	2008
Onondaga Creek, middle, and tribs	pending implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Onondaga Creek, middle, and tribs	pending implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	2008
Onondaga Creek, middle, and tribs	pending implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	2008
Onondaga Creek, upper, and tribs	requires verification of impairment	turbidity	streambank erosion	2008
Seneca River, lower, main stem	requires verification of impairment	pathogens	onsite WTS	1998
Seneca River, lower, main stem	requires verification of cause/pollutant	oxygen demand	invasive species, agriculture	1998

Source:
The Final New York State 2012 Section 303(d) List of Impaired Waters Requiring a TMDL/Other Strategy, on-line at http://www.dec.ny.gov/chemical/31290.html



Label	Sample Type	Sample Location
1	Tributary Sampling Program	Metro Effluent
2	Tributary Sampling Program	Metro Bypass
4	Onondaga Lake-South Deep	Onondaga Lake South Deep
5	Onondaga Lake-North Deep	Onondaga Lake North Deep
6	Onondaga Lake-Nearshore	Ninemile Creek
7	Onondaga Lake-Nearshore	Harbor Brook
8	Onondaga Lake-Nearshore	Metro
9	Onondaga Lake-Nearshore	Ley Creek
10	Onondaga Lake-Nearshore	Eastside
11	Onondaga Lake-Nearshore	Willow Bay
12	Onondaga Lake-Nearshore	Maple Bay
13	Onondaga Lake-Nearshore	Bloody Brook
14	Onondaga Lake-Nearshore	Wastebeds
15	Onondaga Lake-Nearshore	Onondaga Creek
16	Seneca River Sampling Location	Buoy 316
17	USGS Gauge	Dorwin Ave
20	USGS Gauge	Spencer St
21	Tributary Sampling Program	Kirkpatrick St
23	Tributary Sampling Program	East Flume - Manhole 015
24	USGS Gauge	Route 48
25	USGS Gauge	Harbor Brook at Hiawatha B
26	USGS Gauge	Velasko Rd
28	Tributary Sampling Program	Bloody Brook Parkway
29	Tributary Sampling Program	Onondaga Lake Outlet
30	USGS Gauge	Ley Creek at Park Street
31	Tributary Sampling Program	Sawmill Creek
32	Tributary Sampling Program	Tributary 5A
53	Tributary Sampling Program	Harbor Brook at Hiawatha
91	Tributary Sampling Program	Ley Creek at Park Street
92	Tributary Sampling Program	Onondaga Creek at Dorwin Ave
93	Tributary Sampling Program	Ninemile Creek at Rt 48

Figure 1-2. Map of routine AMP monitoring locations, Onondaga Lake and tributaries.

In addition to the overall assessment of use attainment, Onondaga County personnel rely on the AMP data for several related objectives:

- to identify and quantify sources of materials (nutrients, sediment, bacteria and chemicals) entering the lake
- to evaluate stream and lake water quality conditions with respect to compliance with ambient water quality standards (AWQS) and guidance values
- to understand the interactions between Onondaga Lake and the Seneca River
- to track the nature of the biological community
- to support development of mechanistic models for managing water quality conditions

A Data Analysis and Interpretation Plan (DAIP) (Table 1-3) guides program design and is a component of the annual workplan (for a copy of the annual workplan, including the DAIP, see http://static.ongov.net/WEP/wepdf/AMP/2012_AMP_Final_June_2012.pdf), and thus subject to NYSDEC review and approval.

Each year, Onondaga County reviews the laboratory data for quality assurance/quality control criteria (Appendix B-1) prior to uploading the analytical data set to the long-term water quality database. This custom database archives the complete set of Onondaga Lake and tributary monitoring results since 1970. In addition, field activities associated with both the water quality and biological monitoring programs are audited (Appendix B-2) annually to ensure that they are carried out in accordance with the approved workplan. The Onondaga County Laboratory participates in a program of Environment Canada documenting proficiency of low-level phosphorus and mercury analyses (Appendix B-3) in natural waters. Based on proficiency testing studies conducted by Environment Canada, the Onondaga County Laboratory was rated as "very good", the highest laboratory performance rating available.

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

Table 1-3. Overview of the 2012 AMP data analysis and interpretation plan.

Parameters	Sampling Locations	Compliance	TMDL Analysis	Trend Analysis	Trophic Status	Load Analysis	Use Attainment	Effectiveness of CSO Control Measures	Indicator of Water Clarity	Nutrient Cycling	Habitat Conditions	Lake Ecology
Chemical												
Alkalinity	L, T			✓								
Bacteria	L, T	✓		✓		✓	✓	✓				
BOD-5	T, R			✓		✓						
Carbon	L, T, R			✓	✓	✓						
Mercury	L, T	✓		✓								
Metals/Salts	L, T, R	✓		✓		✓						
Nitrogen	L, T, R	✓	✓	✓	✓	✓	✓			✓	✓	✓
Phosphorus	L, T, R	✓	✓	✓	✓	✓				✓		✓
Silica-dissolved	L, T				✓							✓
Solids	L, T, R	✓		✓								
Sulfide	L											
Physical												
Specific conductance	L, T, R	✓		✓			✓					
Dissolved oxygen	L, T, R	✓		✓	✓		✓					✓
LiCor irradiance	L			✓	✓		✓		✓			✓
Salinity	L, T, R	✓		✓			✓					
Secchi transparency	L	✓		✓	✓		✓		✓			✓
Turbidity	L, T, R			✓					✓			
Biological												
Chlorophyll-*a*/ algae	L, R			✓	✓		✓					✓
Zooplankton	L			✓								✓
Macrophytes	L			✓							✓	✓
Macroinvertebrates	L			✓							✓	✓
Fish	L			✓							✓	
Locations: L = Lake; T = Tributaries; R = Seneca, Oneida, and Oswego Rivers												

1.4 Amended Consent Judgment Milestones

The ACJ stipulates a series of specific engineering improvements to the County's wastewater collection and treatment infrastructure. Onondaga County has agreed to undertake a phased program of Metro improvements (Table 1-4). Combined sewer overflows (CSOs) serve older portions of the City of Syracuse. These utilities 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 1-5.

Table 1-4. 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 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 1-5. 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)		

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. NYSDEC used an ensemble modeling approach to evaluate the environmental benefits associated with additional phosphorus removal from Metro and other sources. The Onondaga Lake Water Quality Model (OLWQM) was a key component of this modeling ensemble. OLWQM was developed and calibrated using data from the AMP, and has been subject to outside expert peer review.

1.5 Use of Metrics to Measure and Report Progress

Onondaga County Department of Water Environment Protection, in consultation with NYSDEC and the Onondaga Lake Technical Advisory Committee (OLTAC), has developed a suite of metrics to help organize and report on the extensive AMP data set each year. These metrics relate to the lake's designated "best use" for water contact recreation, fishing, and protection of aquatic life. Table 1-6 documents the extent to which water quality conditions support the lake's designated best uses. Major reductions in loading of ammonia and phosphorus from Metro to Onondaga Lake have resulted in marked improvements in suitability of the lake for water contact recreation, aesthetic appeal, aquatic habitat, and recreational fishing. Metrics selected for Onondaga Lake address both human uses and ecosystem function:

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

Table 1-6. Summary of metrics, Onondaga Lake 2012.

Metrics	Measured By	Target[1]	2012 Results	Comments
Improved Suitability for Water Contact Recreation				
Indicator bacteria	Percent of months in compliance with AWQS[1] for fecal colilform bacteria, April–October (disinfection period). Measured at nearshore sites, Class B segment.	100%	100%	• Class B segments of Onondaga Lake met the designated use for water contact recreation • Class C segments in the southern end of the lake occasionally fail to meet standards for water contact recreation, particularly following runoff events.
Water clarity[2]	Percent of observations with Secchi disk transparency at least 1.2 m (4 ft.) to meet swimming safety guidance[2], June–September (recreational period). Measured at nearshore sites, Class B segment.	100%	100%	
Improved Aesthetic Appeal				
Water clarity	Summer average Secchi disk transparency at least 1.5 m at South Deep during the summer recreational period (June–September).	Summer average at least 1.5 m	Summer average 2.1 m	By these metrics, the lake met its designated use as an aesthetic resource.
Algal blooms[3]	Reduction in average and peak algal biomass and absence of nuisance algal blooms[3]. Measured by the magnitude, frequency and duration of elevated chlorophyll-*a* (Chl-*a*) during the summer recreational period (June–September). Based on laboratory measurements of Chl-*a* at South Deep.	• No more than 15% of Chl-*a* measurements above 15 µg/L • No more than 10% of observations above 30 µg/L	100% of observations less than 15 µg/L	
Algal community structure	Low abundance of cyanobacteria (blue-green algae)	Cyanobacteria represent no more than 10% of the algal biomass	Cyanobacteria were less than 1% of the algal biomass	

Table 1-6. Summary of metrics, Onondaga Lake 2012.

Metrics	Measured By	Target[1]	2012 Results	Comments
Improved Aquatic Life Protection				
Ammonia	South Deep ammonia concentrations compared to AWQS[1]	100% of measurements in compliance, all depths and all times	100% of measurements in compliance, all depths and all times	By these metrics, the lake met its designated use for aquatic life protection (warm water fishery)
Nitrite	South Deep nitrite concentrations[1]	100%	100%	
Dissolved oxygen	Minimum daily average[1] at South Deep Instantaneous minimum[1] at South Deep	>5 mg/L >4 mg/L	7.6 mg/L 5.7 mg/L	
Improving Sustainable Recreational Fishery				
Habitat quality	Percent of the littoral zone that is covered by macrophytes	40%	65%	Littoral zone macrophyte coverage provides high quality habitat for warm water fish community
Fish reproduction	Reproduction of target species: • bass and sunfish • yellow perch • black crappie • rock bass • walleye and northern pike	 occurring occurring occurring occurring occurring	 occurring occurring no evidence no evidence no evidence	Fish reproduction for several target species has not been observed; reproduction of sunfish has been limited in the last 3 years. Adult population of these species are stable and, in some cases, increasing.
The lack of suitable spawning habitat, not water quality, is the limiting factor for the reproduction of some fish species in the lake. Habitat restoration and enhancement are included in the Honeywell lake restoration efforts				

Table 1-6. Summary of metrics, Onondaga Lake 2012.

Metrics	Measured By	Target[1]	2012 Results	Comments
Fish community structure	Percent of fish species intolerant or moderately intolerant of pollution	Increasing presence of fish species in the overall community (based on all sampling methods) that are intolerant or moderately intolerant of pollution.	0% (100% of community is considered pollution tolerant)	The Onondaga Lake fish community includes mostly warmwater species. Most warmwater fish species are classified as relatively tolerant of pollution

[1]Ambient water quality standards (AWQS), criteria and guidance regulatory citations are as follows:

- *FC- fecal coliform bacteria Ambient Water Quality Criteria for Bacteria 1986 - EPA440/5-84-002, (http://water.epa.gov/type/oceb/beaches/upload/2009_04_13_beaches_1986crit.pdf)*
- *fecal coliform bacteria 6 NYCRR Part **703.4** (http://www.dec.ny.gov/regs/4590.html)*
- *ammonia and nitrite 6 NYCRR Part **703.5** (http://www.dec.ny.gov/regs/4590.html)*
- *dissolved oxygen 6 NYCRR Part **703.3** (http://www.dec.ny.gov/regs/4590.html)*

[2]Secchi depth water clarity swimming safety guidance of 4 ft. NYSDOH Title 10, Section 7-2.11

[3]Algal blooms subjectively defined as “impaired” at >15 µg/L and “nuisance” at >30 µg/L

Biological metrics were developed in consultation with members of the Onondaga Lake Technical Advisory Committee and other stakeholders participating in the annual meetings and reviews.

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

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

OCDWEP Technicians Sampling Onondaga Lake

This page intentionally left blank

Section 2. Onondaga Lake and Watershed

2.1 Watershed Size and Hydrology

The Onondaga Lake watershed encompasses approximately 285 square miles (740 km^2), almost entirely within Onondaga County, including six natural sub-basins: Onondaga Creek, Ninemile Creek, Ley Creek, Harbor Brook, Bloody Brook and Sawmill Creek (refer to Figure 1-1). Tributary 5A and the East Flume direct runoff and industrial discharges into the lake. Onondaga County's Metro treatment plant discharges to Onondaga Lake. Onondaga Creek is the largest water source to the lake, followed by Ninemile Creek, Metro, Ley Creek, Harbor Brook, minor tributaries and direct runoff (Figure 2-1). Much of the annual volume of water flowing to Onondaga Lake through the Metro treatment plant originates outside of the watershed. Water supply for the City of Syracuse is drawn from Skaneateles Lake, and for suburban towns and villages, Lake Ontario and Otisco Lake. Onondaga Lake discharges into the Seneca River, which flows in a northerly direction and joins the Oneida River to form the Oswego River, ultimately discharging into Lake Ontario.

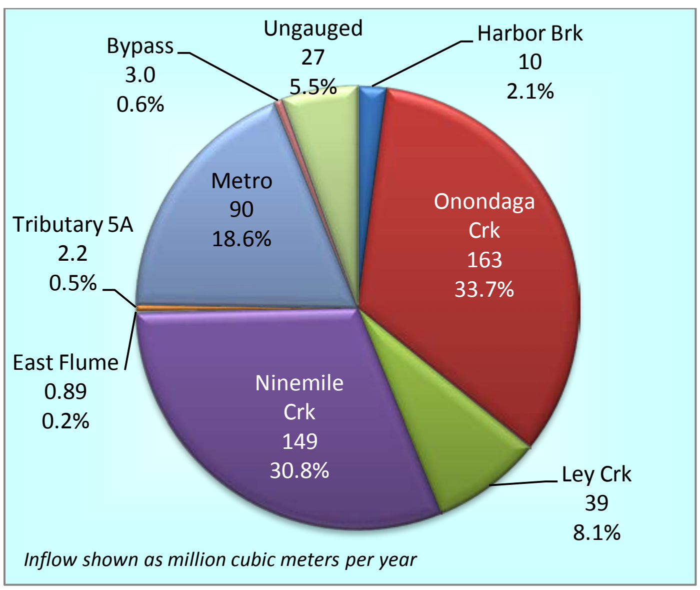


Figure 2-1. Annual average inflows (gauged and ungauged) to Onondaga Lake, 1990–2012.

The tributaries convey surface runoff and groundwater seepage from the watershed toward Onondaga Lake. The volume of runoff, and consequently stream flow varies each 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 rainfall events and to a lesser degree, snowmelt. The Metro effluent volume exhibits less annual variation, although the effects of extreme wet or dry years can be detected due to the portion of the service area served by combined sewers. The goal of the AMP is to sample the tributaries over a range of representative flow conditions, targeting a minimum of five samples collected during high flow (*High flow* is defined as one standard deviation above the long-term monthly average flow). OCDWEP targets high flow sampling events based on real-time provisional data from the USGS flow gage at Onondaga Creek-Spencer Street.

2.2 Land Use

Compared with other lakes in the Seneca-Oneida-Oswego river basin, the watershed of Onondaga Lake is relatively urbanized, as displayed in Figure 2-2, a map of land cover updated in 2006. The National Land Cover Dataset classified approximately 21% of the watershed as developed (urban/suburban), 33% as forested or scrub/shrub, and 30% as cultivated lands or pasture. The remaining 9% is comprised of wetlands, lakes and barren land. Urban areas of the City of Syracuse, two towns and two villages border the lake.

2.3 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. Morphologic characteristics of Onondaga Lake are summarized in Table 2.1. Its bathymetry is characterized by two minor depressions, referred to as the northern and southern basins (also referred to as North and South Deep in much of the literature), separated by a shallower region near the center of its longitudinal axis (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. 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 and shoreline each year.

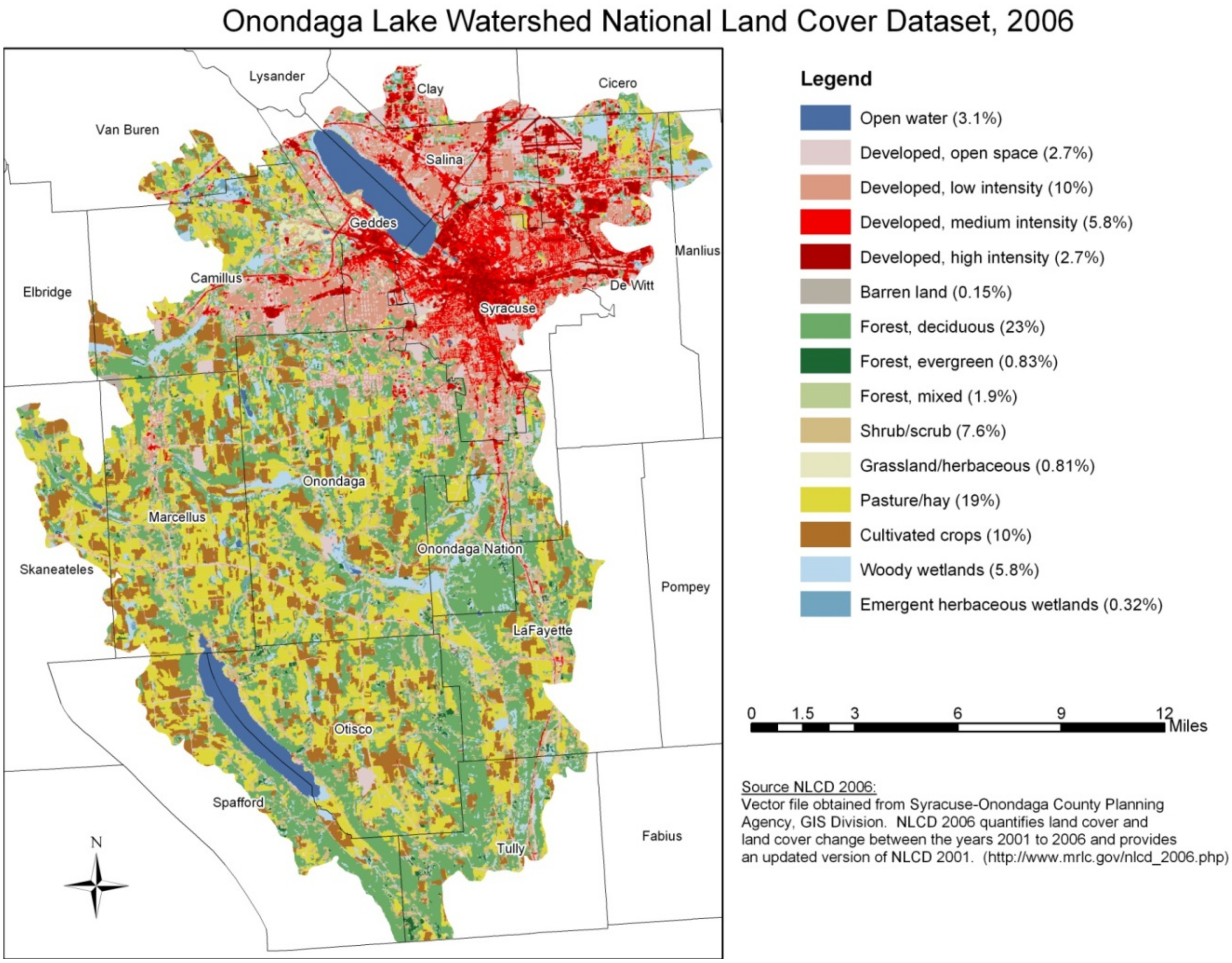


Figure 2-2. Land cover classification map.

Table 2-1. Morphologic characteristics of Onondaga Lake.

Characteristic	Metric	English
Watershed area	738 km^2	285 square miles
Lake:		
Surface area	12 km^2	4.6 square miles
Volume	131 x 10^6 m^3	35 billion gallons
Length	7.6 km	4.6 miles
Width	2 km	1.2 miles
Maximum depth	19.5 m	64 feet
Average depth	11 m	36 feet
Average elevation*	111 m	364 feet
Average flushing rate	~4 times per year	~4 times per year
Sources: http://www.ourlake.org/html/onondaga_lake1.html http://www.dec.ny.gov/chemical/8668.html *Elevation references to mean sea level.		

Aerial View of Onondaga Lake

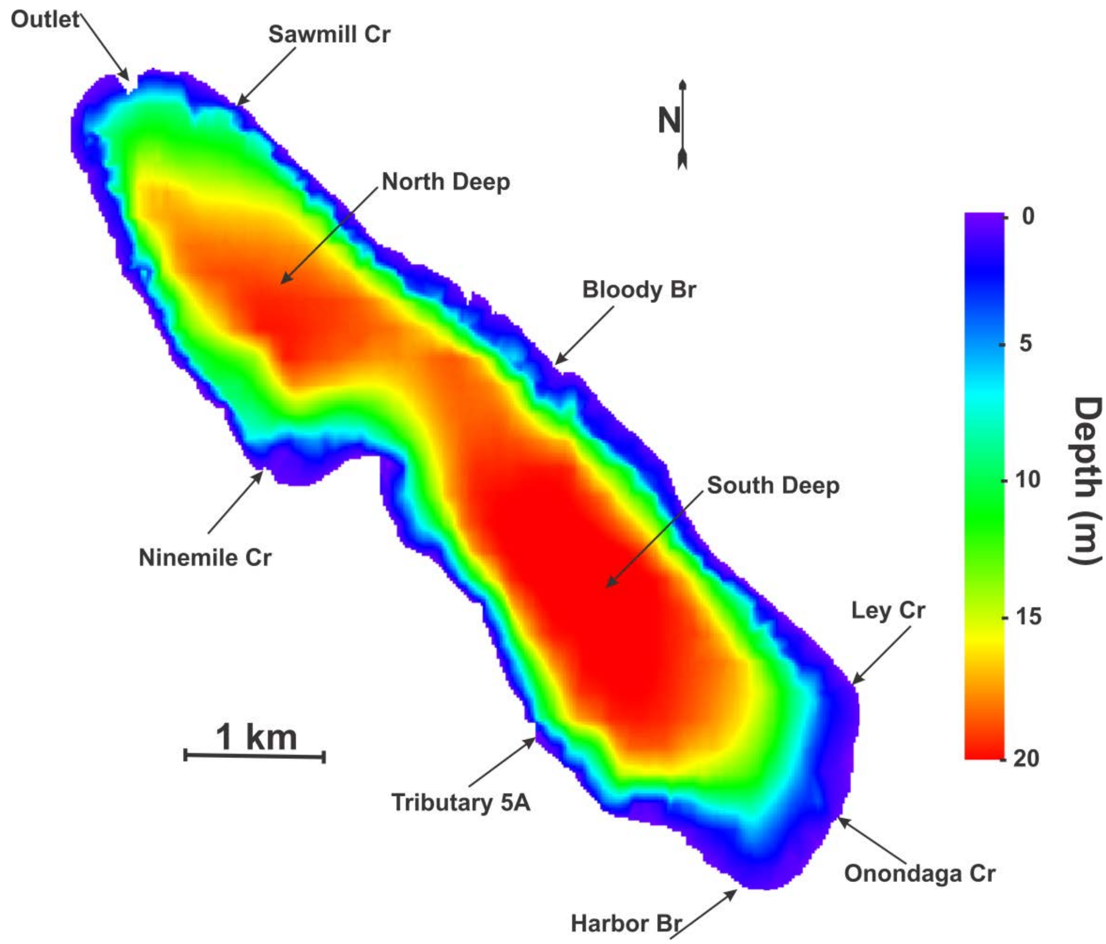


Figure 2-3. Bathymetric map of Onondaga Lake, with tributaries and primary sampling locations (South Deep, North Deep) identified.

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

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 Onondaga Lake has a relatively small volume, and receives drainage from a large watershed, the water residence time is short. For Onondaga Lake, there are 62 km^2 of watershed area for each km^2 of lake surface area. 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; the average water residence time is about three months on a completely mixed basis. Lakes with smaller contributing watersheds and larger volumes have a longer water residence time. For example, Skaneateles Lake has a watershed area to lake area ratio of 4.3 and a water residence time of 18 years. Oneida Lake provides another example; this large, shallow lake has a watershed area to lake area ratio of 17 and a water residence time of one-half year.

This page intentionally left blank

Section 3. Onondaga County Actions and Progress with Related Initiatives

3.1 Onondaga County Projects and Milestones

By signing the ACJ in 1998, Onondaga County agreed to design and construct a series of engineering improvements to the Metro service area. The County has now completed many improvements to the Metro wastewater treatment plant and the wastewater collection system, including the combined sewers (Table 3-1). The improvements to Metro have reduced phosphorus concentrations and altered the speciation of nitrogen in the fully-treated effluent, associated with year-round nitrification treatment.

Abating the CSOs is a significant challenge. The County has employed four strategies to reduce wet weather discharges from the combined sewer system to the Metro treatment plant: sewer separation, construction of regional treatment facilities, capturing of floatable materials and maximization of system storage capacity (Figure 3-1), or “gray infrastructure” (Table 3-2). The County has abandoned (completely eliminated or converted to a storm discharge point only) 26 of 72, or 36 percent, of the pre-ACJ active CSO locations since 1998.

Onondaga County’s Save the Rain (STR) Program was created in response to Fourth Stipulation of the Amended Consent Judgment (ACJ), entered into by Onondaga County, New York State and Atlantic States Legal Foundation (ASLF) on November 16, 2009. The ACJ specifically identified Green Infrastructure (GI) as an acceptable technology to significantly reduce or eliminate the discharge of untreated combined sewage into Onondaga Lake and its tributaries, and bring the County’s effluent discharges into compliance with the applicable water quality standards for the receiving waters.

The ACJ includes a phased schedule for Combined Sewer Overflow (CSO) compliance that uses an incremental approach to meeting the new goal of capture for treatment or elimination of, within the meaning of the Environmental Protection Agency’s (EPA) National CSO Policy, no less than 95 percent by volume of CSO by 2018. To meet this goal the County initiated the “Save the Rain” program which will implement a combination of green and gray infrastructure that focuses on the removal of stormwater from the combined sewer system through GI, CSO storage with conveyance to the Metropolitan Syracuse Wastewater Treatment Plant (Metro), and elimination of CSO discharge points. Building on the success of the 2011 “Project 50” campaign, the STR program had another impressive year in 2012 with over 50 GI projects completed.

Wadsworth Park Rain Garden

Porous Parking Lanes, N. State St

County Executive Joanne Mahoney is championing a Save the Rain (STR) initiative to educate residents about storm water management. The campaign raises awareness of effective ways to improve the environment by using rain barrels, rain gardens, porous pavement, green roofs, cisterns, and vegetated swales. STR continued its approach to rebuilding neighborhoods, developing strong community relationships, and advancing signature projects to solidify its place as a national leader in stormwater management. In addition, STR continued a comprehensive public education and outreach program to engage the local community and provide continued support for program activities. The STR program received numerous awards and recognition in 2012 including the United States Green Building Council (USGBC) 2012 Global Community Leadership award, a feature in *Water Environment and Technology* magazine, presenting at the White House for a conference hosted by the EPA and Council on Environmental Quality, and being featured as a "spotlight city" for the 2012 Urban Water Sustainability Leadership Conference, held by the U.S. Water Alliance in Cincinnati, Ohio.

The 2012 STR Public Education and Outreach Team continued to engage the general public to raise awareness of the benefits of green infrastructure and the County's efforts to implement the program. The outreach campaign included community presentations, demonstration projects, school outreach and the street tree planting program. In addition, STR either coordinated or participated in over 30 project-related public meetings.

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
1998	Amended Consent Judgment (ACJ) signed	• cap on annual ammonia and phosphorus load to the lake • begin selection and design of improvements	evaluation and implementation of nine minimum control measures	summer TP 55 µg/L in lake's upper waters	county begins design of integrated biological monitoring program
1999	--	completed upgrade of aeration system for secondary clarifiers at Metro	Maltbie Floatables Control Facility (FCF)	--	--
2000	--	--	• Franklin FCF • Harbor Brook Interim FCF	--	• Biological AMP begins • littoral zone plant coverage 11% in June
2001	--	--	• Teall FCF • Hiawatha Regional Treatment Facility (RTF)	--	--
2002	--	--	• Erie Blvd Storage System repairs completed • Kirkpatrick St. Pump Station Upgrade	--	strong alewife year class followed by declines in large zooplankton
2003	Three Rivers Water Quality Model peer review completed	--	progress with sewer separation (refer to 2009)	compliance with AWQS for DO in lake upper waters during fall	--
2004	--	• year-round nitrification of ammonia at Metro using BAF • Stage III SPDES limit for ammonia met	progress with sewer separations (refer to 2009)	compliance with AWQS: • ammonia in lake upper waters • for fecal coliform bacteria in lake Class B segments during Metro disinfection period	--

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
2005	--	Actiflo® system on-line to meet Metro Stage II SPDES limit for TP (0.12 mg/L as a 12-month rolling average)	progress with sewer separations (refer to 2009)	--	• no summer algal blooms • littoral zone plant coverage in June: 49%.
2006	ACJ 2nd Amendment motion filed by NYS Attorney General's Office	--	progress with sewer separations (refer to 2009)	compliance with AWQS for nitrite in the lake's upper waters	--
2007	--	• Metro meets Stage 2 SPDES limit for TP on schedule. • Onondaga Lake Water Quality Model development/calibration review (Phase 2).	progress with sewer separations (refer to 2009)	• compliance with AWQS for ammonia in the lake at all depths • Summer TP 25 µg/L in lake's upper waters	mesotrophic conditions achieved
2008	ACJ amended by Stipulation #3	--	Midland Ave. Phase I and II conveyance, storage and RTF	• Onondaga Lake delisted for ammonia. • summer TP 15 µg/L in lake's upper waters	alewife population decline followed by resurgence of large zooplankton
2009	ACJ amended by Stipulation #4	--	• Clinton St. conveyance • Green Infrastructure (GI) program begins • 13 sewer separation projects completed 1999–2009	summer TP 17 µg/L in lake's upper waters	strong alewife year class
2010	--	compliance with interim Stage II TP limit of 0.10 mg/L	• Harbor Brook Interceptor replacement initiated • 40 GI projects completed , eliminating 16.7 acres of impervious surfaces	summer TP 25 µg/L in lake's upper waters	resurgence of alewife; loss of larger zooplankton

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
2011	NYSDEC approved AMP modifications to determine whether CSOs are causing or contributing to violations of the NYS AWQS	compliance with interim TP limit of 0.10 mg/L	• 57 GI projects completed in 2011 • Gate chamber modifications to Erie Blvd. Storage System completed • Harbor Brook Interceptor Sewer 95% complete • CSO-044 Conveyance 90% complete	summer TP 20 µg/L in lake's upper waters	continued high densities of alewife and absence of larger zooplankton
2012	• Metro SPDES permit issued on March 21, 2012 • Onondaga Lake Water Quality Model completed and applied to TMDL for phosphorus • TMDL for phosphorus approved by USEPA on June 29, 2012	compliance with TP limit of 0.10 mg/L as a 12-month rolling average	• 35 GI projects completed in 2012 • CSO-044 Conveyance completed • CSO-022/045 sewer separation constructed • Construction of Harbor Brook Interceptor Sewer completed • Construction of Clinton and Harbor Brook Storage Facilities 50% complete	summer TP 22 µg/L in lake's upper waters	continued high densities of alewife and absence of larger zooplankton

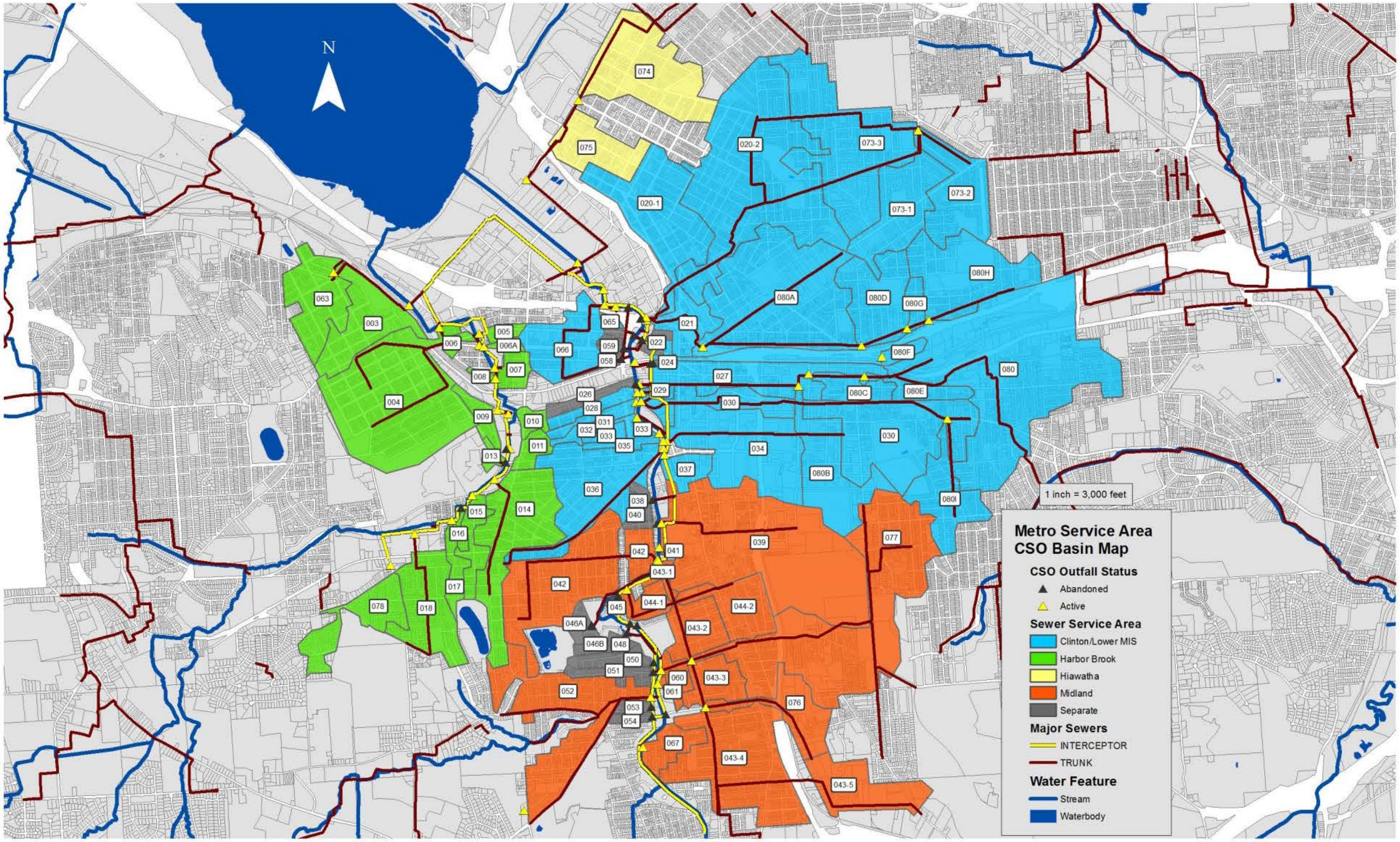


Figure 3-1. Map of CSO areas.

Table 3-2. ACJ and additional gray infrastructure milestone, schedule and compliance status.

Projects	Milestone Description	Milestone Type	Milestone Date	Compliance Status
CSO 044 Conveyances	Plans and specs to NYSDEC for review and approval	Minor	06/01/2010	Achieved
	Commence construction	Minor	12/31/2010	Achieved
	Complete construction and commence operation	Major	12/31/2011	Achieved
Harbor Brook Interceptor Sewer Replacement	Plans and specs to NYSDEC for review and approval	Minor	08/17/2009	Achieved
	Commence construction	Minor	01/01/2010	Achieved
	Complete construction and commence operation	Major	12/31/2013	Achieved
Erie Boulevard Storage System Modifications	Plans and specs to NYSDEC for review and approval	Minor	09/01/2010	Achieved
	Complete required modifications	Major	12/31/2011	Achieved
Clinton Storage Facility	Plans and specs to NYSDEC for review and approval	Minor	02/01/2011[1]	Achieved
	Commence construction	Minor	10/01/2011[1]	Achieved
	Complete construction and commence operation	Major	12/31/2013	In Progress
Harbor Brook Storage Facility	Plans and specs to NYSDEC for review and approval	Minor	04/29/2011[1]	Achieved
	Commence construction	Minor	12/31/2011[1]	Achieved
	Complete construction and commence operation	Major	12/31/2013	In Progress

[1] Date reflects ACJ Milestone extension approved by the NYSDEC on November 4, 2010

Table 3-3. Additional gray infrastructure projects and implementation schedules.

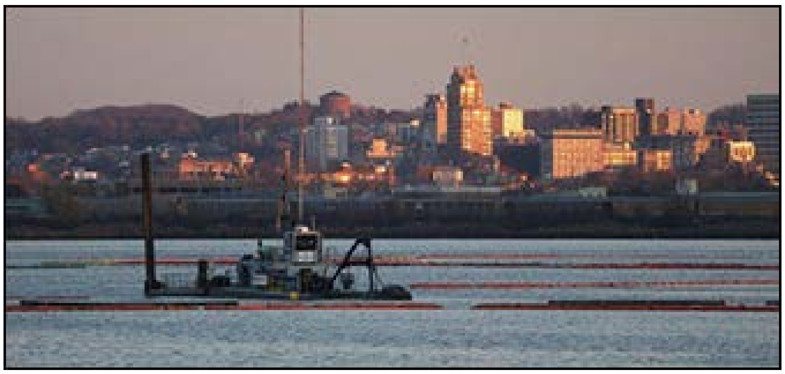
Projects	Task	Compliance Status
CSO 022/045 Sewer Separation Project	Plans and specs to NYSDEC for review and approval	06/06/2011
	Commence construction	01/24/2012
	Complete construction and commence operation	12/31/2012
CSO 063 Conveyances	Submit Final Design Report and 50% design	11/16/2012
	Plans and specs to NYSDEC for review and approval	02/22/2013
	Advertise for bid	05/01/2013
	Commence construction	07/15/2013
	Complete construction	10/01/2014

Clinton Storage Facility

A study of pathogen indicators (fecal coliform bacteria) in Onondaga Creek was conducted by the Onondaga Environmental Institute (OEI) in 2007. Data analyses from this study, as well as routine monitoring conducted by Onondaga County (2000-2006) as part of its Ambient Monitoring Program (AMP), indicated that sources were contributing bacteria to Onondaga Creek and Harbor Brook during periods of dry weather. Thus, precipitation-driven discharges of combined sewer overflows (CSOs) or stormwater outfalls did not account for the elevated levels of bacteria frequently observed in both streams. The United States Environmental Protection Agency (USEPA) Region 2 and New York State Department of Environmental Conservation (NYSDEC) Region 7, as well as other members of the Onondaga Lake Partnership (OLP), recognized the need to locate and identify sources of bacteria to both Onondaga Creek and Harbor Brook. Funding was procured to undertake a "Phase I Microbial Trackdown Study" in these two waterways and the NYSDEC was established as the lead agency for overseeing the project. The emphasis of the Phase I sampling project, conducted in 2008 and 2009, was to monitor the spatial and temporal trends of bacteria, to locate and characterize potential dry weather bacteria sources as a potential source of bacteria. A "Phase I Supplemental" study was funded in fall 2009 to build upon the findings of Phase I. The entire study was undertaken as a joint project of OEI and Onondaga County Department of Water Environment Protection (OCDWEP), with OEI as the principal partner and OCDWEP providing analytical and sampling support. The updated version of the Microbial Trackdown Phase II workplan, dated April 5, 2012, outlined a comprehensive study implemented in 2012 and 2013 to monitor presence of fecal coliform in Harbor Brook and Onondaga Creek, as a follow-up to the findings of the Phase I study. Funding for the Phase II project was provided by USEPA and administered by NYSDEC (Region 7).

3.2 Progress with Related Initiatives

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. Dredging and capping of Onondaga Lake sediments began in summer 2012. About 2 million cubic yards of contaminated sediment will be removed from the lake by hydraulic dredging, which is expected to be about halfway complete by the end of 2013. About 450 acres of the lake bottom are being capped to provide a new habitat layer, prevent erosion, and isolate remaining contaminants. Additional work is under way to remediate and transform 17 acres at Geddes Brook and 30 acres at Ninemile Creek into diverse new habitats for wildlife. Contaminated soil has been removed and 100,000 native shrubs, flowers, and trees are being planted. In 2012, the second-year of a three year pilot test, nitrate was added to the deep waters of Onondaga Lake with the objective of limiting release of methylmercury from the profundal sediments to the hypolimnion. A liquid calcium-nitrate solution was added to the hypolimnion as a neutrally buoyant plume approximately three times per week during the summer stratification interval. Maximum hypolimnetic concentrations of methylmercury and soluble reactive phosphorus decreased 94% and 95% from 2009 levels. Detailed descriptions of Honeywell’s planned remedial projects, designed to prevent the flux of contamination into the lake and restore aquatic habitat, are on the NYSDEC web site http://www.dec.ny.gov/chemical/48828.html. The Onondaga Lake Visitors Center opened on the southwest shoreline of the lake in 2012 to provide the public with access to information on the lake cleanup. Additional information on Honeywell’s remediation activities is available on their project website http://www.lakecleanup.com.



Dredging Operations in Onondaga Lake

Onondaga Lake Visitors Center

In 2012, the Onondaga Environmental Institute (OEI) conducted a detailed examination of the physical, chemical, and biological conditions of sites located in Upper Onondaga Creek. The study report (***An Investigation of Ecological Condition in the Upper Onondaga Creek Watershed: An examination of water and habitat quality, biotic integrity, and contaminant burdens in biota – 2012***) was issued in July 2013.

The engineering improvements to the wastewater collection and treatment infrastructure continue to be the subject of professional and trade publications and presentations. In addition, scientists and academics continue to analyze this important example of lake rehabilitation and publish their findings in the peer-reviewed literature. The human health impacts and ecological analysis of the contaminant issues are of interest to academic and agency scientists, public policy specialists, economists, and engineers. The Onondaga Lake Scientific Forum is convened each year by Upstate Freshwater Institute as a means of disseminating critical scientific information to stakeholders (http://www.upstatefreshwater.org/html/annual_olsf.html). The next meeting is scheduled for March 2014 on the campus of SUNY-ESF in Syracuse.

Onondaga Creek at Bear Mountain Road

This page intentionally left blank

Section 4. Tributary Water Quality: 2012 Results and Long-Term Trends

4.1 Meteorological Drivers and Stream Flow

Meteorological conditions are subject to substantial seasonal variations in this region. These conditions typically vary day-to-day, and noteworthy differences are commonly observed between years. Air temperature influences stream temperatures, which can affect the fate and transport of these inflows in the lake. However, precipitation, as the primary driver of stream flow, is the single most important meteorological attribute affecting material loading from the tributaries. Annual precipitation totaled 35.1 inches in 2012, lower than the 30-year historic (1982-2011) average of 38.7 inches and substantially lower than the 49.5 inches received in 2011. Monthly precipitation totals were lower than the long-term averages for the February to September period and in November (Figure 4-1). January, October, and December were relatively wet months. These three months contributed 44% of the total annual precipitation, with nearly 22% of the total occurring in December.

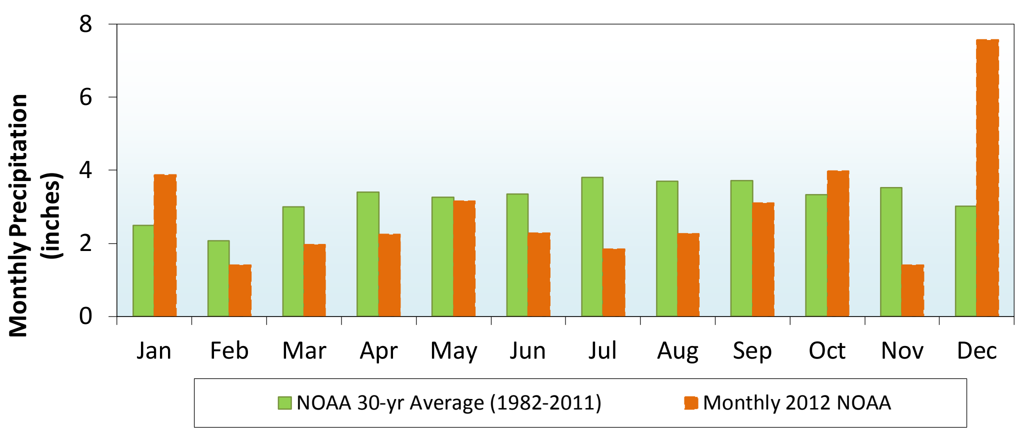


Figure 4-1. Monthly precipitation in 2012 compared to the long-term (1982–2011) average.

Substantial year-to-year variations in precipitation are reflected in the wide range of annual average flows carried by Onondaga Creek during the 1971–2012 interval (Figure 4-2). Lower than average precipitation during most of 2012 resulted in an annual average flow for Onondaga Creek in the lower 20th percentile of the 42-year record (Figure 4-2). Stream flow in 2012 was 32% lower than the long-term average and one-half of the flow in 2011, a particularly wet year.

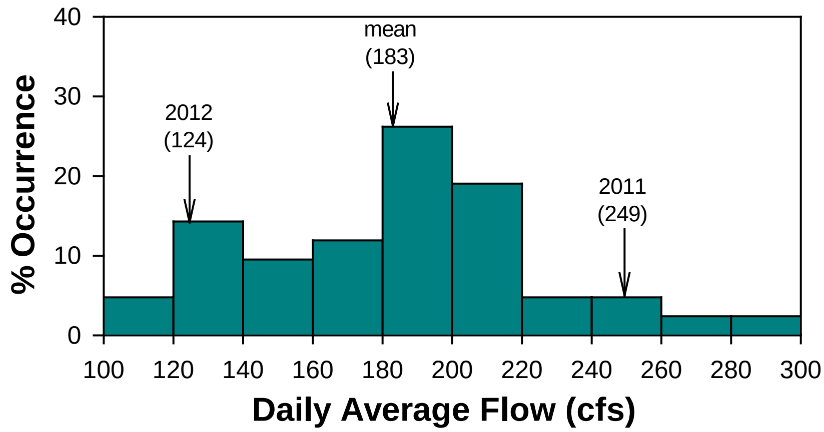


Figure 4-2. Distribution of the annual average of daily average flows for Onondaga Creek at Spencer Street, 1971–2012.

*Note**:** Annual average values for 2011, 2012, and the entire 42-year record are identified.*

Temporally detailed stream flow patterns in the major tributaries in 2012 (Figure 4-3) were noteworthy for the very low flow conditions during much of the February–November period. Snowmelt did not contribute importantly to runoff during 2012. Snowfall for the 2011–2012 winter season totaled just 50.6 inches, far below the 1951–2011 average of 119 inches. Flows were mostly well below the 30-year average, except for major runoff events in January, late April, early May, and December. Spring flows and coupled material loadings are considered particularly important in influencing early summer water quality in receiving lakes. The high flows in January and December of 2012 had relatively minor impacts on water quality.

Concentrations, and thereby loading rates, of many constituents of water quality interest are known to depend importantly on the magnitude of stream flow. In recognition of this, the AMP targets a broad range of flow conditions to support robust loading rate estimates; specifically, a minimum of five sampling events are targeted during high flow conditions (defined as stream flow at the Onondaga Creek-Spencer St. gauge of at least one standard deviation above the long-term monthly average). In 2012 this goal was met at Harbor Brook and exceeded by a wide margin at Onondaga Creek and Ley Creek (Figure 4-3). Only three high flow samples were collected at Ninemile Creek during the relatively dry 2012 sampling season.

The 2012 sampling program continued modifications that were implemented in 2011 for two of the smallest tributaries to Onondaga Lake. The monitoring location for Allied East Flume was a manhole, designated as Allied East Flume-Manhole 015. Tributary 5A was sampled only once between August 23, 2011 and August 28, 2012 due to a remediation project that pumped flows around this stream. Ninemile Creek was sampled at I-695 from April to July of 2012 because construction activities prevented access to the Rt. 48 sampling location.

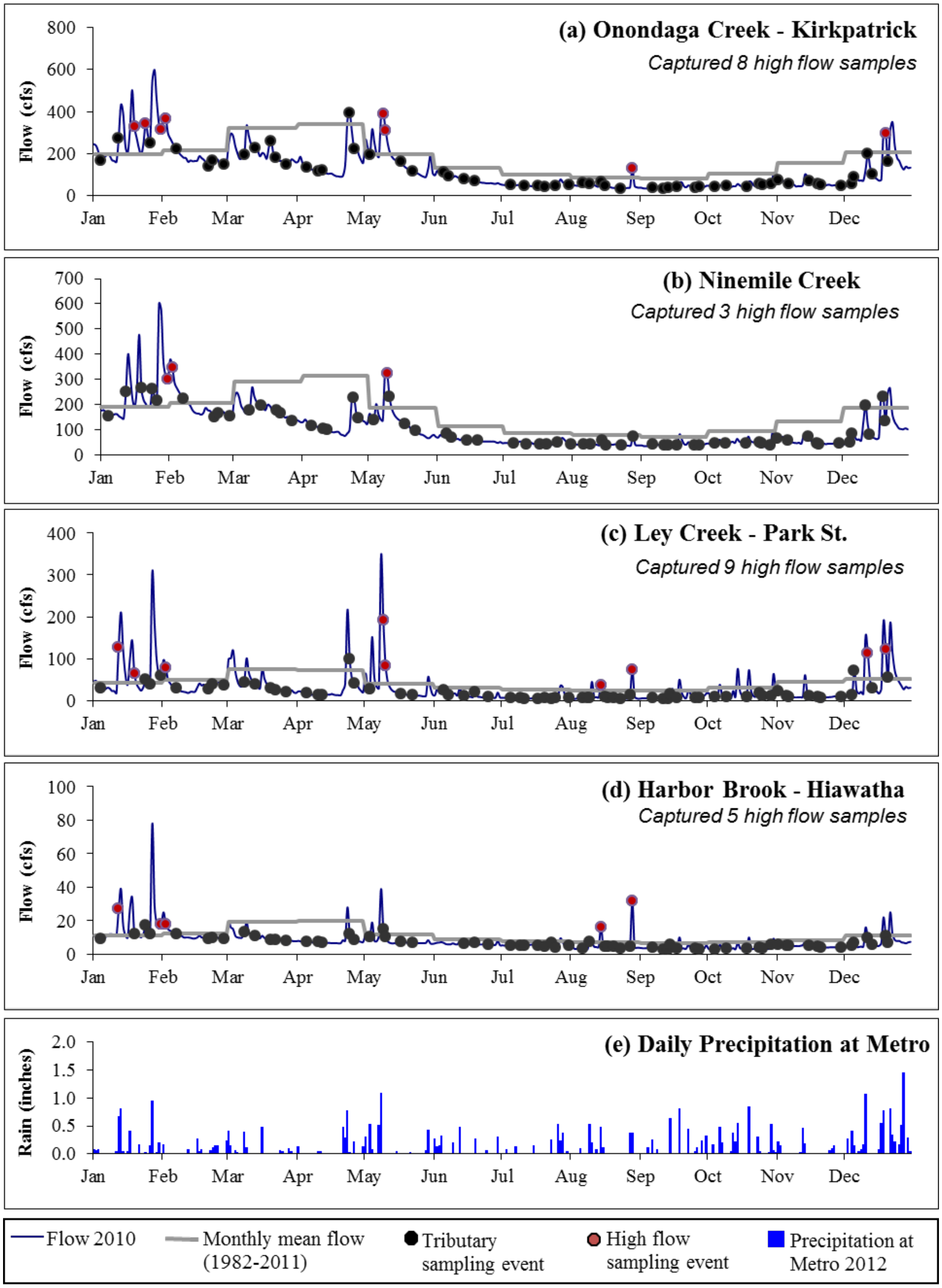


Figure 4-3. Hydrographs showing observed tributary flows in 2012 compared with the 30-year average (1982–2011) USGS average flow for (a) Onondaga Creek, (b) Ninemile Creek, (c) Ley Creek, (d) Harbor Brook, (e) daily precipitation at Metro.

Note: points indicate days of sampling.

4.2 Compliance with Ambient Water Quality Standards

Several segments of Onondaga Lake's tributary streams are included on the 2012 NYSDEC compendium of impaired waters (http://www.dec.ny.gov/chemical/31290.html). NYSDEC places waterbodies on this list when there is evidence that water quality conditions do not meet applicable standards, and/or the water bodies do not support their designated use. Results of Onondaga County's AMP are among the primary data sets used to evaluate compliance with standards and use attainment. No compliance assessment is included for the East Flume - Allied Manhole 015 because this is a manhole sampling location. The 2012 tributary data indicate that the major tributaries were generally in compliance (Table 4-1) with ambient water quality standards (AWQS) for most parameters addressed. Exceptions to 100% compliance included the parameters (1) dissolved oxygen – Onondaga Lake Outlet-2ft. (98%), and (2) dissolved mercury – Harbor Brook at Hiawatha (50%), Tributary 5A (0%), Onondaga Lake Outlet (50%).

The primary exceptions in meeting AWQS in the tributaries were total dissolved solids (TDS) and fecal coliform bacteria (FC). The AWQS for TDS (500 mg/L) was contravened at all of the tributary monitoring sites, and often by a wide margin. Contravention of this standard is primarily associated with the natural hydrogeology of the watershed and not with anthropogenic effects. Compliance with the AWQS for fecal coliform bacteria is specified by NYSDEC as the geometric mean of a minimum of five observations per month being less than or equal to 200 colony forming units (cfu) per 100 milliliters (mL). Onondaga County increased the frequency of bacterial sampling (starting in April 2010) at each tributary sampling location to support assessments of compliance with this AWQS. The abundance of fecal coliform bacteria in the tributaries during wet weather is affected by stormwater runoff and functioning of the combined sewer system. CSO remedial measures and improved stormwater management measures are underway. Among the objectives of the AMP is the tracking of changes in the input of bacteria to Onondaga Lake during wet weather (Table 1-5). WEP also tracks bacterial abundance during non-storm periods; these observations provide a means of identifying potential illicit connections of sanitary waste to the stormwater collection system, or portions of the sewerage infrastructure in need of repair. The following tributaries were 100% compliant with the related standard (Table 4-1): Ninemile Creek at I-695, Tributary 5A, and the Onondaga Lake Outlet. Compliance with the AWQS for fecal coliform bacteria was achieved for less than 50% of the monthly means at Harbor Brook at Hiawatha (18%), Ley Creek at Park (36%), and Onondaga Creek at Kirkpatrick (36%).

Table 4-1. Summary of tributary and outflow compliance (percent of observations in compliance) with ambient water quality standards AWQS, 2012 (dissolved oxygen, ammonia, nitrite, and fecal coliform are specified in the ACJ).

Note: occurrences of less than 100% compliance are highlighted in red text.

	Field Data			Solids	Nitrogen		Metals[1]								Mercury	Bacteria
Site	**Dissolved Oxygen (4 mg/L)**	**Dissolved Oxygen (5 mg/L)**	**pH**	**TDS**	**Ammonia**	**Nitrite**	**Arsenic**	**Cadmium**	**Chromium**	**Copper**	**Cyanide[2]**	**Lead**	**Nickel**	**Zinc**	**Dissolved[3] Mercury**	**Fecal[4] Coliform**
Bloody Brook at Onon. L. Parkway	100%	100%	100%	**4%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**45%**
Harbor Brook at Hiawatha Bvd.	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**50%**	**0%**
Harbor Brook at Bellevue Ave.	100%	100%	100%	**18%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	NC[5]	100%
Harbor Brook at Velasko Rd.	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**67%**
Ley Creek at Park St.	100%	100%	100%	**11%**	100%	100%	100%	100%	100%	100%	**NAS (75%)**	100%	100%	100%	100%	**33%**
Ninemile Creek at Lakeland	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**71%**
Ninemile Creek at I-695	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	NC	100%
Onondaga Creek at Kirkpatrick St.	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**18%**
Onondaga Creek at Dorwin Ave.	100%	100%	100%	**15%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**75%**
Sawmill Creek at Onon. L. Rec. Area	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**25%**
Trib. 5A at State Fair Blvd.	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**0%**	100%
Onondaga Lake Outlet (2ft)	**98%**	**98%**	100%	**8%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Onondaga Lake Outlet (12ft)	100%	100%	100%	**0%**	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**50%**	NC

[1] AWQS for metals apply to the total dissolved form; the 2012 AMP reports total recoverable metals concentrations; if result ≤ AWQS, compliance is assumed; if result or MRL > AWQS, compliance cannot be assessed (designated as NAS; percent of samples where total form was in compliance with AWQS given in parentheses);

[2] AWQS for cyanide applies to free cyanide (CN-); the AMP reports total cyanide (CN-T); if result ≤ AWQS, compliance is assumed; if result or MRL > AWQS, compliance cannot be assessed (designated as NAS; percent of samples where total form was in compliance with AWQS given in parentheses);

[3] standard applies to health fish consumption standard (H(FC));

[4] NS is not sampled. Compliance based on monthly geometric means of at least 5 samples.

[5] NC – not collected

4.2.1 AMP Modifications

The AMP Modifications Workplan, Final dated December 2011 and approved by the DEC, outlines proposed modifications designed to enhance monitoring of tributary water quality in those tributaries impacted by CSOs to determine the effectiveness of the gray and green infrastructure projects.

The overall objectives of the Enhanced Tributary sampling Program are to:

- Evaluate in-stream water quality conditions during the CSO events
- Compare in-stream water quality conditions during wet weather with AWQS

4.2.1.1 Erie Boulevard Storage System

In October 2011, the gate chamber (GC) modifications for EBSS were completed as required by the ACJ. The County estimated that the GC modifications would increase system wide CSO capture by at least 0.2 percent or 8MG on an annual basis. The EBSS is a "real-time control" facility fully automated through the use of level sensors and PLC-based controls that utilize telemetry communications for integration into the County's SCADA at Metro. If maximum storage capacity of the EBSS is reached based on current set-points and the MIS conveyance capacity is reached, the incoming CSO flows to the EBSS are discharged to Onondaga Creek. The volume for EBSS capture (before and after gate modifications) is a calculated volume based on the model output and the average annual year. The gate set point heights and the hydraulic grade line (HGL) based on the model projections have been verified. As with other CSO discharges, there is no real-time verification of a totalized capture volume.

4.2.1.2 2012 In-stream Sampling

Following the completion of the Gate Chamber modifications for EBSS in 2011, OCDWEP implemented a program to collect in-stream data from Onondaga Creek in 2012. The objective of the sampling program was to evaluate compliance with the NYS AWQS, specifically when the EBSS facility is overflowing (during wet weather events). For the two-year period of 2012 and 2013, in-stream sampling for four (4) events was planned. Two (2) sampling events were conducted in May 2012, to evaluate the in-stream water quality at Plum Street, a bridge sampling location approximately 2,640 feet downstream of the EBSS outfall. The two sampling events were conducted during wet weather events that were of sufficient magnitude and intensity to trigger overflow from the EBSS (CSO080) outfall. The May 29, 2012 sampling event also included sampling at the Dorwin Ave. site.

OCDWEP compiled a sampling summary and proposed several sampling program recommendations for NYSDEC and ASLF consideration based on a re-evaluation of sampling program objectives, sampling sites, protocol, data, parameters, event initiation (based on time of travel calculations), and an improved understanding of the EBSS operational performance during

2012. An evaluation of available site-specific data from the Microbial Trackdown Study project (collected during dry weather conditions), and the AMP were referenced in the sampling summary, submitted to NYSDEC in November 2012. The sampling summary was revised in response to DEC comments dated February 1, 2013.

Erie Blvd. Storage System Outfall to Onondaga Creek

4.2.1.3 Compliance Evaluation (Events 1 and 2)

A compliance evaluation was conducted for in-stream data collected from the sampling location downstream of the EBSS outfall (Onondaga Creek at Plum Street) during each of the two (2) sampling events (Table 4-2, Table 4-3, Table 4-4, and Table 4-5). Sampling for Event 1 included the parameters Fecal Coliform and Nutrients (total Phosphorus and total Nitrogen). In addition to Fecal Coliform and Nutrients, Event 2 included the Priority Pollutant parameters. Fecal Coliform bacteria data were evaluated based on the NYS AWQS of a monthly geometric mean of a minimum of five (5) samples. Based on the evaluation, Fecal Coliform data from Events 1 and 2 indicated non-compliance with the AWQS.

As a follow-up to the findings the following measures were instituted as part of a "Source Trackdown."

- OCDWEP staff investigated the conditions in EBSS in November of 2012 that were contributing to the high bacteria samples collected as part of the Microbial Trackdown Study in 2012. It was discovered that a large concrete support beam had collapsed and was restricting the EBSS outfall to Onondaga Creek. It was also determined that Gate Chamber 1 seal was leaking and allowed a small volume of captured CSO to leak under the gate during the storage mode. Gate Chamber 1 seal was repaired in December of 2012, and a purchase requisition was issued for contract services to remove the concrete and grit obstruction from the EBSS outfall location.

- The EBSS sampling program will be implemented, with changes as approved by NYSDEC. The program will include sampling of the EBSS overflow discharge, in conjunction with the flow monitoring data, to evaluate load reductions specifically during wet weather conditions. The data will be used to assess progress towards compliance with the objectives of the ACJ's CSO program. The duration and frequency of sample collection during the sampling event will be based on the precipitation and information from the receiving water hydrograph.
- Results of the Microbial Trackdown Study to identify contributions from point sources between the EBSS outfall and in-stream sampling locations will be compiled and evaluated.

A limited compliance assessment for Nutrients and Priority Pollutant parameters was conducted, due to the following

- Nutrients (Events 1 and 2)
  - Total Phosphorus (TP) and total Nitrogen (TN) data from Event 1 and 2 could not be assessed as Nutrient Criteria for flowing waters are pending.
- Priority Pollutants (Event 2 only)
  - The AWQS for the priority pollutant metals, including arsenic; cadmium; chromium; copper; lead; mercury; and zinc are based on measurements of dissolved forms of these metals. Because Total Recoverable forms were measured, compliance with standards could not be assessed directly. However, compliance was assumed when the concentration of the total form was less than the standard. The standard for cyanide is based on free cyanide (HCN + CN), whereas measurements were for the Total form. The AWQS for silver is expressed in the ionic form and could not be assessed, as analysis was for the Total Recoverable form. Compliance could not be assessed for the parameter mercury, as the sample was not collected during the event. Analysis of the dissolved forms of metals and free cyanide are proposed for the 2013 AMP.
  - Compliance for several Priority Pollutant parameters could not be evaluated as the reported results had no measurable concentrations. Compliance with AWQS was also not assessed for a number of analytes due to either sample matrix and the associated interferences with that matrix or the limitation of the analytical methodology to achieve concentrations at levels of the water quality standards. Also, several Priority Pollutant parameters have no AWQS. Compliance of the PCB Aroclors could not be completed as these samples were not included in the analysis.

Table 4-2. Enhanced tributary monitoring compliance results for *in-situ* field data, nutrients, and fecal coliform bacteria for Onondaga Creek (Plum St.) for Event 1, 5/8/2012.

Water Quality Parameter	NYS Ambient Water Quality Standard- B,C	Plum St.	
		N	Percent Compliance
Dissolved Oxygen (4 mg/L)	observation ≥ 4 mg/L	39	100%
Dissolved Oxygen (5 mg/L)	daily average ≥ 5 mg/L	39	100%
pH	between 6.5 and 8.5	39	100%
Ammonia-N	temperature, pH dependent	18	100%
Nitrite-N[1]	0.1 mg/L	NA[2]	NAS[3]
Total Nitrogen	pending[4]	18	NAS
Total Phosphorus	pending[4]	18	NAS
Fecal Coliform[5]	200 count/100mL	5	0%

[1] combined (nitrite-N + nitrate-N) result reported by OCDWEP (nitrite-N was not reported separately)
[2] NA – not analyzed
[3] NAS – not assessed
[4] pending – nutrient compliance criteria for flowing waters is currently pending
[5] based on geometric mean of not less than 5 samples taken over not more than a 30-day period

Table 4-3. Enhanced tributary monitoring compliance results for *in-situ* field data, nutrients, and fecal coliform bacteria for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2, 5/29/2012 through 5/30/2012.

Water Quality Parameter	NYS Ambient Water Quality Standard- B,C	Dorwin Avenue		Plum St.	
		N	Percent Compliance	N	Percent Compliance
Dissolved Oxygen (4 mg/L)	observation ≥ 4 mg/L	15	100%	45	100%
Dissolved Oxygen (5 mg/L)	daily average ≥ 5 mg/L	15	100%	45	100%
pH	between 6.5 and 8.5	15	100%	45	100%
Ammonia-N	temperature, pH dependent	0	NC[1]	15	NAS[2,3]
Nitrite-N	0.1 mg/L	0	NC	0	NC
Total Nitrogen	pending[4]	0	NC	15	NAS
Total Phosphorus	pending	0	NC	15	NAS
Fecal Coliform[5]	200 count/100mL	5	0%	5	0%
Total Cyanide[6] (chronic)[7]	5.2 µg/L	3	100%	8	100%
Total Cyanide (acute)[8]	22 µg/L	3	100%	8	100%

[1] NC – not collected
[2] NAS – not assessed
[3] ammonia compliance determination requires paired pH and temperature measurements (not available for Event 2)
[4] pending – nutrient compliance criteria for flowing waters is currently pending
[5] based on geometric mean of not less than 5 samples taken over not more than a 30-day period
[6] AWQS for cyanide applies to free cyanide (CN^-); the AMP reports total cyanide (CN-T); if result ≤ AWQS, compliance is assumed; if result or MRL > AWQS, compliance cannot be assessed (designated as NAS; percent of samples where total form was in compliance with AWQS given in parentheses);
[7] (c) – standard applies to aquatic chronic toxicity standard (A(c));
[8] (a) – standard applies to aquatic acute toxicity standard (A(a));

Table 4-4. Enhanced tributary monitoring compliance results for priority pollutant metals for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2, 5/29/2012 through 5/30/2012.

No.	Water Quality Parameter[1]	CAS Registry Number	NYS Ambient Water Quality Standard- B,C (µg/L)	Dorwin Avenue		Plum St.	
				N	Percent Compliance	N	Percent Compliance
1.	Antimony	-	no AWQS[2]	5	-	15	-
2.	Arsenic (chronic)	-	150 µg/L (c)[3]	5	100%	15	100%
	Arsenic (acute)	-	340 µg/L (a)[4]	5	100%	15	100%
3.	Beryllium (chronic)	-	1100 µg/L (hardness > 75 ppm) (c)	5	100%	15	100%
4.	Cadmium (chronic)	-	(0.85) exp(0.7852 [ln (ppm hardness)] - 2.715) (c)	5	**NAS[5] (40%)**	15	**NAS (93%)**
	Cadmium (acute)	-	(0.85) exp(1.128 [ln (ppm hardness)] - 3.6867) (a)	5	100%	15	100%
5.	Chromium (chronic)	-	(0.86) exp(0.819 [ln (ppm hardness)] + 0.6848) (c)	5	100%	15	100%
	Chromium (acute)	-	(0.316) exp(0.819 [ln (ppm hardness)] + 3.7256) (a)	5	100%	15	100%
6.	Copper (chronic)	-	(0.96) exp(0.8545 [ln (ppm hardness)] - 1.702) (c)	5	100%	15	**NAS (87%)**
	Copper (acute)	-	(0.96) exp(0.9422 [ln (ppm hardness)] - 1.7) (a)	5	100%	15	100%
7.	Lead (chronic)	-	{1.46203 - [ln (ppm hardness) (0.145712)]} exp (1.273 [ln (ppm hardness)] - 4.297) (c)	5	100%	15	**NAS (73%)**
	Lead (acute)	-	{1.46203 - [ln (ppm hardness) (0.145712)]} exp (1.273 [ln (ppm hardness)] - 1.052) (a)	5	100%	15	100%
8.	Mercury	-	$7E^{-4}$ µg/L (hfc)[6]	0	NC[7]	0	NC
9.	Nickel (chronic)	-	(0.997) exp (0.846 [ln (ppm hardness)] + 0.0584) (c)	5	100%	15	100%
	Nickel (acute)	-	(0.998) exp (0.846 [ln (ppm hardness)] + 2.255) (a)	5	100%	15	100%
10.	Selenium (chronic)	-	4.6 µg/L (c)	5	100%	15	100%

Table 4-4. Enhanced tributary monitoring compliance results for priority pollutant metals for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2, 5/29/2012 through 5/30/2012.

No.	Water Quality Parameter[1]	CAS Registry Number	NYS Ambient Water Quality Standard- B,C (µg/L)	Dorwin Avenue		Plum St.	
				N	Percent Compliance	N	Percent Compliance
11.	Silver[8] (chronic)	-	0.1 µg/L (c)	5	100%	15	100%
12.	Thallium (chronic)	-	8 µg/L (c)	5	100%	15	100%
	Thallium (acute)	-	20 µg/L (a)	5	100%	15	100%
13.	Zinc (chronic)	-	(0.85 [ln (ppm hardness)] + 0.50) (c)	5	100%	15	100%
	Zinc (acute)	-	0.978 exp(0.8473 [ln (ppm hardness)] + 0.884) (a)	5	100%	15	100%

[1] AWQS for metals apply to the total dissolved form; the 2012 AMP reports total recoverable metals concentrations; if result ≤ AWQS, compliance is assumed; if result or MRL > AWQS, compliance cannot be assessed (designated as NAS; percent of samples where total form was in compliance with AWQS given in parentheses);
[2] no AWQS - currently no Ambient Water Quality Standard (B, C waters), percent compliance listed as "-";
[3] (c) – standard applies to aquatic chronic toxicity standard (A(c));
[4] (a) – standard applies to aquatic acute toxicity standard (A(a));
[5] NAS – not assessed
[6] standard applies to health fish consumption standard (H(FC));
[7] NC – not collected
[8] standard for silver applies to ionic silver

Table 4-5. Enhanced tributary monitoring compliance results for priority pollutants for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2 (5/29/2012 through 5/30/2012).

Note: priority pollutants that have NYS AWQS are highlighted in light blue

No.	Primary Pollutant[1,2]	CAS Registry Number	Compliance Assessment Criteria [a]	Compliance Value (µg/L)	Type [b]	Dorwin Ave.		Plum St.	
						N	Percent Compliance	N	Percent Compliance
1.	Acenaphthene [1][c]	83-32-9	GV	5.3	A(C)	2	NAS1[d]	6	NAS1
			GV	48	A(A)	2	100%	6	100%
2.	Acenaphthylene [77]	208-96-8	ns	-	-	2	NAS2[e]	6	NAS2
3.	Acrolein [2]	107-02-8	ns	-	-	NA[f]	NAS3[g]	NA	NAS3
4.	Acrylonitrile [3]	107-13-1	ns	-	-	NA	NAS3	NA	NAS3
5.	Aldrin [89]	309-00-2	AWQS	0.001[h]	H(FC)	2	NAS1	6	NAS1
6.	Alpha-Endosulfan (*endosulfanI*) [95]	959-98-8	ns	-	-	2	NAS2	6	NAS2
7.	Alpha-Lindane [102] (*alphaBHC, alpha-hexachlorocyclohexane*)	319-84-6	AWQS	0.002	H(FC)	2	NAS1	6	NAS1
8.	Anthracene [78]	120-12-7	GV	3.8	A(C)	2	NAS1	6	NAS1
			GV	35	A(A)	2	100%	6	100%
9.	Arochlor (PCB) 1016 [112]	12674-11-2	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
10.	Arochlor (PCB) 1221 [108]	11104-28-2	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
11.	Arochlor (PCB) 1232 [109]	11141-16-5	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
12.	Arochlor (PCB) 1242 [106]	53469-21-9	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
13.	Arochlor (PCB) 1248 [110]	12672-29-6	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
14.	Arochlor (PCB) 1254 [107]	11097-69-1	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
15.	Arochlor (PCB) 1260 [111]	11096-82-5	AWQS	$1E^{-6}$	H(FC)	NA	NAS3	NA	NAS3
16.	Asbestos [116]	-	ns	-	-	NA	NAS3	NA	NAS3
17.	Benzene [4]	71-43-2	AWQS	10	H(FC)	2	100%	6	100%
18.	Benzidine [5]	92-87-5	AWQS	0.1	A(C)	2	NAS1	6	NAS1
19.	Benz(a)anthracene [72]	56-55-3	GV	0.03	A(C)	2	NAS1	6	NAS1
			GV	0.23	A(A)	2	NAS1	6	NAS1
20.	Benzo(a)pyrene [73]	50-32-8	GV	0.0012	H(FC)	2	NAS1	6	NAS1
21.	Benzo(b)fluoranthene [74]	205-99-2	ns	-	-	2	NAS2	6	NAS2
22.	Benzo(ghi)perylene [79]	191-24-2	ns	-	-	2	NAS2	6	NAS2
23.	Benzo(k)fluorathene [75]	207-08-9	ns	-	-	2	NAS2	6	NAS2
24.	Butyl Benzyl phthalate [67]	85-68-7	ns	-	-	2	NAS2	6	NAS2
25.	Beta-endosulfan (*endosulfanII*) [96]	33213-65-9	ns	-	-	2	NAS2	6	NAS2
26.	Beta-lindane(*betaBHC*) [103] (*betaBHC, beta-hexachlorocyclohexane*)	319-85-7	AWQS	0.007	H(FC)	2	NAS1	6	NAS1
27.	Bis(2-chloroethoxy)methane [43]	111-91-1	ns	-	-	2	NAS2	6	NAS2
28.	Bis(2-Chloroethyl) ether [18]	111-44-4	ns	-	-	2	NAS2	6	NAS2
29.	Bis(2-chloroisopropyl)ether [42]	39638-32-9	ns	-	-	2	NAS2	6	NAS2
30.	Bis(2-ethylhexyl)phthalate [66]	117-81-7	AWQS	0.6	A(C)	2	NAS1	6	NAS1

Table 4-5. Enhanced tributary monitoring compliance results for priority pollutants for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2 (5/29/2012 through 5/30/2012).

Note: priority pollutants that have NYS AWQS are highlighted in light blue

No.	Primary Pollutant[1,2]	CAS Registry Number	Compliance Assessment Criteria [a]	Compliance Value (µg/L)	Type [b]	Dorwin Ave.		Plum St.	
						N	Percent Compliance	N	Percent Compliance
31.	4-Bromophenyl phenyl ether [41]	101-55-3	ns	-	-	2	NAS2	6	NAS2
32.	Toxaphene (*Camphechlor*) [113]	8001-35-2	AWQS	0.005	A(C)	2	NAS1	6	NAS1
			AWQS	$6E^{-6}$	H(FC)	2	NAS1	6	NAS1
33.	Carbon tetrachloride [6]	56-23-5	ns	-	-	2	NAS2	6	NAS2
34.	4-Chlor-m-cresol (*parachlorometa cresol*) [22]	59-50-7	ns	-	-	NA	NAS2	NA	NAS2
35.	Chlordane[i] [91]	57-74-9	AWQS	$2E^{-5}$	H(FC)	2	NAS1	6	NAS1
36.	Chlorobenzene [7]	108-90-7	AWQS	400	H(FC)	2	100%	6	100%
			AWQS	5	A(C)	2	100%	6	100%
37.	Chlorodibromomethane [51] (*dibromochloromethane)*	124-48-1	ns	-	-	2	NAS2	6	NAS2
38.	Chloroethane [16]	75-00-3	ns	-	-	2	NAS2	6	NAS2
39.	2-Chloroethyl vinyl ether [19]	110-75-8	ns	-	-	2	NAS2	6	NAS2
40.	Chloroform [23]	67-66-3	ns	-	-	2	NAS2	6	NAS2
41.	Chloromethane (*methyl chloride*) [45]	74-87-3	ns	-	-	2	NAS2	6	NAS2
42.	2-Chloronaphthalene [20]	91-58-7	ns	-	-	2	NAS2	6	NAS2
43.	2-Chlorophenol [24]	95-57-8	ns	-	-	1	NAS2	5	NAS2
44.	4-Chlorophenyl phenyl ether [40]	7005-72-3	ns	-	-	2	NAS2	6	NAS2
45.	Chrysene [76]	218-01-9	ns	-	-	2	NAS2	6	NAS2
46.	p,p DDD [94]	72-54-8	AWQS	$8E^{-5}$	H(FC)	2	NAS1	6	NAS1
47.	p,p DDE [93]	72-55-9	AWQS	$7E^{-6}$	H(FC)	2	NAS1	6	NAS1
48.	p,p DDT [92]	50-29-3	AWQS	$1E^{-5}$	H(FC)	2	NAS1	6	NAS1
49.	Delta-Lindane [105] (*delta BHC, delta-hexachlorocyclohexane*)	319-86-8	AWQS	0.008	H(FC)	2	NAS1	6	NAS1
50.	Di-n-octyl- phthalate [69]	117-84-0	ns	-	-	2	NAS2	6	NAS2
51.	Di-N-propylnitrosamine [63] (*N-nitroso-di-n-propylamine*)	621-64-7	AWQS	5[j]	E	2	NAS1	6	NAS1
52.	Dibenz(a,h)anthracene [82]	53-70-3	ns	-	-	2	NAS2	6	NAS2
53.	Dibutyl phthalate [68] (*di-n-butyl phthalate*)	84-74-2	ns	-	-	2	NAS2	6	NAS2
54.	1,4-Dichlorobenzene [27]	106-46-7	AWQS	5[k]	A(C)	2	100%	6	100%
55.	1,2-Dichlorobenzene [25]	95-50-1	AWQS	5[k]	A(C)	2	100%	6	100%
56.	1,3-Dichlorobenzene [26]	541-73-1	AWQS	5[k]	A(C)	2	100%	6	100%
57.	3,3'-Dichlorobenzidine [28]	91-94-1	ns	-	-	2	NAS2	6	NAS2
58.	Dichlorobromomethane [48] (*bromodichloromethane*)	75-27-4	ns	-	-	2	NAS2	6	NAS2

Table 4-5. Enhanced tributary monitoring compliance results for priority pollutants for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2 (5/29/2012 through 5/30/2012).

Note: priority pollutants that have NYS AWQS are highlighted in light blue

No.	Primary Pollutant[1,2]	CAS Registry Number	Compliance Assessment Criteria [a]	Compliance Value (µg/L)	Type [b]	Dorwin Ave. N	Dorwin Ave. Percent Compliance	Plum St. N	Plum St. Percent Compliance
59.	1,2-Dichloroethane [10]	107-06-2	ns	-	-	2	NAS2	6	NAS2
60.	1,1-Dichloroethane [13]	75-34-3	ns	-	-	2	NAS2	6	NAS2
61.	1,1-Dichloroethylene [29] (*1,1-Dichloroethene*)	75-35-4	ns	-	-	2	NAS2	6	NAS2
62.	Dichloromethane [44] (*methylene chloride*)	75-09-2	AWQS	200	H(FC)	2	100%	6	100%
63.	2,4-Dichlorophenol [31]	120-83-2	AWQS	1[i]	E	NA	NAS3	NA	NAS3
64.	1,2-Dichloropropane [32]	78-87-5	ns	-	-	2	NAS2	6	NAS2
65.	1,2-Dichloropropene [33]	563-58-6	ns	-	-	NA	NAS3	NA	NAS3
66.	Dieldrin [90]	60-57-1	AWQS	$6E^{-7}$	H(FC)	2	NAS1	6	NAS1
			AWQS	0.056	A(C)	2	100%	6	100%
			AWQS	0.24	A(A)	2	100%	6	100%
67.	Diethyl phthalate [70]	84-66-2	ns	-	-	2	NAS2	6	NAS2
68.	Dimethyl phthalate [71]	131-11-3	ns	-	-	2	NAS2	6	NAS2
69.	2,4-Dimethyphenol [34]	105-67-9	AWQS	1000	H(FC)	1	100%	5	100%
			AWQS	5[j]	E	1	NAS1	5	NAS1
70.	4,6-Dinitro-o-cresol [60]	534-52-1	ns	-	-	NA	NAS3	NA	NAS3
71.	2,4-Dinitrophenol [59]	51-28-5	AWQS	400	H(FC)	1	100%	5	100%
			AWQS	5[j]	E	1	NAS1	5	NAS1
72.	2,4-Dinitrotoluene [35]	121-14-2	ns	-	-	2	NAS2	6	NAS2
73.	2,6-Dinitrotoluene [36]	606-20-2	ns	-	-	2	NAS2	6	NAS2
74.	1,2-Diphenylhydrazine [37]	122-66-7	ns	-	-	NA	NAS3	NA	NAS3
75.	Hexachlorobutadiene [52]	87-68-3	AWQS	0.01	H(FC)	2	NAS1	6	NAS1
			AWQS	1.0	A(C)	2	NAS1	6	NAS1
76.	Endrin [98]	72-20-8	AWQS	0.002	H(FC)	2	NAS1	6	NAS1
			AWQS	0.036	A(C)	2	NAS1	6	NAS1
			AWQS	0.086	A(A)	2	100%	6	100%
77.	Endrin aldehyde [99]	7421-93-4	ns	-	-	2	NAS2	6	NAS2
78.	Endosulfan sulfate [97]	1031-07-8	ns	-	-	2	NAS2	6	NAS2
79.	Ethylbenzene [38]	100-41-4	GV	17	A(C)	2	100%	6	100%
			GV	150	A(A)	2	100%	6	100%
80.	Fluoranthene [39]	206-44-0	ns	-	-	2	NAS2	6	NAS2
81.	Fluorene [80]	86-73-7	GV	0.54	A(C)	2	NAS1	6	NAS1
			GV	4.8	A(A)	2	NAS1	6	NAS1
82.	Gamma-lindane [104]	58-89-9	AWQS	0.008	H(FC)	2	NAS1	6	NAS1

Table 4-5. Enhanced tributary monitoring compliance results for priority pollutants for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2 (5/29/2012 through 5/30/2012).

Note: priority pollutants that have NYS AWQS are highlighted in light blue

No.	Primary Pollutant[1,2]	CAS Registry Number	Compliance Assessment Criteria [a]	Compliance Value (µg/L)	Type [b]	Dorwin Ave.		Plum St.	
						N	Percent Compliance	N	Percent Compliance
	(*gamma BHC, gamma-hexachlorocyclohexane*)								
			AWQS	0.95	A(A)	2	100%	6	100%
83.	Heptachlor [100]	76-44-8	AWQS	$2E^{-4}$	H(FC)	2	NAS1	6	NAS1
84.	Heptachlor epoxide [101]	1024-57-3	AWQS	$3E^{-4}$	H(FC)	2	NAS1	6	NAS1
85.	Hexachlorobenzene [9]	118-74-1	AWQS	$3E^{-5}$	H(FC)	2	NAS1	6	NAS1
86.	Hexachlorocyclopentadiene [53]	77-47-4	AWQS	0.45	A(C)	2	NAS1	6	NAS1
87.	Hexachloroethane [12]	67-72-1	AWQS	0.6	H(FC)	2	NAS1	6	NAS1
88.	Indeno(1,2,3-cd)pyrene [83]	193-39-5	ns	-	-	2	NAS2	6	NAS2
89.	Isophorone [54]	78-59-1	ns	-	-	2	NAS2	6	NAS2
90.	Methanamine, N-methyl-N-Nitroso [61] (*N-nitrosodimethylamine*)	62-75-9	AQWS	5[j]	E	2	NAS1	6	NAS1
91.	Methyl Bromide [46] (*bromomethane*)	74-83-9	ns	-	-	2	NAS2	6	NAS2
92.	N-Nitrosodiphenylamine [62]	86-30-6	AWQS	5[j]	E	2	NAS1	6	NAS1
93.	Naphthalene [55]	91-20-3	GV	13	A(C)	2	NAS1 (50%)[m]	6	NAS1
			GV	110	A(A)	2	100%	6	100%
94.	Nitrobenzene [56]	98-95-3	ns	-	-	2	NAS2	6	NAS2
95.	4-Nitrophenol [58]	100-02-7	AWQS	5[j]	E	1	NAS1	5	NAS1
96.	2-Nitrophenol [57]	88-75-5	AWQS	5[j]	E	1	NAS1	5	NAS1
97.	Pentachlorophenol [64]	87-86-5	AWQS	1[l]	E	1	NAS1	5	NAS1
			AWQS[n]	exp (1.005pH- 5.1340	A(C)	1	NAS1	5	NAS1
			AWQS[1n]	exp (1.005pH- 4.869	A(A)	1	NAS1	5	NAS1
98.	Phenanthrene [81]	85-01-8	GV	5	A(C)	2	NAS1	6	NAS1
			GV	45	A(A)	2	100%	6	100%
99.	Phenol [65]	108-95-2	AWQS	5[j]	E	2	NAS1	6	NAS1
100.	Pyrene [84]	129-00-0	GV	4.6	A(C)	2	NAS1	6	NAS1
			GV	42	A(A)	2	100%	6	100%
101.	2,3,7,8-Tetrachlorodbenzo-P-Dioxin (TCDD) [129]	1746-01-6	AWQS	$6E^{-10}$	H(FC)	NA	NAS3	NA	NAS3
102.	1,1,2,2-Tetrachloroethane [15]	79-34-5	ns	-	-	2	NAS2	6	NAS2

Table 4-5. Enhanced tributary monitoring compliance results for priority pollutants for Onondaga Creek (Dorwin Ave. and Plum St.) for Event 2 (5/29/2012 through 5/30/2012).

Note: priority pollutants that have NYS AWQS are highlighted in light blue

No.	Primary Pollutant[1,2]	CAS Registry Number	Compliance Assessment Criteria [a]	Compliance Value (µg/L)	Type [b]	Dorwin Ave.		Plum St.	
						N	Percent Compliance	N	Percent Compliance
103.	Tetrachloroethene [85]	127-18-4	GV	1	H(FC)	2	100%[o]	6	100%[o]
104.	Toluene [86]	108-88-3	AWQS	6000	H(FC)	2	100%	6	100%
105.	1,2-Trans-Dichloroethylene [30]	156-60-5	ns	-	-	2	NAS2	6	NAS2
106.	Tribromomethane [47] (*bromoform*)	75-25-2	ns	-	-	2	NAS2	6	NAS2
107.	1,2,4-Trichlorobenzene [8]	120-82-1	AWQS	5	A(C)	2	NAS4[p]	6	NAS4[p]
108.	1,1,2-Trichloroethane [14]	79-00-5	ns	-	-	2	NAS2	6	NAS2
109.	1,1,1-Trichloroethane [11]	71-55-6	ns	-	-	2	NAS2	6	NAS2
110.	Trichloroethene [87]	79-01-6	AWQS	40	H(FC)	2	100%	6	100%
111.	2,4,6-Trichlorophenol [21]	88-06-2	AWQS	1[l]	E	1	NAS1	5	NAS1
112.	Vinyl chloride [88]	75-01-4	ns	-	-	2	NAS2	6	NAS2

[1] Division of Water Technical and Operational Guidance Series (TOGS version 1.1 998)
[2] Analysis method (GC/MS)
[a] Compliance Assessment Criteria – the value upon which compliance was assessed, AWQS = New York State Ambient Water Quality Standard, GV = New York State Guidance Value, ns = no standard or guidance value currently exists (for Class B,C waters);
[b] Type – classification of standard or guidance value, A(C) = toxic to aquatic life chronic toxicity levels, A(A) = toxic to aquatic life acute toxicity levels, H(FC) = toxic to human health from fish consumption, E = aesthetic;
[c] EPA priority pollutant number code
[d] NAS1 – not assessed code 1, compliance could not be assessed because water quality parameter method reporting limit (MRL) was greater than the AWQS or GV;
[e] NAS2 – not assessed code 2, compliance could not be assessed because water quality parameter does not have a AWQS or GV;
[f] NA – not analyzed by the contract lab;
[g] NAS3 - not assessed code 3, compliance could not be assessed because the water quality parameter was not analyzed by the contract lab;
[h] compliance value based on the sum of aldrin and dieldrin;
[i] alpha and gamma chlordane were analyzed, both MRLs>AWQS, therefore NAS1 assumed for chlordane
[j] compliance based on the sum of total unchlorinated phenols;
[k] compliance based on the sum of 1,4, 1,2, and 1,3-Dichlorobenzene;
[l] compliance based on the sum of total chlorinated phenols;
[m] NAS1 (%), compliance not entirely assessed because there were different MRLs for the water quality parameter some of which had values greater than the AWQS;
[n] compliance test requires paired pH values which were unavailable, compliance was NAS1 using event average pH conditions for each site
[o] result was at MRL (< 1µg/L), GV was equal to 1.0 µg/L
[p] NAS4 - not assessed code 4, compliance could not be assessed because compliance is based the sum of all isomers and not all required isomers (1,2,3- and 1,3,5 trichlorobenzene) were analyzed

4.3 Loading Estimates

4.3.1 Calculations and Results for Key Constituents

Dr. William Walker developed customized software for WEP staff to calculate annual loads using the program AUTOFLUX, method 5. This software is designed to support load estimates from detailed (e.g., continuous) flow measurements and the results of analyses of less frequent (often biweekly) tributary water quality samples. This software was used to compute all of the loading estimates presented in this report. Annual loading estimates for selected parameters are presented for 2012 (Table 4-6), mostly in units of metric tons (mt). Forms of phosphorus and nitrogen are measured frequently in the Metro effluent. Tributary loading calculations were supported by at least 23 observations within the year, except for Tributary 5A (n=11). Fecal coliform samples were collected more frequently to allow for determination of compliance with the AWQS.

The largest total phosphorus (TP) loads to Onondaga Lake were delivered by the Metro effluent (001) and the two largest tributaries, Onondaga and Ninemile Creeks (Table 4-6). The Metro bypass (002) load was estimated to be the fifth highest, following Ley Creek. Metro's contribution was substantially greater before the Actiflo® upgrade. Total phosphorus loads were much lower in 2012 than in 2011, consistent with decreases in precipitation and stream flow. For example, the total Metro load (001+002) decreased 20% while loads from Onondaga and Ninemile Creeks decreased by 68% and 69%, respectively. The Metro effluent also had the highest total dissolved phosphorus (TDP) loads in 2012, followed by Onondaga and Ninemile Creeks.

Sawmill Creek entering Onondaga Lake

Table 4-6. Estimated annual loading estimates for selected water quality constituents to Onondaga Lake, 2012.

Notes: mt = metric tons. n represents the number of water quality samples included in the annual load calculation.

Parameters[1]	TP		TDP		TN[7]		NH_3-N		TSS		FC[2]	
units	mt	n	mt	n	mt	n[3]	mt	n	mt	n	10^{10} cfu	n
Metro:												
Treated Effluent (001)[5]	6.8	366	1.8	245	1,091	366	33.4	366	413	366	44,498	211
Bypass (002)[6]	1.4	30	0.2	10	14.1	31	8.2	31	73	29	330,018	18
Watershed:												
Allied East Flume[4] Manhole 015	0.1	24	0.1	24	5.7	24	0.5	24	8	24	140	56
Harbor Brook[4]	0.3	23	0.1	22	12.4	23	0.4	23	76	23	10,099	66
Ley Creek[4]	1.9	27	0.4	27	28.1	27	5.9	27	541	27	19,813	75
Ninemile Creek[4]	4.8	26	1.1	26	157.8	26	21.9	26	1,688	26	34,775	63
Onondaga Creek[4]	6.8	26	1.3	26	167.3	27	8.5	27	5,331	27	102,963	66
Tributary 5A[4]	0.04	11	0.02	11	0.5	11	0.1	11	4	11	11	25
Total	22.1	--	5.0	--	1,477	--	78.9	--	8,134	--	542,317	--

Notes:

[1]Parameters are: TP (total phosphorus), TDP (total dissolved P), TN (total nitrogen), NH_3-N (ammonia-N), TSS (total suspended solids), and FC (Fecal coliform bacteria). Because TDP was not measured on the Bypass, SRP loads are reported rather than TDP loads.

[2]FC- fecal coliform bacteria loads have a very high standard error due to the episodic nature of the FC inputs.

[3]Not measured directly, counts reflect NH_3-N counts.

[4]Tributary loading results are calculated using 2012 observations (n = number of samples for 2012) and processed through AutoFlux Method 5 and are reported here for the sampling locations closest to Onondaga Lake.

[5]Metro Effluent Outfall 001 loads for TP, TSS, and NH_3-N are calculated using daily observations, and FC are collected biweekly as part of the long-term tributary program and daily from April 1 to October 15.

[6]Metro Bypass Outfall 002 loads are calculated using periodic grab samples when Outfall 002 is active (high flow events when the capacity of Metro is exceeded).

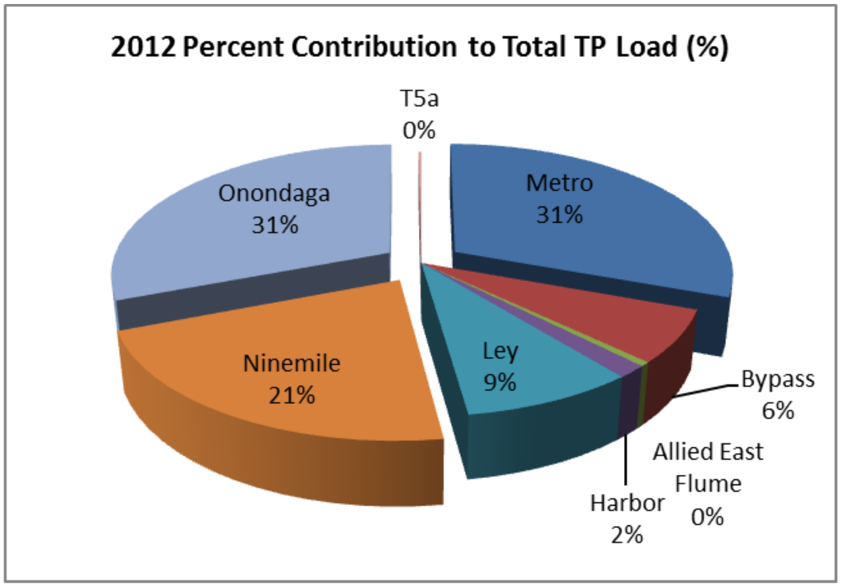
[7]All TN loads were calculated by summing the annual NH_3-N, NO_3-N, NO_2-N, and ORG-N loads

The Metro effluent was also the leading source of total nitrogen (TN) and ammonia nitrogen (NH_3-N) to the lake in 2012 (Table 4-6). Ninemile Creek continues to be an important source of ammonia; it had the second highest load in 2012. The total suspended solids (TSS) load from Onondaga Creek exceeded the next largest source, Ninemile Creek (with similar flow), by a factor of 3, and the Metro input by a factor of 13. The particularly high load of TSS in Onondaga Creek is at least in part attributable to inputs from the mud boils in upstream portions of its watershed. Annual loading of TSS from the tributaries decreased 62% from 2011 to 2012, associated with relatively high runoff in 2011 and low runoff in 2012 (Figure 4-2).

The primary sources of fecal coliform bacteria were the Metro bypass (002) and Onondaga Creek. However, the Metro effluent (001) and the other primary tributaries made noteworthy contributions as well (Table 4-6). Loading contributions of gauged inputs for selected constituents in 2012 are presented here in both tabular (Table 4-7) and graphical (Figure 4-4) formats. 2012 loading estimates for additional constituents are provided in Appendix D-1. Total annual loads (sum of tributaries and Metro) to Onondaga Lake for the 1993–2012 interval are presented in Appendix D-2.

Table 4-7. Percent annual loading contribution by gauged inflow in 2012, rounded to the nearest percent.

Parameter	TP	TDP	TN	NH_3-N	TSS	FC	Water
Metro:							
Treated Effluent (001)	31%	36%	74%	42%	6%	8%	24%
Bypass (002)	7%	4%	1%	10%	1%	61 %	0%
Watershed:							
Harbor Brook	2%	3%	1%	1%	1%	2%	2%
Ley Creek	9%	9%	2%	8%	7%	4%	8%
Ninemile Creek	21%	22%	11%	28%	21%	6%	31%
Onondaga Creek	31%	26%	11%	11%	66%	19%	35%
Tributary 5A	0%	0%	0%	0%	0%	0%	0%



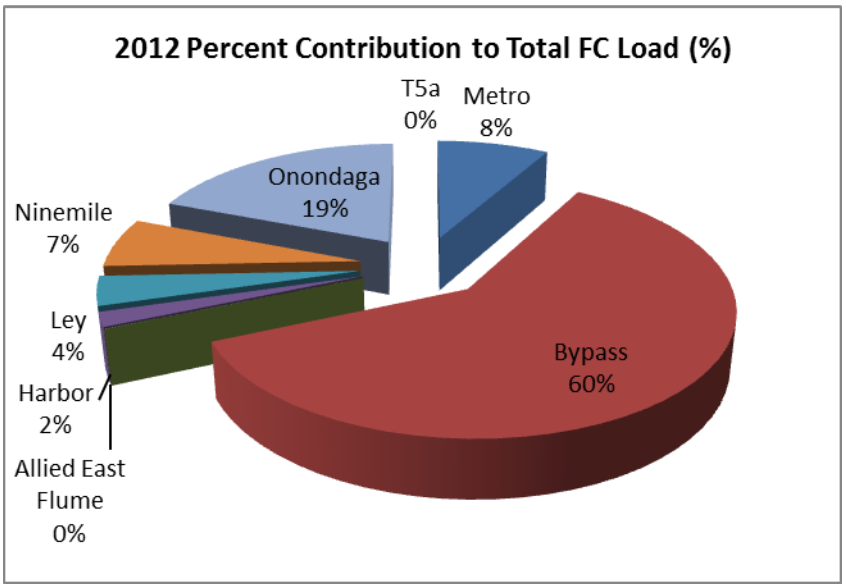


Figure 4-4. Percent contributions to 2012 total load to Onondaga Lake for (a) total phosphorus and (b) fecal coliform bacteria.

The relative potency of the various inflows can be represented by comparisons of annual flow-weighted average concentrations (total annual loads (mass) ÷ total flow (volume)) calculated for each input. Flow-weighted concentrations for 2012 are presented for the same selected constituents (Table 4-8). Total phosphorus concentrations ranged from 46 µg/L in Ninemile Creek to 179 µg/L in Allied East Flume, but were of course much higher for the partially treated Metro bypass (1,496 µg/L). Concentrations of TDP were lowest in Ninemile and Onondaga Creeks and highest in the bypass. The Metro effluent and bypass were enriched

Table 4-8. Flow-weighted average concentrations for selected constituents in Onondaga Lake tributaries, 2012.

Parameters[1]	TP		TDP		TN[7]		NH_3-N		TSS		FC[2]	
units	µg/L	n	µg/L	n	mg/L	n[3]	mg/L	n	mg/L	n	10^{10} cfu	n
Metro:												
Treated Effluent (001)[5]	89	366	23	245	14.35	366	0.44	366	5	366	585	211
Bypass (002)[6]	1,496	30	223	10	14.05	31	8.54	31	76	29	343,194	18
Watershed:												
Allied East Flume[4] Manhole 015	179	24	151	24	8.97	24	0.77	24	13	24	221	56
Harbor Brook[4]	49	23	21	22	1.77	23	0.06	23	11	23	1,444	66
Ley Creek[4]	73	27	16	27	1.04	27	0.22	27	20	27	746	75
Ninemile Creek[4]	46	26	11	26	1.61	26	0.22	26	17	26	356	63
Onondaga Creek[4]	61	26	11	26	1.51	27	0.08	27	48	27	928	66
Tributary 5A[4]	111	11	48	11	1.52	11	0.20	11	11	11	31	25

Notes:

1 Parameters are TP (total phosphorus), TDP (total dissolved P), TN (total nitrogen), NH_3-N (ammonia), TSS (total suspended solids), and FC (fecal coliforms). Because TDP was not measured on the Bypass, SRP loads are reported rather than TDP loads.

2 FC loads have a very high standard error due to the episodic nature of the FC inputs.

3 Not measured directly, counts reflect NH_3-N counts.

4 Tributary flow-weighted concentrations are calculated using 2012 observations (n = number of samples for 2012) processed through AutoFlux Method 5 and reported here for the sampling locations closest to Onondaga Lake.

5 Metro Effluent Outfall 001 loads for TP, TSS, and NH_3-N are calculated using daily observations; FC are collected biweekly as part of the long-term tributary program and daily April through mid-October.

6 Metro Bypass Outfall 002 loads are calculated using periodic grab samples when Outfall 002 is active (high flow events when the capacity of Metro is exceeded).

7 All TN flow-weighted concentrations were calculated by dividing the total TN load (see Table 4-3) by the total flow volume for each site.

in TN and ammonia relative to the other inputs. Concentrations of TSS were highest in Onondaga Creek and the bypass and lowest in fully treated Metro effluent. The highest fecal coliform concentrations were in the bypass, followed by Harbor Brook, Onondaga Creek, and Ley Creek. The complete list of constituent flow-weighted average concentrations, along with the relative error of the means, is presented in tabular format (Appendix D-3).

4.3.2 Selected Phosphorus Topics

Estimates of total phosphorus loads for the tributaries have generally been greater in higher runoff years (Figure 4-5). Variations in rainfall for the 1990–2012 period explained 45% of the differences in total phosphorus loading according to linear least-squares regression (p=0.001). Two- to three-fold differences in total phosphorus loads from the watershed can be expected due to natural variations in rainfall. Clearly, variations in runoff need to be considered in evaluating year-to-year dynamics of in-lake water quality.

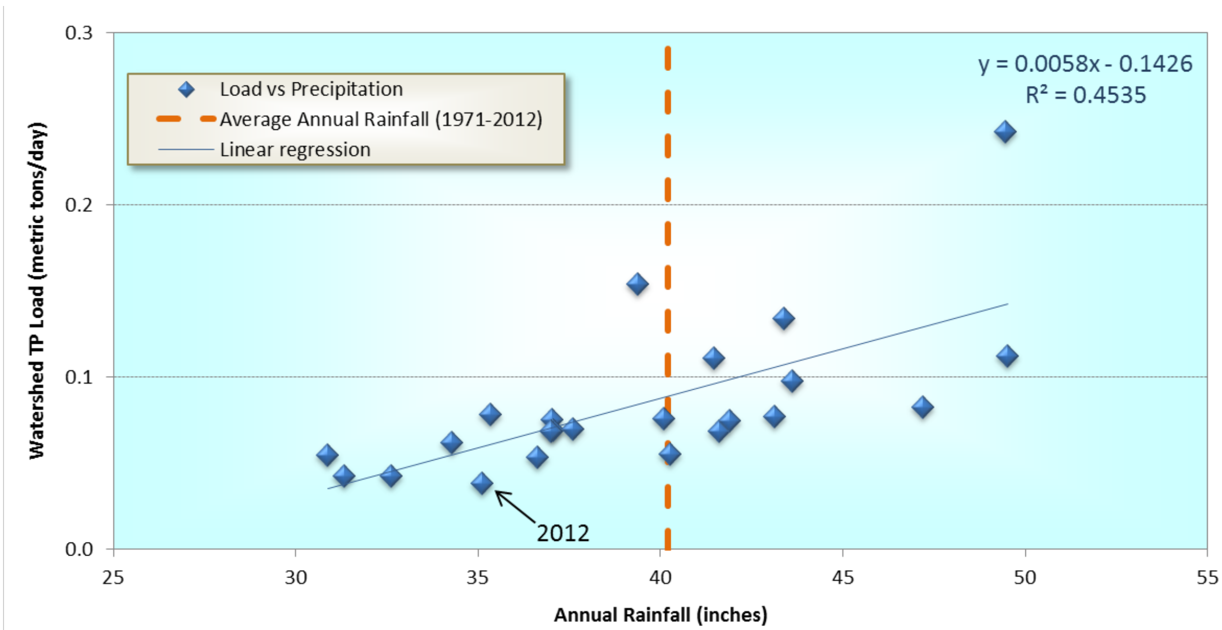


Figure 4-5. Evaluation of the dependence of the daily average total phosphorus (TP) load from the watershed (non-Metro), annually, on the annual precipitation for the 1990–2012 period.

Note: precipitation data from: http://www.nws.noaa.gov/climate/xmacis.php?wfo=bgm

The timing of phosphorus loads within a year is a potentially important factor relative to algal growth during the critical summer months, particularly in the context of the rapid flushing rate of Onondaga Lake (~ 4 times/yr). For example, loads received in the fall to winter interval are largely flushed through the lake, or particulate forms are deposited, by the following spring. Accordingly, late spring and summer loads are expected to be the most important for this lake. Monthly total phosphorus loads are presented for 2012 (Figure 4-6). Monthly total phosphorus loads are presented for the years 2008–2011 for comparison (Appendix D-4). There is a recurring seasonality driven by the seasonality of runoff, with the lowest loads generally prevailing in the summer and the highest in winter and spring. Substantial interannual differences have occurred because of the dependency on runoff. In 2012, watershed loading of total phosphorus was relatively high in January and December and particularly low during the June–September interval.

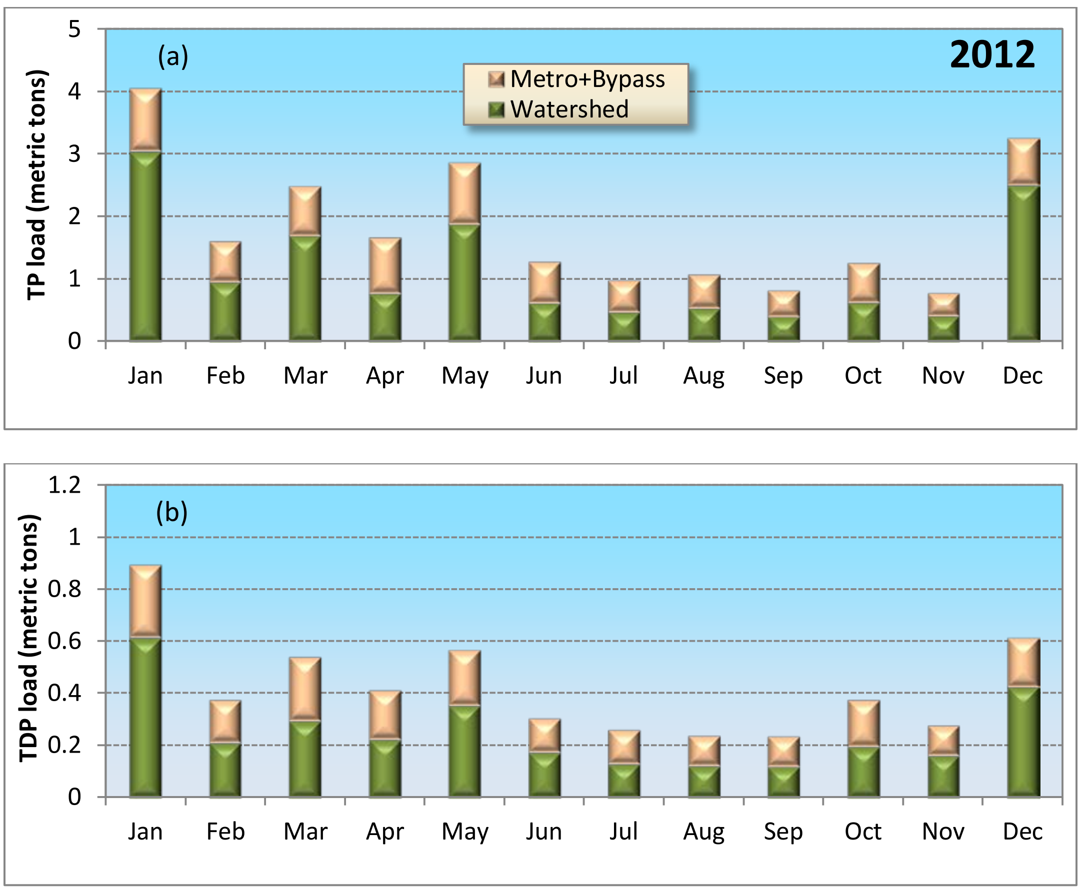


Figure 4-6. Monthly phosphorus loading to Onondaga Lake from Metro and watershed sources in 2012: (a) total phosphorus (TP) and (b) total dissolved phosphorus (TDP).

Contemporary lake management programs are increasingly considering the processes that diminish the effectiveness of total phosphorus loads to support algal growth. First, only dissolved forms of phosphorus can be utilized by algae. Much of the total phosphorus loading from the primary tributaries and Metro is in the form of particulate phosphorus (PP). Only a fraction of this PP can be converted to dissolved forms that are available to support algal growth. At least two other processes act to diminish the effectiveness of external total phosphorus loads, settling of PP before it can be transformed, and the plunging of dense inputs (e.g., those that are colder or more saline than the upper layers of the lake). Experiments conducted with the Metro effluent in 2009 established the limited bioavailability of this phosphorus load (Effler et al., 2012). Only about 30% of the total phosphorus load from Metro is in a dissolved form, while the remaining 70% is in particulate form. Bioavailability assays established that only 1% of the particle bound phosphorus is available to support algae growth. Moreover, the PP from Metro had an unusually high settling rate and a portion plunged below layers where algae grow. These findings indicate that pursuit of further optimization of phosphorus treatment at Metro should focus on the dissolved fraction. Further reductions in PP would not contribute importantly to achievement of water quality goals. In contrast, the bioavailability of PP from the primary tributaries ranged from 22% to 52% (Effler et al., 2002).

Bioavailability considerations highlight the importance of assessing loading rates for the major forms of phosphorus. The changes in total phosphorus (Table 4-9), total dissolved phosphorus (Table 4-10) and soluble reactive phosphorus (Table 4-11) loading from Metro and the tributaries from the 1990–1998 interval (before the ACJ) to after implementation of Actiflo® (2007–2011) are presented here. Loading of total phosphorus was reduced by 85% for the fully treated Metro effluent (Table 4-9). The 75% decrease in the total phosphorus load from the bypass is also noteworthy. The changes for the tributaries over this period have been smaller, including 46% and 25% decreases for Ley Creek and Onondaga Creek, respectively. In recent years (post-Actiflo®), Metro (effluent plus bypass) has represented about 26% of the total phosphorus load, the second largest source, after Onondaga Creek.

Loading rates of total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) are particularly important, as these forms of phosphorus are generally available to support algal growth. The contributions of Metro versus those of the tributaries to annual TDP loading for the 2007–2012 interval (post-Actiflo® upgrade) are presented in Table 4-10. Metro's average contribution to the TDP load over this interval was 24%, the third highest, following Ninemile Creek (29%) and Onondaga Creek (26%). The Metro bypass was the fifth largest contributor at 6%. Flow-weighted total dissolved phosphorus concentrations for the three smallest tributaries considered (Harbor Brook, Tributary 5A, and East Flume-Manhole 015) were higher than for the Metro effluent (0.030 mg/L). The Actiflo® upgrade resulted in the greatest decrease in SRP loading, a 98% reduction (Table 4-11). This phosphorus fraction is noteworthy because it is immediately available to support algae growth. The SRP load from the bypass declined by 80%

over this period. Metro's combined SRP load represents about 15% of the contemporary total, less than one-half of the inputs from Onondaga Creek or Ninemile Creek.

Table 4-9. Tributary and Metro total phosphorus (TP) loading to Onondaga Lake and flow-weighted concentration, pre-ACJ and post-Actiflo® implementation.

Note: (mt = metric tons; concentrations flow-weighted)

Site	1990-1998 (pre ACJ)				2007- 2012 (post-Actiflo®)			
	Flow (%)	TP (mt P/yr)	TP (% load)	TP (mg P/L)	Flow (%)	TP (mt P/yr)	TP (% load)	TP (mg P/L)
Metro:								
fully treated	21%	52	57%	0.56	19%	8	21%	0.09
Bypass	0.94%	8.5	7.5%	1.8	0.38%	2.1	5.4%	1.2
Watershed:								
Allied East Flume Manhole 015	0.23%	0.19	0.18%	0.20	0.20%	0.11	0.31%	0.13
Harbor Brook	2.1%	0.71	0.71%	0.070	2.4%	0.89	2.30%	0.078
Ley Creek	8.7%	5.7	5.8%	0.14	8.3%	3.1	8.1%	0.08
Ninemile Creek	32%	10	10%	0.065	33%	10	25%	0.064
Onondaga Creek	34%	20	19%	0.12	37%	15	38%	0.09
Tributary 5A	0.72%	0.17	0.19%	0.054	0.21%	0.11	0.28%	0.109
Total		**97**				**39**		

Table 4-10. Tributary and Metro total dissolved phosphorus (TDP) loading and flow-weighted concentrations to Onondaga Lake for post-Actiflo implementation.

Note: (mt = metric tons; concentrations flow-weighted)

Site	1990-1998 (pre ACJ)				2007- 2012 (post-Actiflo®)			
	Flow (%)	TDP (mt P/yr)	TDP (% load)	TDP (mg P/L)	Flow (%)	TDP (mt P/yr)	TDP (% load)	TDP (mg P/L)
Metro:								
fully treated	21%	-	-	-	19%	2	24%	0.03
Bypass	0.94%	-	-	-	0.38%	0.6	6.0%	0.3
Watershed:								
Allied East Flume Manhole 015	0.23%	-	-	-	0.20%	0.07	0.84%	0.08
Harbor Brook	2.1%	-	-	-	2.4%	0.41	4.17%	0.036
Ley Creek	8.7%	-	-	-	8.3%	0.9	9.2%	0.02
Ninemile Creek	32%	-	-	-	33%	3	29%	0.018
Onondaga Creek	34%	-	-	-	37%	3	26%	0.01
Tributary 5A	0.72%	-	-	-	0.21%	0.04	0.44%	0.043
Total						**10**		

Table 4-11. Tributary and Metro soluble reactive phosphorus (SRP) loading to Onondaga Lake, and flow-weighted concentrations, pre-ACJ and post-Actiflo® implementation.

Note: (mt = metric tons; concentrations flow-weighted)

Site	1990-1998 (pre ACJ)				2007- 2012 (post-Actiflo®)			
	Flow (%)	SRP (mt P/yr)	SRP (% load)	SRP (mg P/L)	Flow (%)	SRP (mt P/yr)	SRP (% load)	SRP (mg P/L)
Metro:								
fully treated	21%	12	59%	0.13	19%	0.3	6%	0.003
Bypass	0.94%	2.5	9.7%	0.5	0.38%	0.5	9.0%	0.3
Watershed:								
Allied East Flume Manhole 015	0.23%	0.07	0.29%	0.09	0.20%	0.05	1.09%	0.05
Harbor Brook	2.1%	0.25	1.10%	0.024	2.4%	0.36	7.26%	0.031
Ley Creek	8.7%	1.4	6.1%	0.03	8.3%	0.5	10.2%	0.01
Ninemile Creek	32%	2	8%	0.011	33%	2	32%	0.011
Onondaga Creek	34%	3	16%	0.02	37%	2	34%	0.01
Tributary 5A	0.72%	0.03	0.17%	0.010	0.21%	0.03	0.67%	0.032
Total		**21**				**5**		

4.3.3 Metro Performance

The ammonia concentration of the Metro effluent decreased dramatically with the implementation of the BAF treatment upgrade in 2004 (Figure 4-7). Implementation of this treatment resulted in a 98% decrease in ammonia loading to the lake from Metro (Figure 4-7). Efficient, year-round nitrification of ammonia reduced Metro's contribution to the total annual load (Metro + tributaries) from 91% to 53% (Figure 4-8). The seasonal regulatory limits for ammonia concentrations in the Metro effluent are presently 1.2 mg/L for the June 1 to October 31 interval and 2.4 mg/L for November 1 to May 31. Monthly average concentrations continued to meet these limits by a wide margin in 2012; 2011 conditions are included for reference (Figure 4-9). Seasonality in the performance of the nitrification treatment is observed, with the lowest ammonia concentrations reported in summer. This seasonality is consistent with the timing of the limits, as well as the known dependence of nitrification treatment performance on temperature.

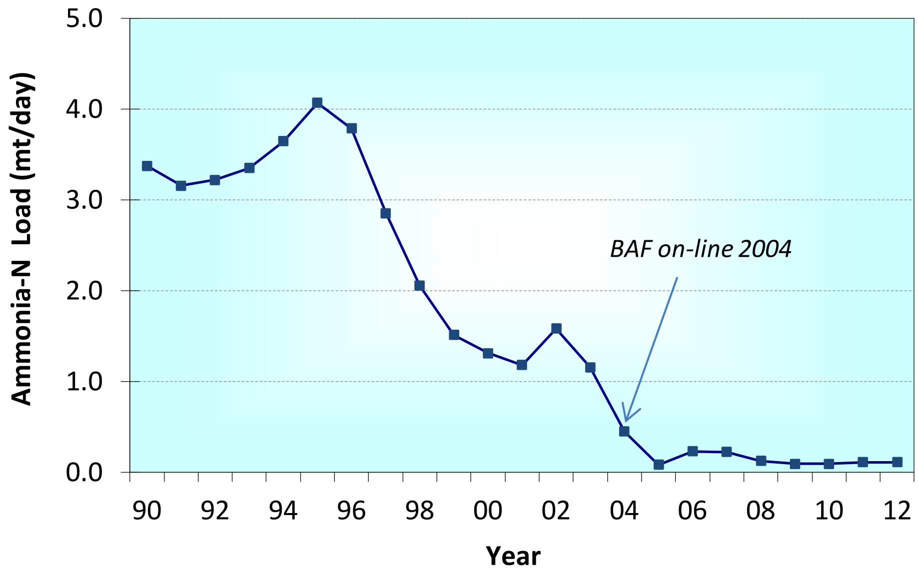


Figure 4-7. Time plot of the annual daily average Metro (outfalls 001+002) ammonia-N loading (metric tons/d) to Onondaga Lake, 1990–2012.

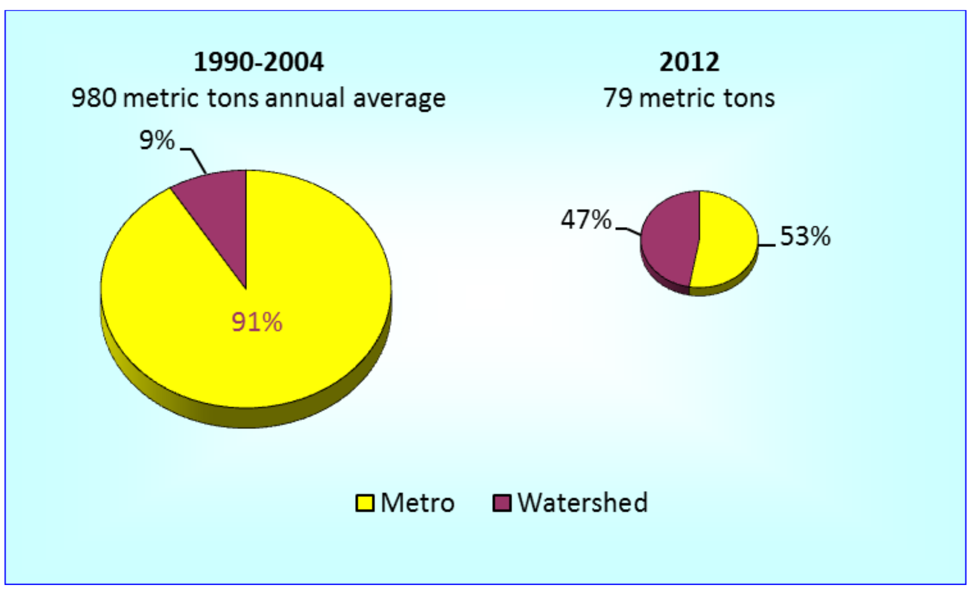


Figure 4-8. Contributions of Metro (outfalls 001+002) and the watershed to the total annual input of ammonia-N to Onondaga Lake, average for 1990–2004 compared to 2012.

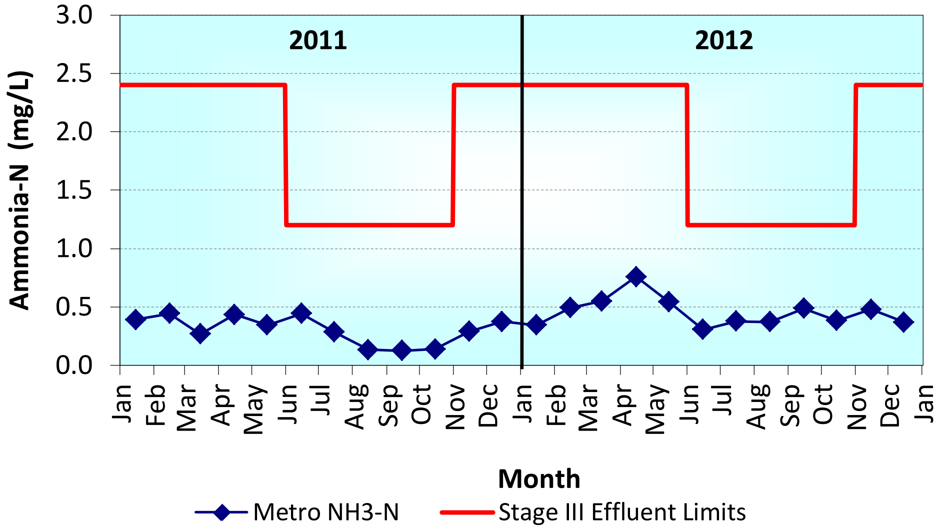


Figure 4-9. Metro effluent monthly average ammonia-N concentrations compared to permit limits for 2011 and 2012.

The total phosphorus concentration of Metro's effluent and associated loading (Figure 4-10) decreased dramatically with the implementation of the Actiflo® treatment upgrade. Moreover, Metro's contribution to the total annual phosphorus load has decreased from 61% over the 1990 to 2004 interval to 37% in 2012 (Figure 4-11). Total phosphorus concentrations for the 2006–2012 interval are presented as a rolling average monthly concentration, consistent with the format of the regulatory limit (Figure 4-12). Accordingly, each monthly value on the plot corresponds to the average total phosphorus concentration of that month combined with the 11 preceding months. Initially, the limit was 0.12 mg/L (or 120 µg/L), starting in the spring of 2007. As part of the November 2009 Fourth Stipulation Amending the ACJ, the interim Stage II total phosphorus effluent limit became 0.10 mg/L (Figure 4-12). These limits have been successfully met with the Actiflo® treatment upgrade. Since mid-2008 the rolling average total phosphorus concentration in the Metro effluent has remained below 0.10 mg/L (Figure 4-12).

Beginning in March 2012, the Metro plant began to experience higher levels of total phosphorus in the effluent. The increases were at first attributed to normal process variability, which is to be expected for wastewater treatment plants that treat nutrients to very low phosphorus levels, and is especially true for facilities subject to significant wet weather variability. When total phosphorus concentrations increased to a monthly average of 0.14 mg/L in April, operations staff began making adjustments to improve performance. Several operational enhancements and evaluations were implemented individually over time to monitor the treatment plant's response to changes without masking the actual solution for recovery. These included increasing the iron dosages in both the secondary and tertiary treatment process, increase in polymer dosages in the HRFS, additional backwashing of the BAF filters to effectively slough biomass, inspection of the physical/mechanical processes of the HRFS system, and relocation of County operated sludge hauling (sludge disposal from four (4) of the outlying WWTP) from the influent headworks, to the solids handling blend tank, thereby reducing the influent loading. By the end of July, TP concentrations had returned to pre-March levels. The recovery in performance was attributed to two (2) operational enhancements: (1) maximizing the TP removal in the secondary process through increased ferric chloride dosing to achieve more consistent TP concentrations from the secondary effluent in the 0.4 to 0.6 mg/l range, and (2) relocation of the outlying treatment plant sludge disposal location from the plant headworks to the blend tank for the solids handling end of the treatment process (previously routed to the headworks to accommodate the anaerobic digester cleaning efforts). Monthly average effluent total phosphorus concentrations have been exceptionally low (<0.07 mg/L) since September 2012. Metro performance relative to SPDES permit requirements is provided in Appendix C-3.

High Rate Flocculation and Settling (HRFS) Building

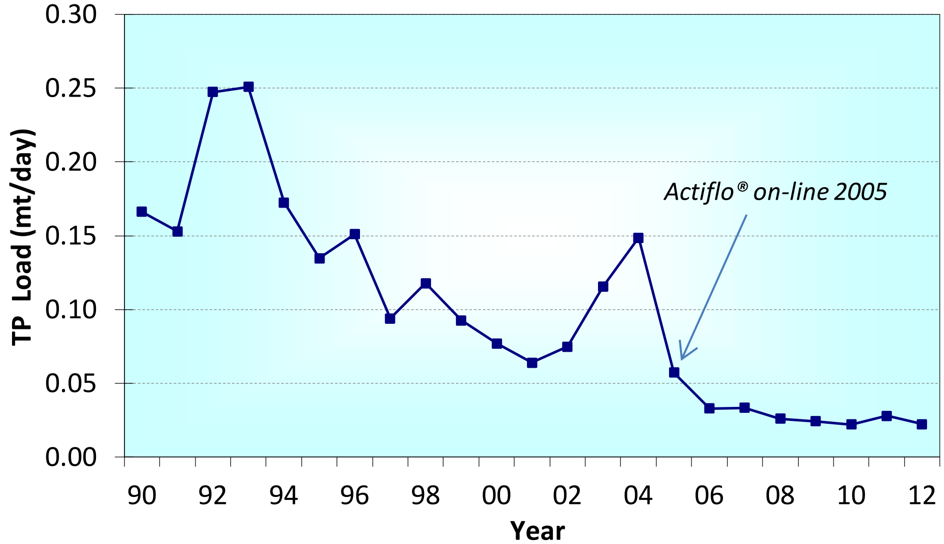


Figure 4-10. Time plot of the annual daily average Metro (outfalls 001+002) total phosphorus (TP) loading (metric tons/day) to Onondaga Lake, 1990–2012.

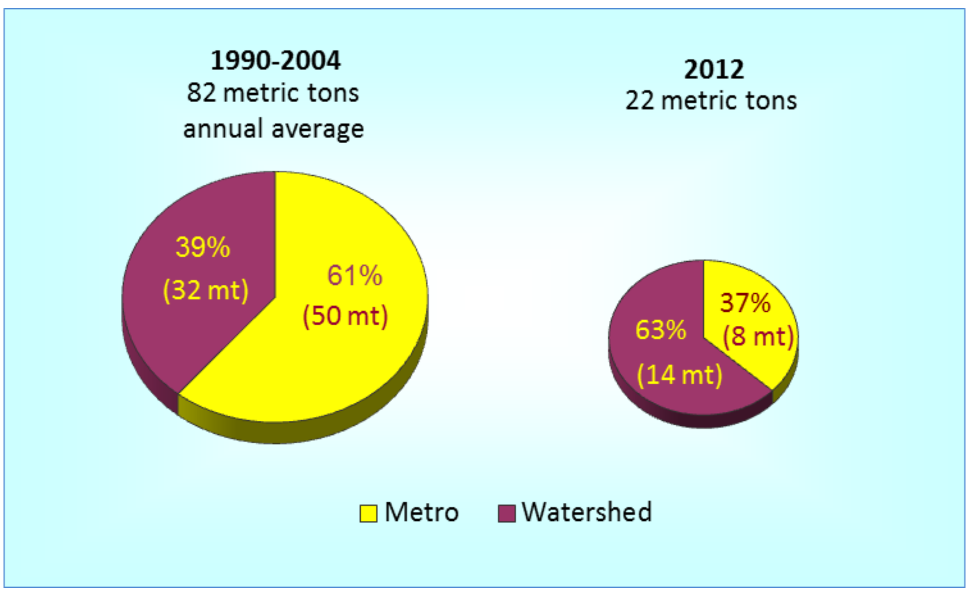


Figure 4-11. Contributions of Metro (outfalls 001+002) and the watershed to the annual input of total phosphorus to Onondaga Lake, average for 1990–2004 compared to 2012.

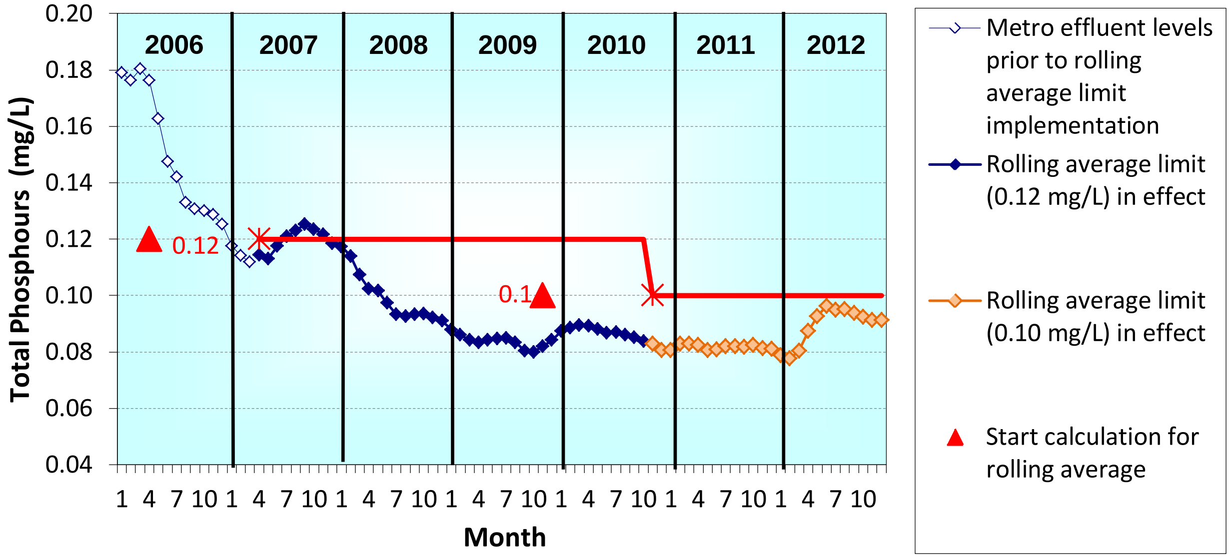


Figure 4-12. Metro effluent total phosphorus concentrations compared to permit limits for the 2006–2012 interval. Concentrations are monthly rolling average values for 12-month intervals.

The major reductions in ammonia and total phosphorus loading from treatment upgrades at Metro (BAF and Actiflo®, respectively) were identified and graphically supported (Figure 4-7 for ammonia, Figure 4-10 for total phosphorus). The BAF upgrade resulted in a 98% decrease in ammonia loading to the lake from Metro. Implementation of the Actiflo® upgrade achieved an 85% decrease in total phosphorus loading from Metro compared to the early 1990s. Loading of total nitrogen from Metro has not changed substantially from the BAF upgrade, but a highly desirable shift in the contribution of the various forms has been achieved. Implementation of the BAF treatment reduced the Metro loading of nitrite, another form of nitrogen that is a water quality concern, but increased the input of nitrate. Nitrate is not a water quality concern for Onondaga Lake. Moreover, the increased nitrate loading from Metro is having beneficial effects on the lake by diminishing the cycling of phosphorus and mercury (Matthews et al. 2013).

During particularly high runoff intervals, inflows to Metro can exceed the capacity of the facility to provide full treatment of wastewater. Portions of this inflow receive partial treatment, usually primary treatment and disinfection, and are discharged via outfall 002 (Appendix C-1). These inputs are of concern because concentrations of various constituents are higher compared to the fully treated effluent, as described above. Rarely, under particularly extreme runoff conditions, a small portion of the inflow to the facility receives no treatment (plant headworks are bypassed; Appendix C-2). There were no headworks bypasses in 2012. The extent to which bypasses occur depends critically on runoff, and therefore precipitation, both of which are subject to substantial variability. Discharges via outfall 002 occurred on 40 days in 2012, for a cumulative duration of 186.5 hours. A total of 213.8 million gallons were discharged via outfall 002 in 2012, compared to 750 million gallons in 2011. Another 12.2 million gallons were discharged through Outfall 001 as a result of tertiary bypasses. Documentation of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) throughout the Onondaga County service area are presented in Appendix C-4 and Appendix C-5, respectively.

Specific conductance and other measures of ionic content (e.g., chloride, TDS) increased conspicuously in the Metro effluent during the summer of 2012 (Figure 4-13). This increase in ionic content was caused by Metro's acceptance of saline groundwater from dewatering activities during construction of the Clinton and Harbor Brook Storage facilities. Whole effluent toxicity testing (WET) of the Metro effluent in the third and fourth quarters of 2012 indicated the effluent was both acutely and chronically toxic. This was likely the result of temporarily elevated salinity levels from dewatering activities.

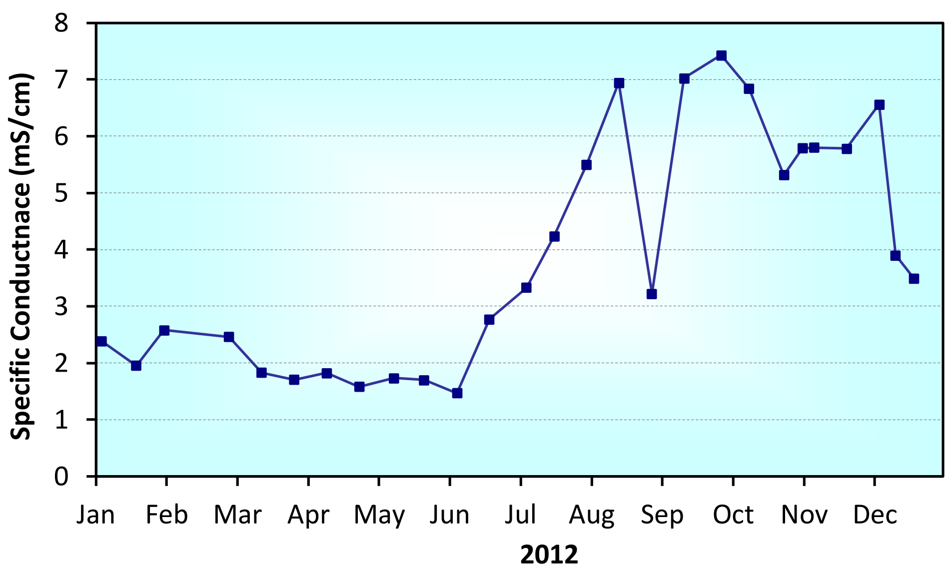


Figure 4-13. Time series of specific conductance in the Metro effluent (outfall 001) in 2012.

4.3.4 Trends

Loading trends for Metro and the tributaries over the 1991–2012 interval are presented graphically for selected constituents (Figure 4-14). Annual loads for additional constituents are presented in tabular format in Appendix D-4. Long-term decreases in loading of total phosphorus and total dissolved phosphorus have been driven mostly by reductions in the Metro contribution. Year-to-year variations in phosphorus loading from the watershed are regulated to a large extent by differences in the timing and magnitude of runoff. Phosphorus inputs from the tributaries were particularly low in the low runoff year of 2012. Long-term decreases in ammonia loading and increases in nitrate loading are associated with implementation of efficient, year-round nitrification treatment at Metro. Variations in ammonia and nitrate loading from the tributaries have been modest in comparison. Noteworthy reductions in loading of fecal coliform bacteria have occurred since the 1990s, led by decreasing inputs from the Metro bypass.

Seasonal Kendall tests were conducted for the 10 year period 2003–2012 to identify significant (p<0.1) trends in tributary concentrations (Table 4-12). Tributary loading trends were analyzed and tested using a linear regression analysis of annual load in metric tons (mt) versus time (Table 4-13). Annual loading trend slopes with p-values less than 0.1 were considered statistically significant. Statistically significant changes for constituents involved in the Metro treatment upgrades were evident, including decreases in phosphorus, nitrite, organic carbon, total suspended solids, and BOD_5, and increases in nitrate and chloride. Nitrate concentrations in the tributaries have decreased since the early 1990s (Table 4-12). Significant decreases in ammonia and nitrate loading are indicated since 2003 for nearly all of the tributaries to Onondaga Lake (Table 4-13). A cause for this decrease in nitrogen loading is not apparent at this time. Ninemile Creek is the largest tributary source of ammonia to the lake and has contributed most to the overall decrease. Increases in total phosphorus and soluble reactive phosphorus concentrations were observed for both the upstream (Dorwin Ave.) and downstream (Kirkpatrick St.) sites on Onondaga Creek. Decreasing trends were identified for dissolved oxygen (DO) for those same sites. Total suspended solids concentrations increased at Dorwin Ave., but not at Kirkpatrick St. Increases in chloride have occurred in Harbor Brook. The increase in suspended solids loading in Onondaga Creek has been linked to the resurgence of mud boil activity in the Tully Valley, which likely also contributed to increased total phosphorus loading.

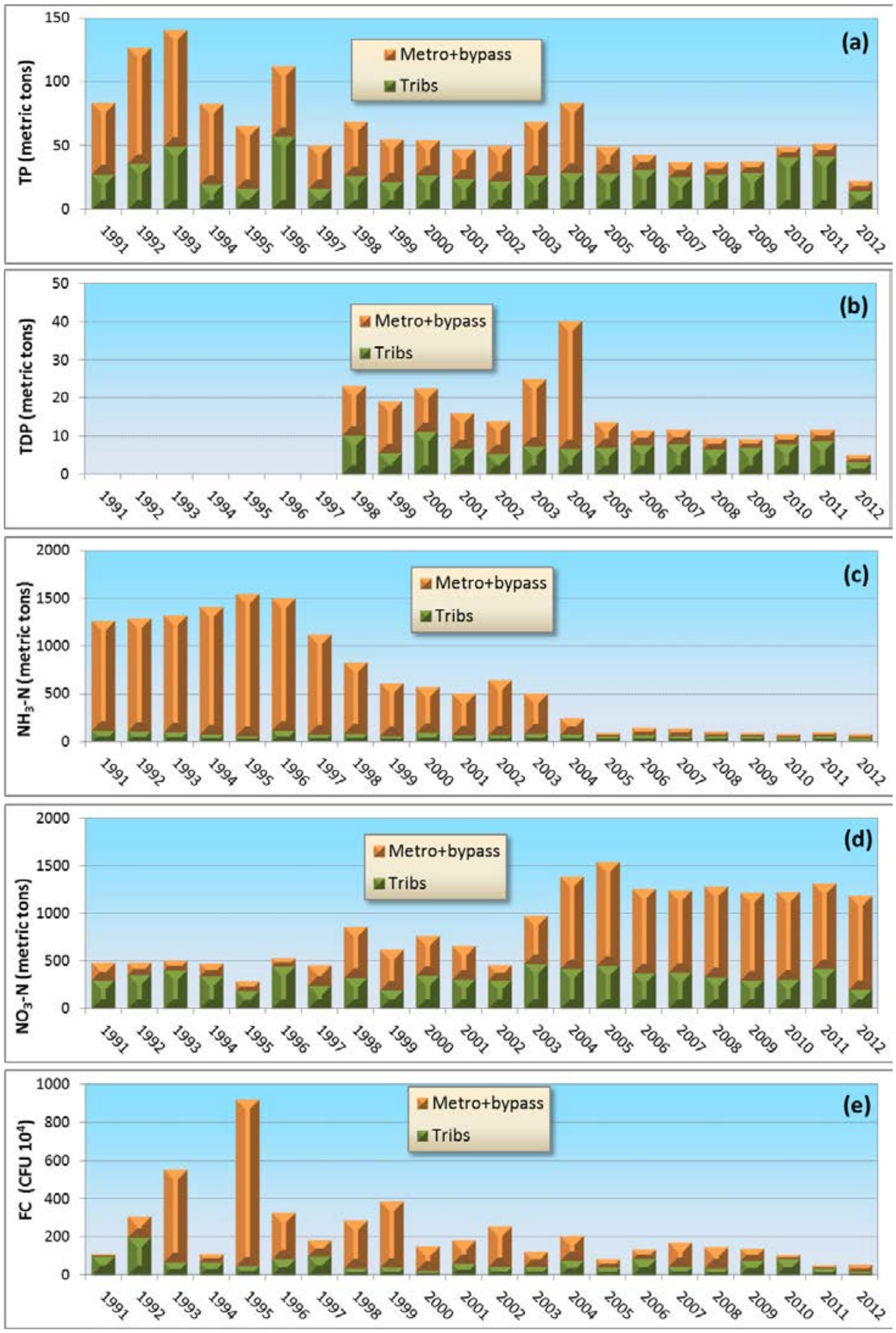


Figure 4-14. Annual loading of selected constituents to Onondaga Lake from Metro and watershed sources, 1991–2012: (a) total phosphorus (TP), (b) total dissolved phosphorus (TDP), (c) ammonia-N (NH_3-N), (d) nitrate (NO_3-N), and (e) fecal coliform (FC) bacteria.

Table 4-12. Ten-year (2003–2012) trends in tributary concentrations, from application of seasonal Kendall test.

Variable		Metro		Onondaga Creek		Harbor Brook		Ley Creek	Ninemile Creek	Trib 5a
		Treated Effluent	Bypass	Dorwin	Kirkpatrick	Velasko	Hiawatha	Park	Route 48	
Nitrogen	Ammonia (NH_3-N)	○	↑	↓	○	↓	○	○	○	○
	Nitrite (NO_2-N)	↓	○	↑	↑	○	○	○	○	○
	Nitrate (NO_3-N)	↑	↓	↓	↓	↓	↓	↓	↓	○
	Organic Nitrogen	○	○	↑	↑	↑	○	○	↑	○
	Total Kjeldahl Nitrogen (TKN)	○	○	↑	↑	○	○	○	○	○
Phosphorus	Total Phosphorus (TP)	↓	○	↑	↑	↓	○	○	○	○
	Soluble Reactive Phosphorus (SRP)	↓	○	↑	↑	↓	○	↓	○	○
Solids	Total Suspended Solids (TSS)	↓	○	↑	○	○	○	○	○	○
	Total Dissolved Solids (TDS)	○	↓	○	○	↑	↑	○	○	○
	Volatile Suspended Solids (VSS)	○	○	○	○	○	○	○	○	○
Carbon	Total Inorganic Carbon (TIC)	↓	○	↓	↓	○	↓	○	↓	○
	Total Organic Carbon (TOC)	↓	○	○	○	↓	↓	↓	↓	↓
	Total Organic Carbon, filtered (TOC_F)	↓	○	○	○	↓	↓	↓	○	○
Other	Alkalinity	↓	○	○	○	↑	○	○	↑	○
	BOD_5*	↓	↑	○	○	○	○	○	○	○
	Calcium (Ca)	↑	○	↑	↑	↑	↑	○	○	○
	Chloride (Cl)	↑	○	○	○	↑	↑	○	↓	○

Table 4-12. Ten-year (2003–2012) trends in tributary concentrations, from application of seasonal Kendall test.

Variable	Metro		Onondaga Creek		Harbor Brook		Ley Creek	Ninemile Creek	Trib 5a
	Treated Effluent	Bypass	Dorwin	Kirkpatrick	Velasko	Hiawatha	Park	Route 48	
Specific Conductance	○	○	○	○	↑	↑	○	○	○
Dissolved Oxygen (DO)	○	○	↓	↓	○	○	○	○	↑
Fecal Coliform Bacteria	○	○	○	○	○	○	○	○	○
Hardness	↑	○	↑	↑	↑	↑	○	○	○
Magnesium (Mg)	↓	○	○	○	↑	○	○	○	○
Sodium (Na)	○	○	○	○	↑	↑	○	○	○
pH	○	○	○	○	○	↑	↑	○	○
Silica (SiO_2)	○	○	○	↑	↑	○	○	○	○
Sulfates (SO_4)	○	○	○	○	○	○	○	○	↓
Temperature (°C)	○	○	↑	○	↓	↑	↑	↑	↓

Notes:
Significance level, two-tailed, seasonal Kendall test accounting for serial correlation.
↓ indicates decreasing trend ($p < 0.1$)
↑ indicates increasing trend ($p < 0.1$)
○ indicates no trend ($p > 0.1$)
- dash indicates parameter is not measured at this location.
*BOD_5 (Biochemical Oxygen Demand (5-day)) trend analysis results are accurate only for METRO & BYPASS because of the preponderance of data less than the MRL (PQL) in other inputs.

Table 4-13. Ten-year (2003–2012) trends in tributary loading, from linear regression of annual load versus time.

Variable		Metro		Onondaga Creek		Harbor Brook		Ley Creek	Ninemile Creek	Trib. 5a
		Treated Effluent	Bypass	Dorwin	Kirkpatrick	Velasko	Hiawatha	Park	Route 48	
Nitrogen	Ammonia (NH_3-N)	↓	o	↓	↓	↓	↓	↓	↓	↓
	Nitrite (NO_2-N)	↓	o	o	o	o	o	o	o	↓
	Nitrate (NO_3-N)	o	o	↓	↓	↓	↓	↓	↓	↓
	Total Kjeldahl Nitrogen (TKN)	↓	o	o	o	o	o	↓	o	↓
Phosphorus	Total Phosphorus (TP)	↓	o	o	o	↓	o	o	o	o
	Soluble Reactive Phosphorus (SRP)	↓	o	o	o	↓	o	o	o	o
Solids	Total Suspended Solids (TSS)	↓	o	o	o	o	o	↓	o	o
Carbon	Total Inorganic Carbon (TIC)	↓	o	↓	↓	↓	o	↓	↓	↓
	Total Organic Carbon (TOC)	↓	o	↓	o	↓	↓	o	↓	↓
	Total Organic Carbon, filtered (TOC_F)	↓	o	↓	o	↓	↓	o	o	↓
Other	Alkalinity	↓	o	↓	o	o	o	o	o	o
	BOD_5*	↓	o	o	o	↓	o	o	o	↓
	Calcium (Ca)	o	o	o	o	o	o	↓	↓	↓
	Chloride (Cl)	o	o	↓	o	o	o	↓	↓	↓
	Fecal Coliform Bacteria	↓	o	o	o	o	o	o	o	o
	Sodium (Na)	o	o	↓	o	o	o	o	↓	↓
	Silica (SiO_2)	↓	o	↓	o	o	o	o	o	↓

Notes:
Significance level calculated from linear regression of annual load versus time.
↓ indicates decreasing trend ($p < 0.1$); ↑ indicates increasing trend ($p < 0.1$); ○ indicates no trend ($p > 0.1$)
*BOD5 (Biological Oxygen Demand (5-day)) test reliable only for METRO & BYPASS because of variations in detection limits.

4.3.5 Special Topic: Analysis of Fecal Coliform Data from Onondaga Lake Tributaries

W. W. Walker, Jr. and J. D. Walker conducted exploratory and statistical analyses of fecal coliform data collected by the AMP at seven monitoring sites on four major tributaries to Onondaga Lake between 1999 and 2012 (Table 4-14). The full report is provided in Appendix D-5. Here we summarize a number of key findings of this report. The report focuses on measuring frequency and long-term trends in compliance with the AWQS for fecal coliform bacteria (monthly geometric mean less than 200 cfu/100 mL based on at least 5 samples), which is determined using periodic samples collected without regard to weather. In addition, correlations between fecal coliform concentrations and season, precipitation, and flow were evaluated and recommendations were provided for monitoring program design and further data analysis.

Table 4-14. Tributary sampling stations.

Site Name	Site Code	Waterbody
Ley Creek @ Park	PARK	Ley Creek
Ninemile Creek @ RT48	RT48	Ninemile Creek
Harbor Brook @ Velasko	VELASKO	Harbor Brook
Harbor Brook @ Hiawatha	HIAWATHA	Harbor Brook
Onondaga Creek @ Dorwin	DORWIN	Onondaga Creek
Onondaga Creek @ Kirkpatrick	KIRKPAT	Onondaga Creek

The annual geometric mean fecal coliform concentration at each site with 95% confidence intervals and reference lines indicating the approximate date of completion for site-specific CSO remediation projects are shown in Figure 4-15. Distributions by site and month (Figure 4-16) depict a distinct seasonality in fecal coliform concentrations, which tend to be higher in the summer months at all six sites. These figures include a reference line at 200 cfu/100 mL (2.3 in $\log_{10}$ units), which is the NYS AWQ standard for fecal coliform. Because this standard strictly applies to a monthly geometric mean based on a minimum of 5 samples, it is only included for numerical perspective.

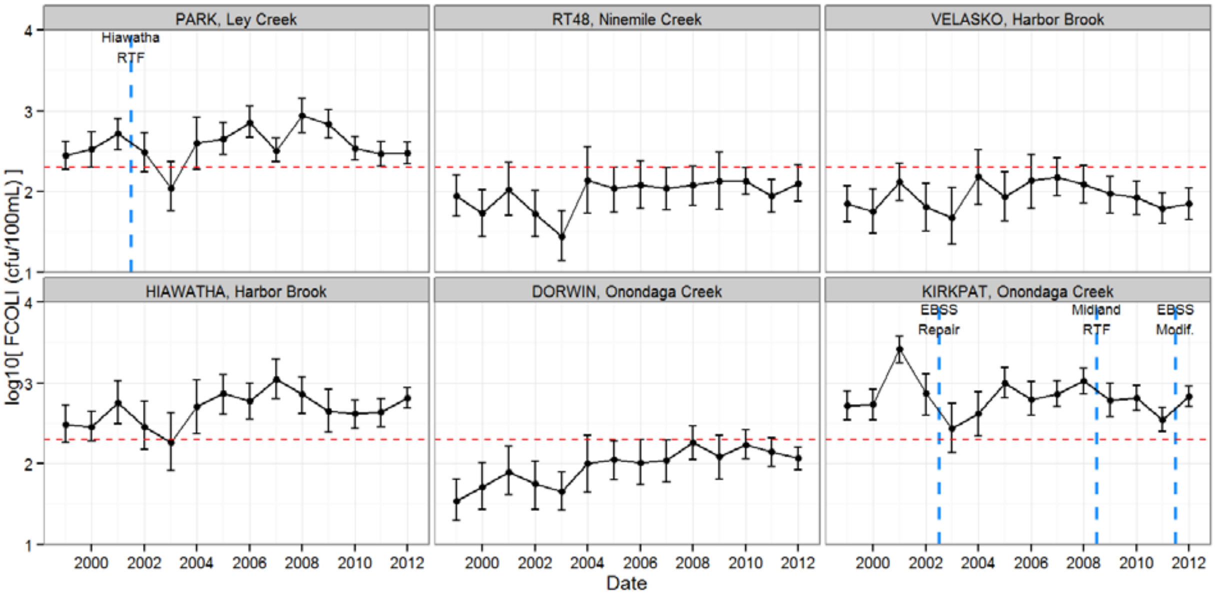


Figure 4-15. Annual geometric mean fecal coliform concentrations.

Note: error bars represent 95% confidence intervals. Dashed red line indicates 200 cfu/100mL reference. Dashed blue lines indicate completion dates of CSO remediation projects.

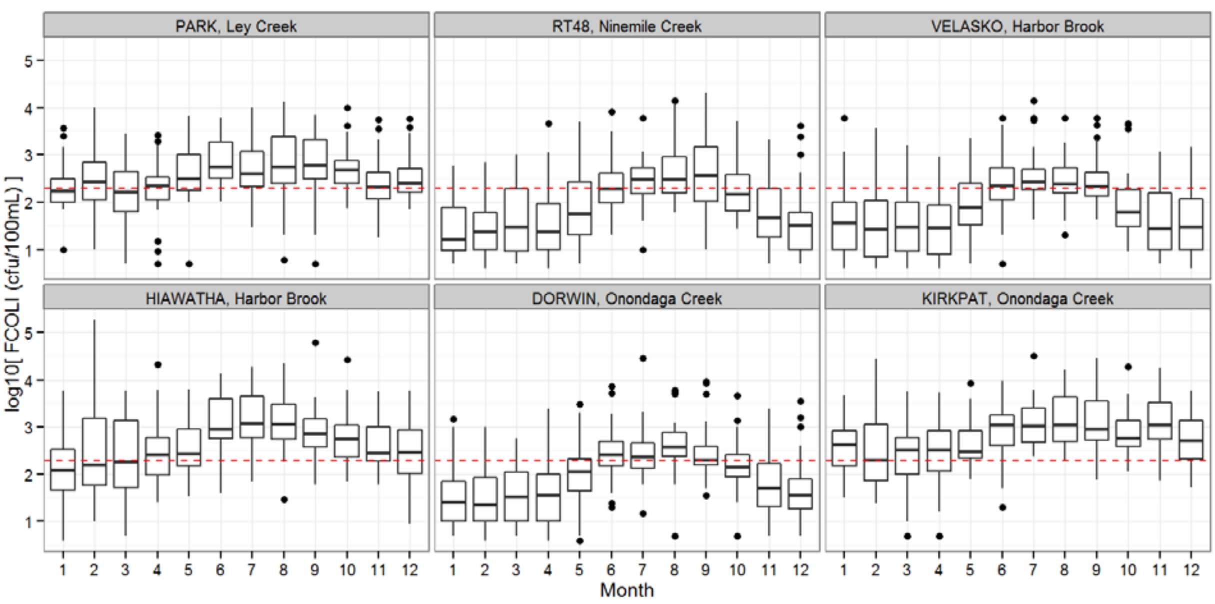


Figure 4-16. Boxplots of fecal coliform concentrations by site and month showing seasonality.

Note: Dashed red line indicates 200 cfu/100mL reference

There is strong evidence of increasing fecal coliform concentrations at a rate of about 10% per year under both dry and wet weather conditions at the upstream station (Dorwin Ave.) on Onondaga Creek. There is also evidence of increasing long-term trends in fecal coliform concentrations at the mouths of Ninemile Creek (6.3% per year) and Harbor Brook (4.6% per year). Compliance with the AWQS for fecal coliforms was observed in 70% of the months at the upstream sites, as compared with 15-25% at the downstream sites. Achieving compliance with the standard in 90% of the months would require >60% reductions at the upstream sites and >90% reductions at downstream sites. Achieving higher compliance rates would require significantly higher reductions.

Onondaga Creek at Spencer Street

This page intentionally left blank

Section 5. Onondaga Lake Water Quality: 2012 Results and Trends

5.1 Sampling Locations

Trained Water Environment Protection (WEP) technicians collect samples from Onondaga Lake throughout the year to characterize water quality and biological conditions. Most sampling occurs between April and November when the lake is free of ice. Winter sampling is conducted as conditions allow. The ambient monitoring program (AMP) encompasses multiple parameters (Table 1-2) with a focus on evaluating compliance with ambient water quality standards (AWQS) and assessment of trends toward attainment of designated uses. WEP also tracks physical factors, such as the development and extent of ice cover. During the winter of 2011–2012, ice covered the north basin of the lake on 8 days and the entire lake on 3 days. In 2012–2013, ice cover extended for 53 days in the north basin and 46 days lake wide.

The lake's main sampling station, referred to as South Deep, is the deepest point in the southern basin. South Deep has been the long-term reference monitoring location on Onondaga Lake since the County initiated monitoring in 1970. In addition to the routine biweekly sampling at South Deep, WEP technicians collect samples from the deepest point of the lake's northern basin (North Deep) four times each year to confirm that water quality conditions measured at the South Deep station adequately characterize open water conditions. Results from North Deep and South Deep remained generally comparable in 2012 (Appendix E-1).

The AMP also includes sampling of a network of ten near-shore locations for parameters related to suitability for water contact recreation. These parameters include Secchi disk transparency, turbidity, and fecal coliform bacteria.

5.2 Compliance with AWQS

The 2012 monitoring results indicate that the open waters of Onondaga Lake were in compliance with most ambient water quality standards (AWQS), with exceptions noted in Table 5-1. The concentration of total dissolved solids (TDS), which primarily reflects the concentrations of the major cations and anions (calcium (Ca^{2+}), sodium (Na^{+}), magnesium (Mg^{2+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), sulfate (SO_4^{2-})), exceeded the AWQS of 500 mg/L by a wide margin. Exceedance of this standard is associated with the lake's natural hydrogeology and not with anthropogenic effects. The bedrock in Onondaga County is comprised of Paleozoic sedimentary rocks with high concentrations of calcium and sulfate, which contribute to the high TDS levels in Onondaga Lake and its tributaries.

New York State has promulgated a narrative standard for phosphorus in water: "None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSCRR §703.2). For ponded waters the narrative standard is interpreted using a guidance value of 20 µg/L, calculated as the average total phosphorus concentration in the lake's upper waters between June 1 and September 30. A total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake has been developed to meet this water quality goal. The phosphorus TMDL was approved by USEPA on June 29, 2012. The 2012 summer average total phosphorus (TP) concentration in the lake's upper waters was 22 µg/L, somewhat higher than the state's guidance value of 20 µg/L.

Table 5-1. Percentage of measurements in compliance with ambient water quality standards (AWQS) and guidance values in the upper mixed and lower water layers of Onondaga Lake at South Deep in 2012.

Note: occurrences of less than 100% compliance are highlight in red text.

Parameter[7]	South Deep	
	Upper Mixed Layer (0-6 m)	**Lower Water Layer (12-18 m)**
Field Data		
Dissolved Oxygen (>4mg/L)[1]	100%	**53%**
Dissolved Oxygen (>5 mg/L)[1]	100%	**50%**
pH	100%	100%
Nutrients		
Total Phosphorus	**0% (21.7 µg/L)**	--[6]
Ammonia	100%	100%
Nitrite	100%	100%
Total Dissolved Solids	**0%**	**0%**
Metals[5]		
Arsenic	100%	100%
Cadmium	100%	100%
Chromium	100%	100%
Copper	100%	100%
Lead	100%	100%
Nickel	100%	100%
Zinc	100%	100%
Mercury		
Dissolved Mercury[3]	100%	100%
Bacteria		
Fecal Coliform[2]	100%	--[6]

Notes:
[1] Dissolved oxygen compliance based on 15-min. buoy data at 2 m and 12 m depths
[2] The AWQS for fecal coliform bacteria is specified as the monthly geometric mean (GM) 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).
[3] Dissolved mercury samples were collected at 3 m and 18 m depths on one date (10/16/12)
[4] Total phosphorus compliance based on 0-3m average biweekly samples averaged for June 1 – Sept 30
[5] AWQS for metals, arsenic, cadmium, copper, lead, nickel and zinc apply to the dissolved forms. Total recoverable concentrations of these metals were measured in 2012.
[6] Dashed lines indicate that compliance is not evaluated in the lower water layer.
[7] Parameters listed in bold are cited in the ACJ.

Samples for analysis of total mercury and methylmercury were collected from South Deep and North Deep at two depths (3 meters and 18 meters) in April, August, and October of 2012. Methylmercury is of particular concern because it bioaccumulates strongly in aquatic food webs, resulting in toxic effects at upper trophic levels when concentrations are high. Samples were collected for analysis of dissolved total mercury on a single date (10/16/12) at depths of 3 m and 18 m at North Deep and South Deep. The AWQS for total dissolved mercury in Class B and C waters is 0.7 nanograms per liter (ng/L). All total dissolved mercury concentrations were below the detection limit of 0.5 ng/L. The time series of total mercury and methylmercury concentrations measured in both the upper and lower waters of Onondaga Lake since 1999 indicate a decline in the concentration of this heavy metal (Figure 5-1).

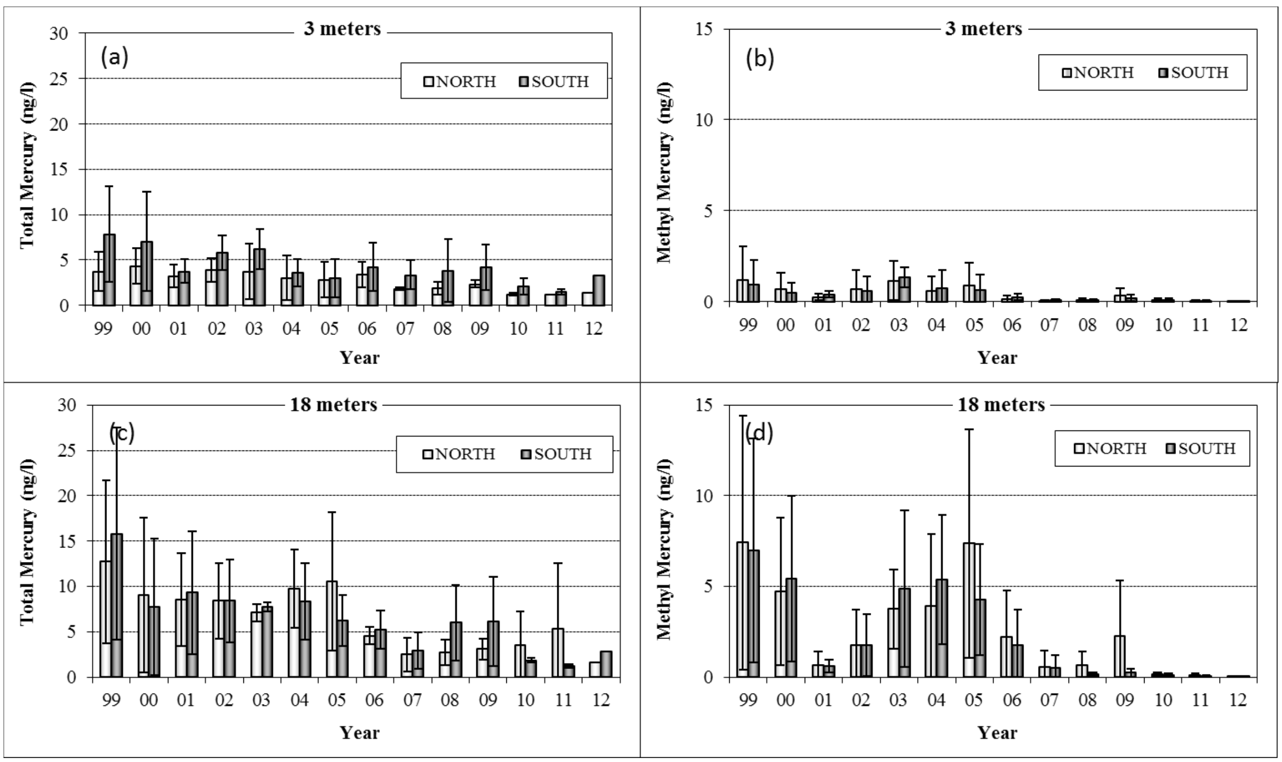


Figure 5-1. Time plot of annual average mercury concentrations at the North and South Deep stations of Onondaga Lake, 1999–2012 (a) total mercury at 3 m, (b) methylmercury at 3 m, (c) total mercury at 18 m, and (d) methylmercury at 18 m.

Note: The error bars depict one standard deviation of the annual mean concentration.

Dissolved oxygen (DO) concentrations met the AWQS (Table 5-2) in the upper waters of Onondaga Lake throughout the 2012 sampling period. DO concentrations in the lower waters were below the minimum 4 mg/L during a portion of the summer stratified period. However, this situation is not uncommon in stratified lakes where the volume of the lower stratum (the hypolimnion) is relatively small. In New York, an estimated 70% of assessed lakes do not meet the minimum DO standards in the deep waters (NYSDEC Consolidated Assessment and Listing Methodology, May 2009). In the ***TMDL for Phosphorus in Onondaga Lake***, NYSDEC concluded that the Lake is unable to meet the existing statewide DO water quality standard at all times during the year in the lower depths of the Lake because natural conditions contribute to the depletion of oxygen in the hypolimnion. NYSDEC has not classified Onondaga Lake as trout water (T) or trout spawning water (TS). The onset of anoxia in the lake's lower waters is occurring later, suggesting improved water quality and habitat conditions.

Table 5-2. New York State water quality standards for dissolved oxygen.

AA, A, B, C, AA-Special	For trout spawning waters (TS), the DO concentration shall not be less than 7.0 mg/L from other than natural conditions. For trout waters (T), the minimum daily average shall not be less than 6.0 mg/L, and at no time shall the concentration be less than 5.0 mg/L. For non-trout waters, the minimum daily average shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L.

In 2012, the measured fecal coliform bacteria counts at the Onondaga Lake monitoring stations were in compliance with the ambient water quality standard (monthly geometric mean concentration from at least five samples less than or equal to 200 cfu/100 mL) at offshore and nearshore locations within the Class B portion of the lake. Fecal coliform counts exceeded the standard at a single site located adjacent to the Metro outfall within the Class C water segment in April (see Section 5.6). This location was in compliance with the fecal coliform standard during May–October. All other locations within the Class C water segment met the ambient water quality standard for all monitored months.

5.3 Trophic State

The trophic state of a lake refers to its level of primary production (production of organic matter through photosynthesis). This is a fundamental feature of the ecology of lakes that also has important water quality implications. Highly productive lakes are termed eutrophic, while lakes with low levels of productivity are termed oligotrophic. Those with intermediate levels of productivity are described as mesotrophic. Excessive productivity can result in conditions that impair a waterbody for a particular use, such as water supply or recreation.

Primary production in Onondaga Lake, like most lakes in the Northeast, is limited by the availability of the nutrient phosphorus. Addition of phosphorus to lakes causes increased primary production, described as eutrophication. This is generally accompanied by higher concentrations of algae and often cyanobacteria (blue-green algae), which can have deleterious effects on water quality. Certain cyanobacteria can produce harmful toxins.

Decay of settled algae contributes to the depletion of dissolved oxygen in the lower stratified layers. Where this decay is substantial, oxygen can be depleted to levels that make these layers uninhabitable for fish and other oxygen-requiring biota. The complete absence of dissolved oxygen (anoxia) enables the release of a number of undesirable substances from the sediments, including ammonia, soluble phosphorus, and various oxygen-demanding constituents, such as hydrogen sulfide and methane.

Much effort has been directed at decreasing primary production in Onondaga Lake through reductions in phosphorus loading. The progress of this program has been tracked by monitoring multiple measures of the lake's trophic state. This has included measurements of the three common trophic state parameters, total phosphorus (TP), chlorophyll-*a* (Chl-*a*), and Secchi disk (SD) transparency, as well as related chemical metrics of the deep waters, and the composition and abundance of the algal community (see Section 6). Each of these parameters has shortcomings, but together they represent a robust representation of trophic state conditions. The three most often monitored parameters are all related to the amount of phytoplankton (microscopic algae) present in the water column. Much of the phosphorus and all of the chlorophyll-*a* (the dominant pigment of algae) is associated with phytoplankton. The Secchi disk measurement is more indirectly related to trophic state and controlled primarily by the concentration of particles in the water. The common case of dominance of the overall particle population by phytoplankton makes Secchi disk a valuable trophic state metric. These metrics of trophic state can all be influenced by both bottom-up (e.g., phosphorus supply) and top-down (food web) effects. Top-down effects associated with large zooplankton that effectively feed on (graze) phytoplankton can confound relationships between phosphorus loading and common metrics of trophic state.

5.3.1 Total Phosphorus

Total phosphorus (TP) concentrations in the lakes upper waters remained below 20 µg/L during the January–April interval of 2012 (Figure 5-2). Substantially higher TP concentrations were measured in early May, early July, and from September to December. Total phosphorus concentrations in the lake's upper waters averaged 22 µg/L over the summer (June–September) of 2012. Long-term trends in TP concentrations in the lake's upper waters depict major decreases since the early 1990s (Figure 5-3). Since 2007, summer total phosphorus concentrations in the upper waters of Onondaga Lake have been close to the guidance value of 20 µg/L. With the advanced treatment system at Metro producing consistently low effluent total phosphorus, the year-to-year variability in lake phosphorus levels probably reflects changes in precipitation patterns and the resultant watershed loading as well as changes in the food web structure. A substantial portion of the total phosphorus in certain lakes may be associated with inorganic particles rather than phytoplankton, making it a conservative metric of trophic state.

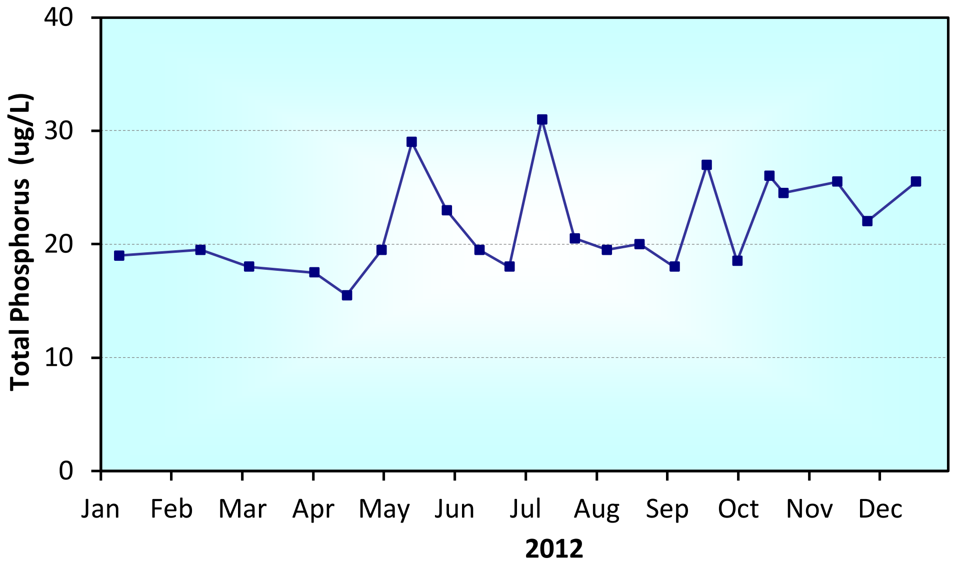


Figure 5-2. Seasonal time plot of the average total phosphorus concentration in the upper waters (0-3 meters) of Onondaga Lake during 2012.

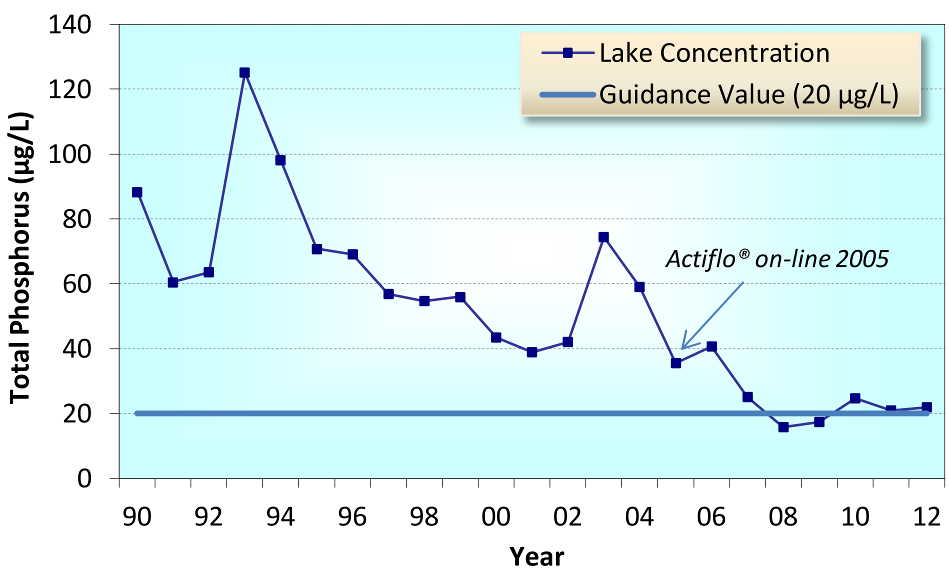


Figure 5-3. Summer (June to September) average total phosphorus concentration in the upper waters (0-3 meters) of Onondaga Lake, 1990–2012.

5.3.2 Chlorophyll-a

Chlorophyll-*a* (Chl-*a*) concentrations in the lakes upper waters in 2012 ranged from 2 µg/L in February and November to peaks approaching 15 µg/L in May and July (Figure 5-4). The summer average Chl-*a* concentration was 6.3 µg/L, similar to values observed in recent years (Figure 5-5). The average and peak concentrations of this plant pigment have declined substantially, particularly since the Actiflo® upgrade at Metro (Figure 5-5). Summer data (June–September) are used to track suitability of the lake for recreational uses.

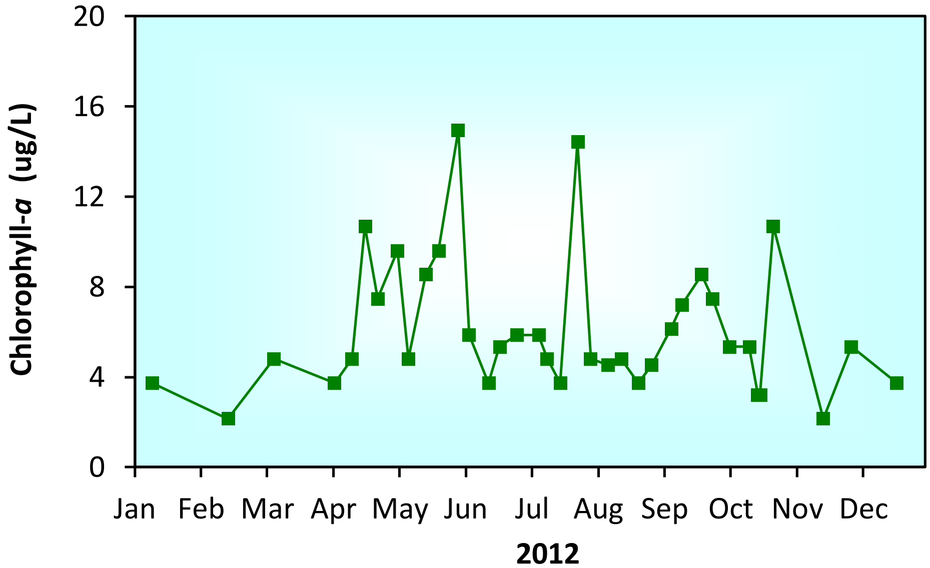
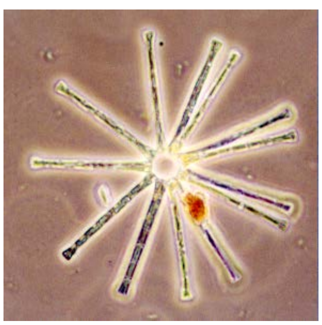


Figure 5-4. Seasonal time plot of average chlorophyll-*a* concentration in the upper waters (0-3 meters) of Onondaga Lake, 2012.



Diatoms – A Major Group of Algae in Onondaga Lake

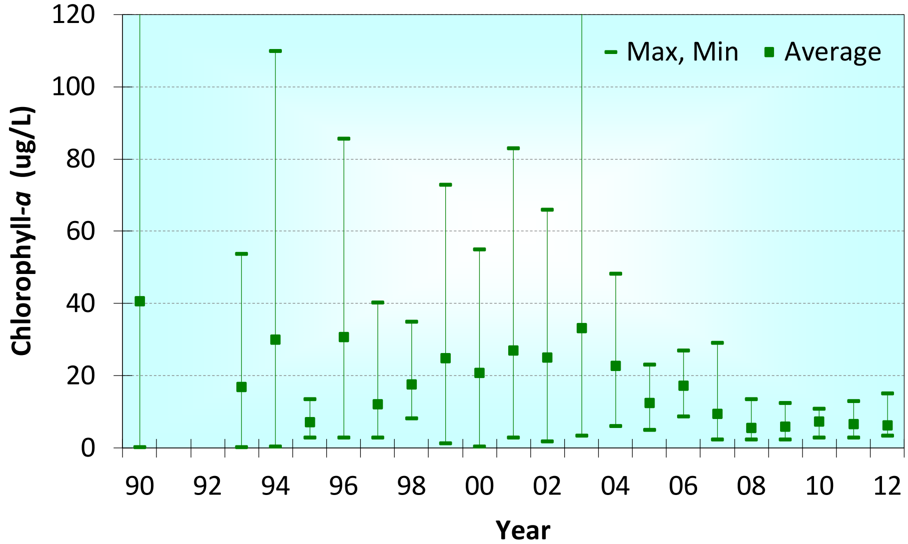
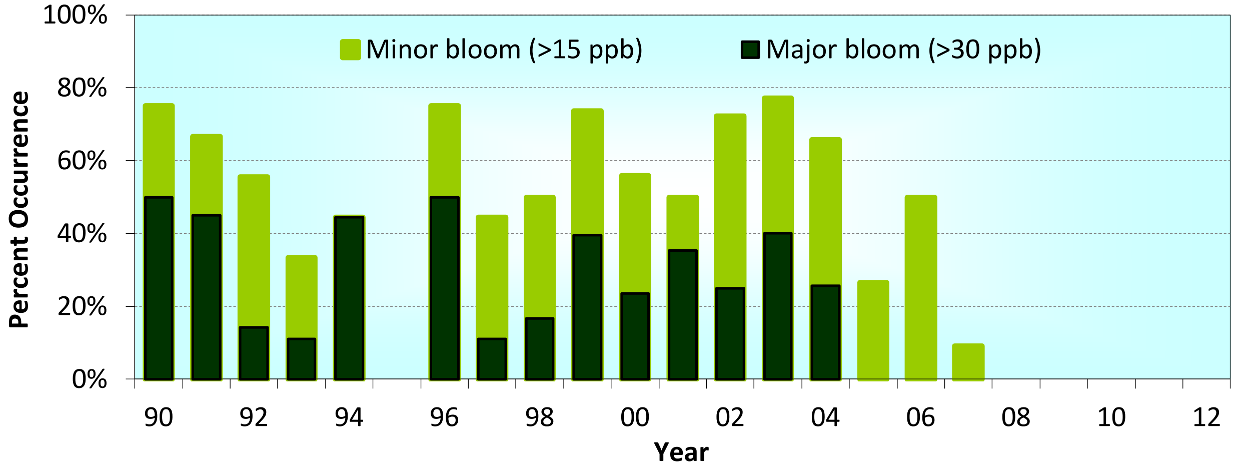


Figure 5-5. Summer average (June–September) chlorophyll-*a* concentrations in the upper waters of Onondaga Lake (South Deep), 1990–2012.

Note: points represent summer average; bars represent the min and max in summer.

The EPA and NYSDEC are developing nutrient criteria for lakes to protect aquatic life, water supply and recreational uses, as well as deriving numerical limits on response variables such as chlorophyll-*a*. Algal blooms are generally esthetically undesirable, accompanied by a turbid green appearance in Onondaga Lake. In the absence of state or federal criteria, the AMP has used subjective thresholds of 15 µg/L and 30 µg/L to represent minor blooms (impaired conditions) and major blooms (nuisance conditions), respectively. According to the criteria adopted here, and based on weekly measurements, there were no algal blooms in Onondaga Lake during the summer recreational period (June–September) of 2012 (Figure 5-6).

The total phosphorus concentration in spring has been a good predictor of the occurrence of severe summertime blooms (Figure 5-7), which have not been observed when the total phosphorus concentration is less than 50 µg/L. The Metro total phosphorus load has been a good predictor of the summer average Chl-*a* (Figure 5-8) concentration of the upper waters, with decreases in Chl-*a* observed as the TP load has been reduced. This analysis uses TP loads from the full water year (October–September) to account for loading that may influence algal growth during summer.



No blooms were observed during summer in 1995, 2008, 2009, 2010 , 2011, or 2012

Figure 5-6. Summer (June to September) algal bloom percent occurrences in Onondaga Lake evaluated annually for the 1990–2012 period, based on chlorophyll-*a* measurements.

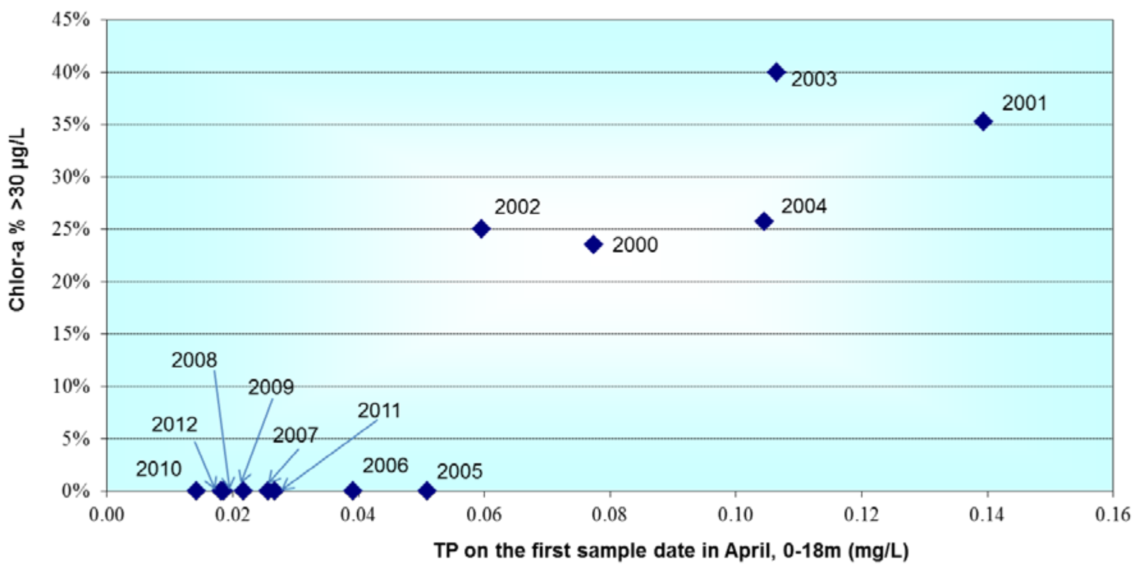


Figure 5-7. Relationship between the frequency of summertime nuisance algal blooms and the total phosphorus concentration in spring, 2000–2012.

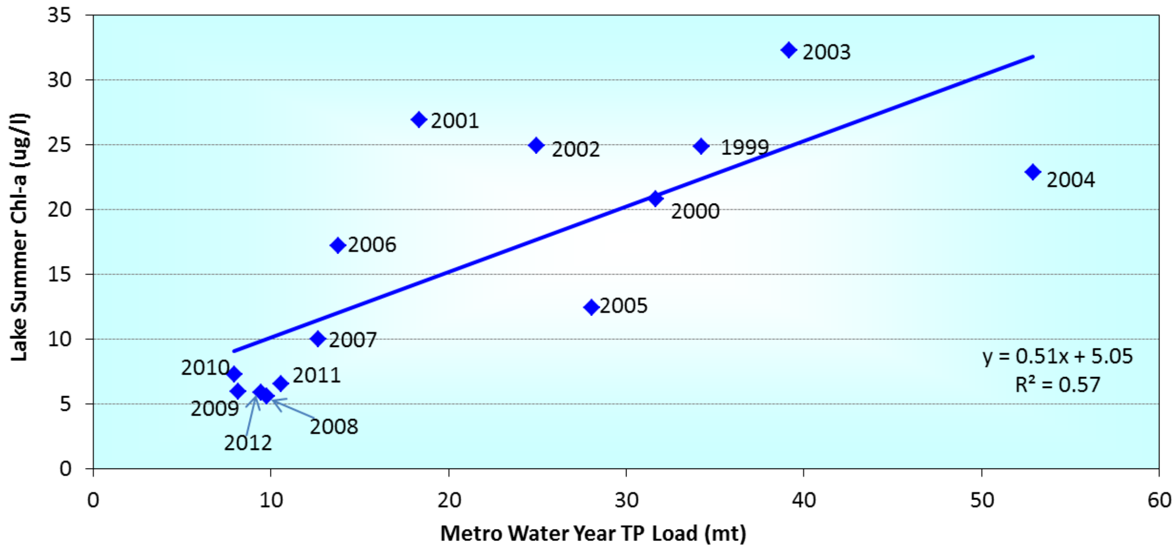


Figure 5-8. Relationship between summer (June–September) average chlorophyll-*a* concentrations in the upper waters and total phosphorus loading from Metro over the full water year (October–September).

In lakes where phytoplankton production is limited by phosphorus, total phosphorus and chlorophyll-*a* are highly correlated. Data from regional lakes, including Onondaga, (Figure 5-9) illustrate this relationship and provide a valuable regional context. Data for the Finger Lakes represent results of a NYSDEC survey conducted between 1996 and 1999. The NYSDEC study design called for sampling each Finger Lake monthly between June and August at a single mid-lake station, with the exception of Cayuga Lake, which was sampled at three locations (Callinan 2001). Data for Onondaga and Oneida Lakes have been averaged over these same summer months in this presentation, for data comparability. Oneida Lake data were provided by the Cornell Biological Field Station (Rudstam 2013). Oneida Lake is notably shallower than the Finger Lakes, has a larger proportion of the bottom suitable for zebra mussels, and does not develop stable thermal stratification during the summer, features that may contribute to the observed deviations from the other lakes.

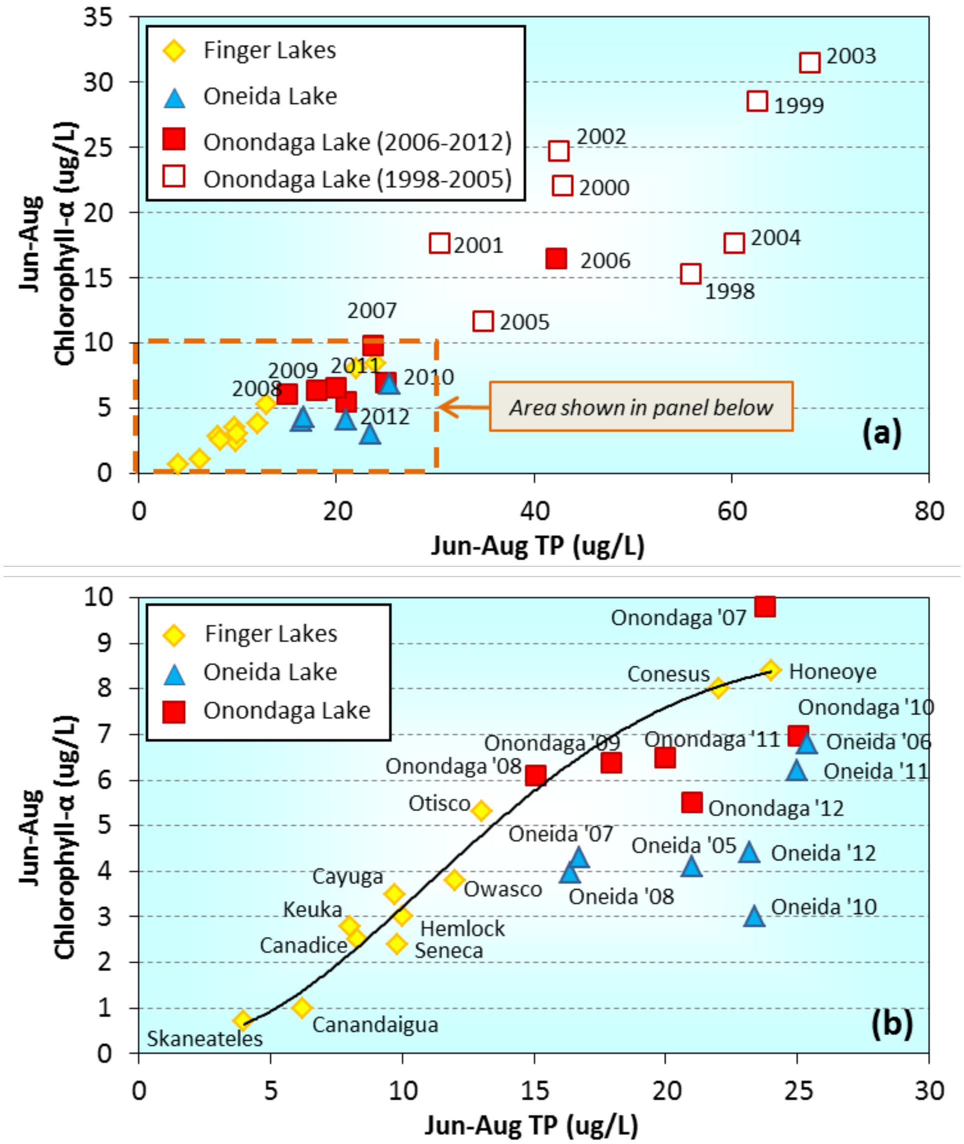


Figure 5-9. Summer (June to August) average total phosphorus (TP) and chlorophyll-*a* concentrations in Onondaga Lake compared with selected regional lakes.

Note: (a) The top panel shows Onondaga Lake concentrations pre-Actiflo® (1998-2005) and post-Actiflo® (2006-2012). (b) The bottom panel represents the same data, scaled to show the 2007-2012 Onondaga Lake data and a best-fit trendline (R^2 = 0.97) of the Finger Lakes concentrations (1996-1999), and Oneida Lake concentrations (2005-2012; Rudstam 2013).

5.3.3 Secchi Disk Transparency

A Secchi disk is a 25 centimeter diameter disk with alternating black and white quadrants. The depth at which it can no longer be seen is known as the Secchi disk transparency. Greater depth indicates clearer waters with lower concentrations of particles, often in the form of phytoplankton. Secchi disk transparency greater than 1.2 meters (4 feet) is required to meet swimming safety guidance at designated beaches. There is no New York State standard or guidance value for Secchi disk transparency for off-shore waters. Most lake monitoring programs in the state make Secchi disk measurements at a mid-lake station overlying the deepest water, comparable to the Onondaga Lake South Deep station. A summer average Secchi disk transparency of at least 1.5 meters at South Deep has been established for Onondaga Lake as a target for improved aesthetic appeal (Table 1-5). The Citizens Statewide Lake Assessment Program (CSLAP), a joint effort of NYSDEC and the NYS Federation of Lake Associations, considers summer average Secchi disk transparency greater than 2 meters as indicative of mesotrophic conditions (Kishbaugh 2009). The average water clarity of Onondaga Lake met both of these thresholds during the summer of 2012, averaging 2.1 meters and ranging from 1.6 to 2.9 meters over the June to September interval (Figure 5-10). Water clarity conditions in 2012 were comparable to those observed in 2010 and 2011 (Figure 5-11).

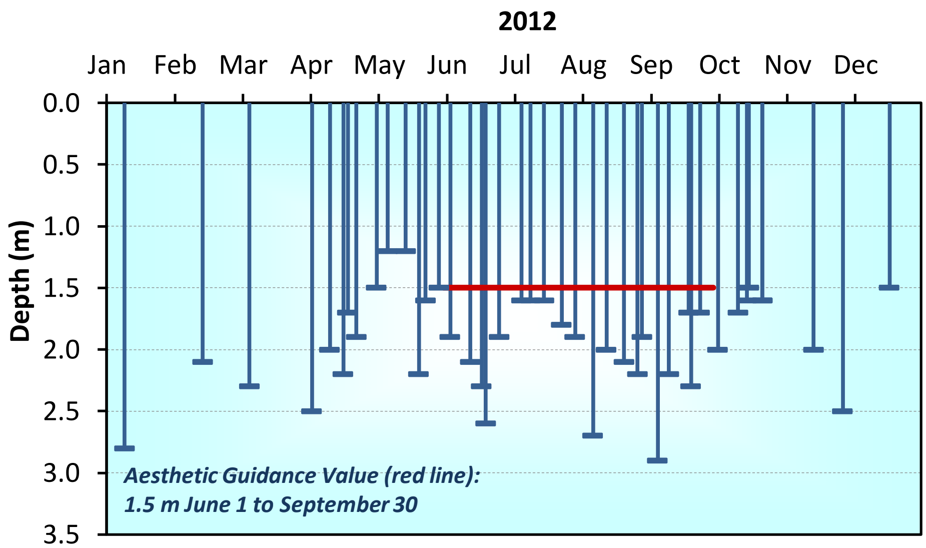


Figure 5-10. Secchi disk transparency, Onondaga Lake South Deep, 2012.

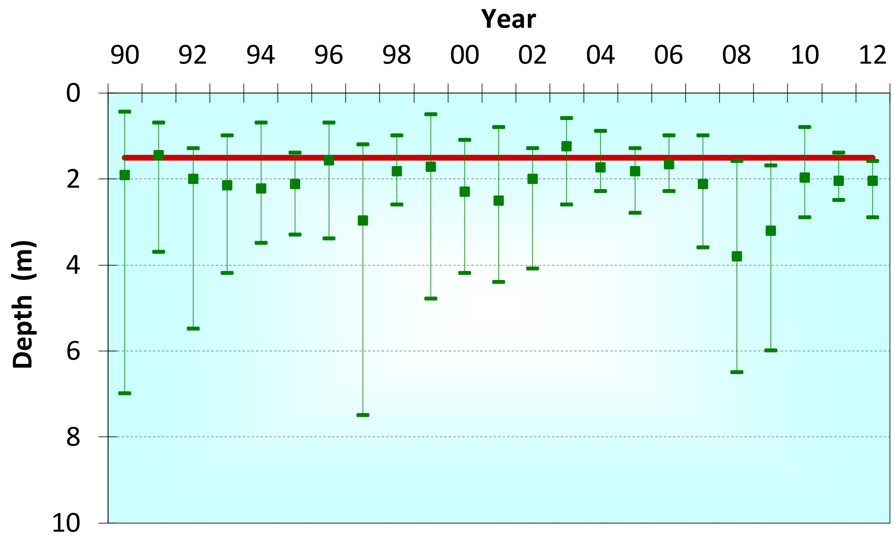


Figure 5-11. Long-term summer average Secchi disk transparency, Onondaga Lake South Deep, 1990–2012.

Note: points represent summer average; bars represent the min and max in summer. The aesthetic guidance value of 1.5 m is shown in red.

5.3.4 Trophic State Indicators

Summer (June–September) average values of the three trophic state indicator parameters (total phosphorus, chlorophyll-*a*, Secchi disk transparency) are presented for the 1998–2012 interval (Figure 5-12). According to these parameters, trophic conditions have varied little since 2010. These trophic indicators are expressed relative to the trophic state boundary values presented by Cooke et al. (2005). Although the specific values of these trophic boundaries are somewhat subjective, they do serve as convenient general indicators of lake productivity. According to total phosphorus and chlorophyll-*a*, the trophic state of Onondaga Lake has shifted from eutrophy to mesotrophy since 2008. Secchi disk transparency was higher in 2008 and 2009 due to grazing of particles by *Daphnia*, a large, filter feeding zooplankter. However, no systematic improvement in summer average Secchi disk transparency has been observed since 1998. Two factors likely contribute to this inconsistency for Secchi disk versus total phosphorus and chlorophyll-*a* (Effler et al. 2008): (1) inputs of inorganic particles that decrease clarity; and (2) the recent absence of the grazing effects of larger zooplankton that efficiently consume/remove phytoplankton as well as non-phytoplankton particles. The mud boils on upper Onondaga Creek have contributed to the diminished water clarity of the lake, and therefore to the disparity in trophic state based on Secchi disk versus the other two metrics. As observed in 2010 and 2011, efficient grazers of phytoplankton (i.e., *Daphnia*) continued to be essentially absent in 2012, consistent with the continuing large population of the alewife (*Alosa pseudoharengus*). See Section 6 for a detailed discussion of food web dynamics.

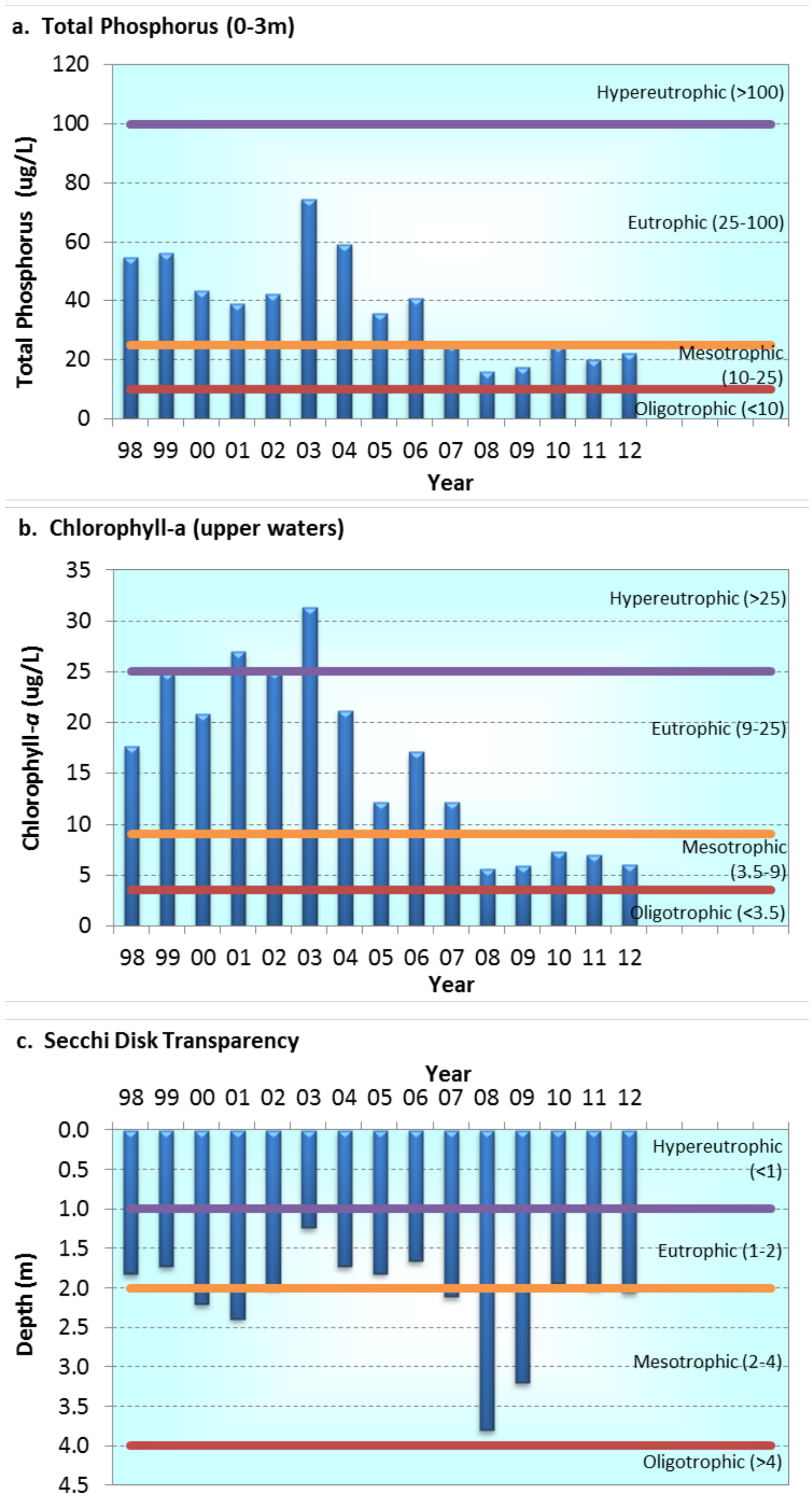


Figure 5-12. Time series of common trophic state indicators based on summer average (June–September) data, 1998–2012.

5.4 Dissolved Oxygen

Adequate dissolved oxygen (DO) content is critical for aquatic life and a common focus of water quality monitoring programs. Vertically detailed profiles of temperature and DO were collected bi-weekly and are presented here as color contour plots (Figure 5-13). In addition, continuous measurements of DO were made at depths of 2 and 12 meters at South Deep with a monitoring buoy over the spring to fall interval. DO concentrations were uniformly high throughout the water column during the January to mid-May interval. Depletion of DO from the lower layers began with the onset of thermal stratification in mid-May, and by mid-July the lake was largely anoxic below a depth of 6 meters (Figure 5-13). The lower waters were replenished with DO in October with the occurrence of fall turnover. There was no noteworthy depletion of DO in the upper waters during the fall of 2012, and the minimum concentration remained well above the AWQS of 4 mg/L (Figure 5-14).

A high priority goal for rehabilitation of the lake was elimination of severe depletion of DO in the upper waters during the approach to fall turnover in October (Figure 5-14), and contravention of the related AWQS. This goal has been achieved through reductions in Metro loading of both ammonia (Figure 4-7) and total phosphorus (Figure 4-10). Other improvements in the lake's oxygen resources have been observed, particularly within the lower stratified layers (hypolimnion). Following the onset of summer stratification, these layers are subject to oxygen depletion from decay of depositing organic constituents and demand from the underlying sediments. Decreases in deposition of phytoplankton from reductions in Metro phosphorus loading have resulted in lower rates of DO depletion, manifested as a delay in the onset of anoxic conditions and decreases in "volume-days of anoxia" (Figure 5-15). Linear regression analysis indicates that significant decreases in both volume days of anoxia (R^2=0.40, p=0.02) and volume days of anoxia + hypoxia (R^2=0.40, p=0.02) have continued since 2000, although at lower rates than observed in the earlier portion of the record (Figure 5-15). Since the Actiflo® process came on line in 2005, anoxia has been delayed for a period of several weeks in the lower waters. Some interannual variability is to be expected in this metric due to variations in the onset of stratification from natural meteorological variability. The implications of these improved conditions for the lake's fish community are discussed in Section 6.4.

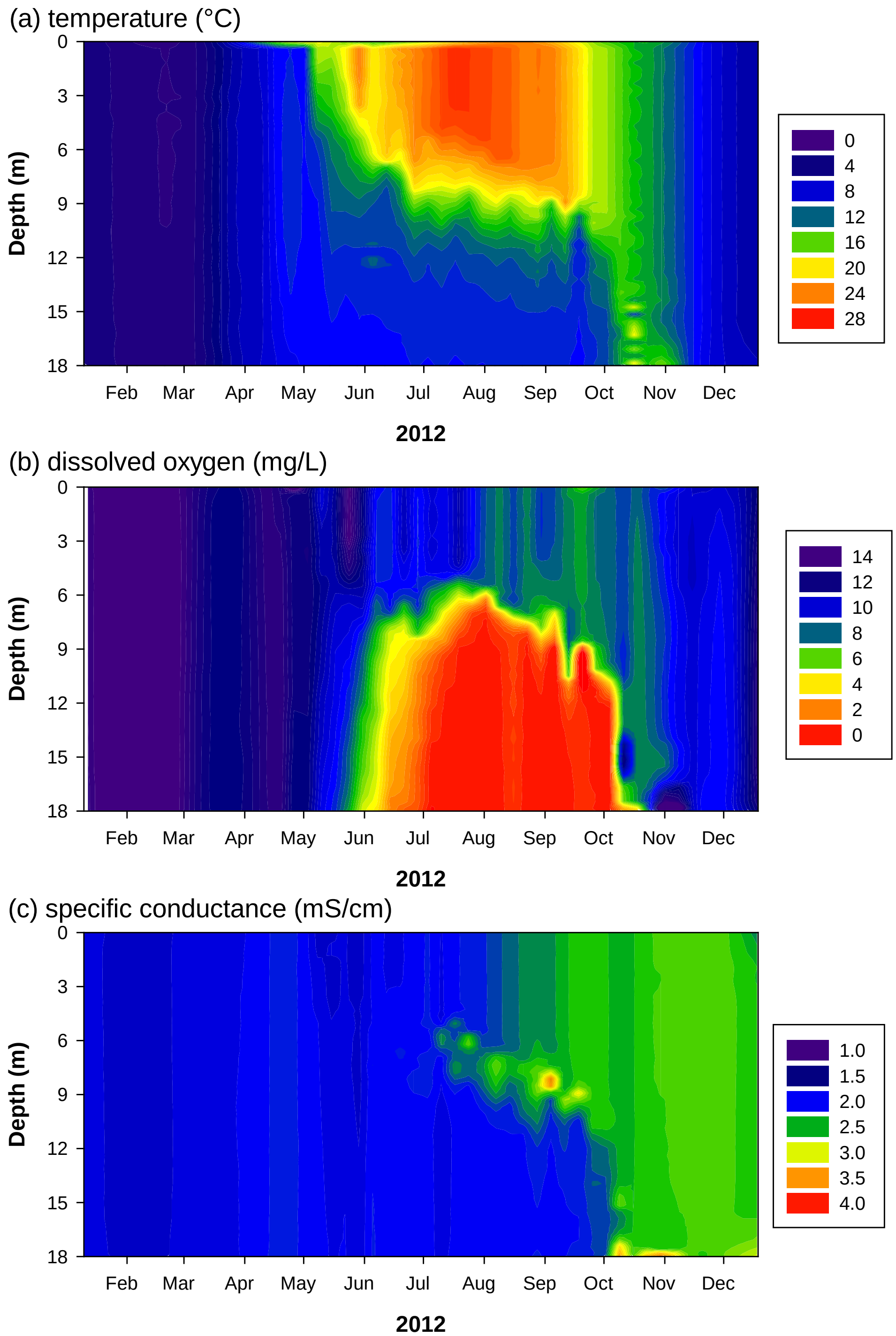


Figure 5-13. Color contour plots of Onondaga Lake in 2012, based on biweekly sensor profiles conducted at South Deep: (a) temperature (°C), (b) dissolved oxygen (mg/L), and (c) specific conductance (mS/cm).

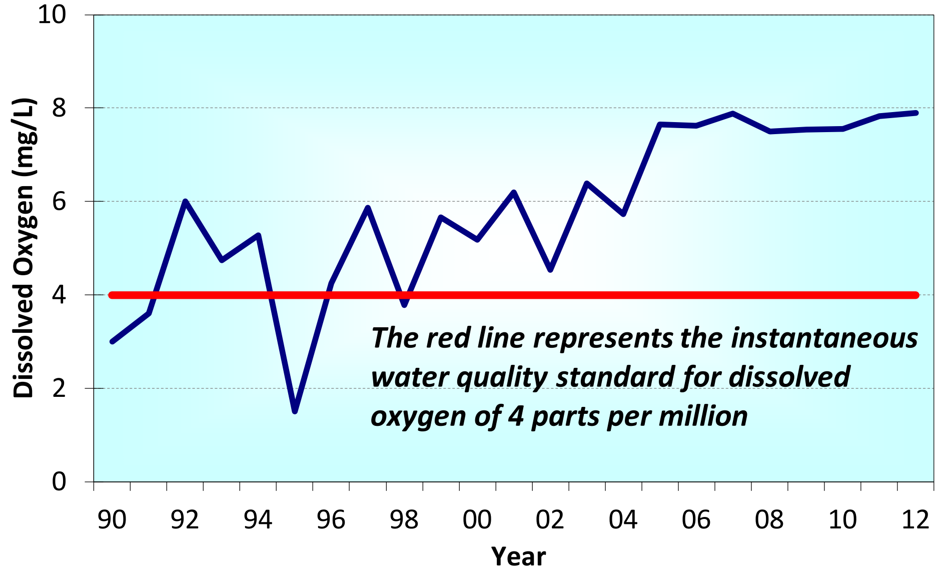


Figure 5-14. Minimum dissolved oxygen (DO) concentration in the upper waters (0-3 meters) of Onondaga Lake during October, annually 1990–2012.

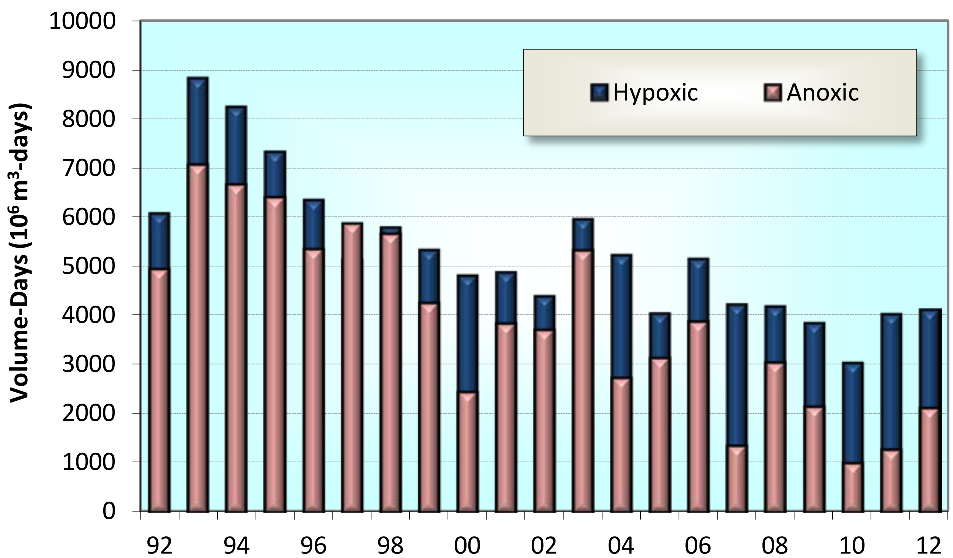


Figure 5-15. Volume-days of anoxia (dissolved oxygen less than 0.5 mg/L) and hypoxia (dissolved oxygen less than 2 mg/L), in Onondaga Lake during the summer, 1992–2012.

5.5 Ammonia, Nitrite, and Nitrate

Prior to the engineering improvements at Metro to bring about efficient year-round nitrification of wastewater, Onondaga Lake was impaired by elevated concentrations of ammonia (NH_3-N). Concentrations of this potentially harmful form of nitrogen exceeded the state ambient water quality standard for protection of aquatic life. Implementation of the BAF technology in 2004 further reduced ammonia concentrations in the upper waters of the lake (Figure 5-16, Figure 5-17a), enabling a more diverse biota. The lake is now in full compliance with the ambient water quality standards for ammonia (Table 5-3), and in 2008 was officially removed from the New York State's 303(d) list of impaired waterbodies for this water quality parameter.

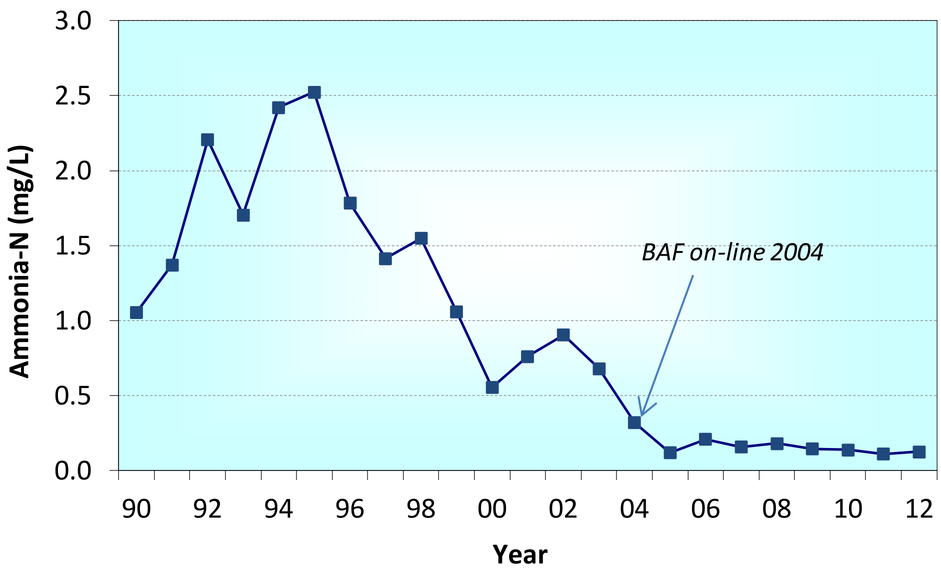


Figure 5-16. Annual average ammonia-N (NH_3-N) concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2012.

Table 5-3. Percent of Onondaga Lake ammonia measurements in compliance with ambient water quality standards, 1998–2012.

Depth (m)	Percent measurements in compliance, NYS Standards														
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
0	64	62	86	95	68	96	100	100	100	100	100	100	100	100	100
3	45	67	90	90	68	96	100	100	100	100	100	100	100	100	100
6	50	86	90	95	73	100	100	100	100	100	100	100	100	100	100
9	41	76	90	95	73	100	100	100	100	100	100	100	100	100	100
12	18	52	90	81	50	80	100	100	100	100	100	100	100	100	100
15	23	52	57	52	41	56	80	100	100	100	100	100	100	100	100
18	23	48	52	38	32	48	75	95	95	100	100	100	100	100	100

OCDWEP Technicians Collecting Onondaga Lake Water Samples

Efficient year-round nitrification treatment from implementation of the biologically aerated filter (BAF) resulted in increased nitrate (NO_3-N) loading to the lake and increased in-lake concentrations (Figure 5-17b). These changes have had some unintended benefits for the lake rehabilitation initiatives, including diminished release of phosphorus and mercury from the sediments during intervals of anoxia (Matthews et al. 2013). In 2011 and 2012, a whole-lake nitrate addition pilot test was conducted as part of the Honeywell cleanup with the objective of limiting release of mercury from the deep-water sediments through maintenance of nitrate concentrations > 1 mg/L. This pilot test is scheduled to continue during the summer of 2013, the final year of a 3-year pilot test.

Acceptance of saline groundwater at Metro beginning in June 2012 (Figure 4-13) caused the effluent to be unusually dense and to plunge to the metalimnion during July, August, and most of September. The plunging character of the effluent is clearly manifested as localized specific conductance maxima located between 6 and 12 meters depth (Figure 5-13c). During late September the effluent entered the hypolimnion, and in October it plunged to the bottom of the lake (Figure 5-13c). Metro was an important source of nitrate to the hypolimnion during this latter interval, supplementing inputs from the nitrate addition pilot project.

Nitrite (NO_2-N) concentrations also often exceeded the limit to protect against possible toxicity effects within the upper waters of the lake before the BAF upgrade at Metro. These exceedances were also eliminated with the lower in-lake nitrite concentrations that accompanied the treatment upgrade (Figure 5-17c). Exceedances of the AWQS now only occur in the lower layers of the lake when hypoxia prevails (dissolved oxygen concentrations less than 2 mg/L). These conditions reflect incomplete nitrification of ammonia within those lower lake depths. However, these exceedances are not limiting to fish habitat. Rather, the limiting condition is the low oxygen concentration in these lower layers during summer stratification. At oxygen levels required to support fish, these higher nitrite levels would likely not be observed because complete nitrification would occur.

OCDWEP Technicians Changing Water Quality Sensors on Onondaga Lake Buoy

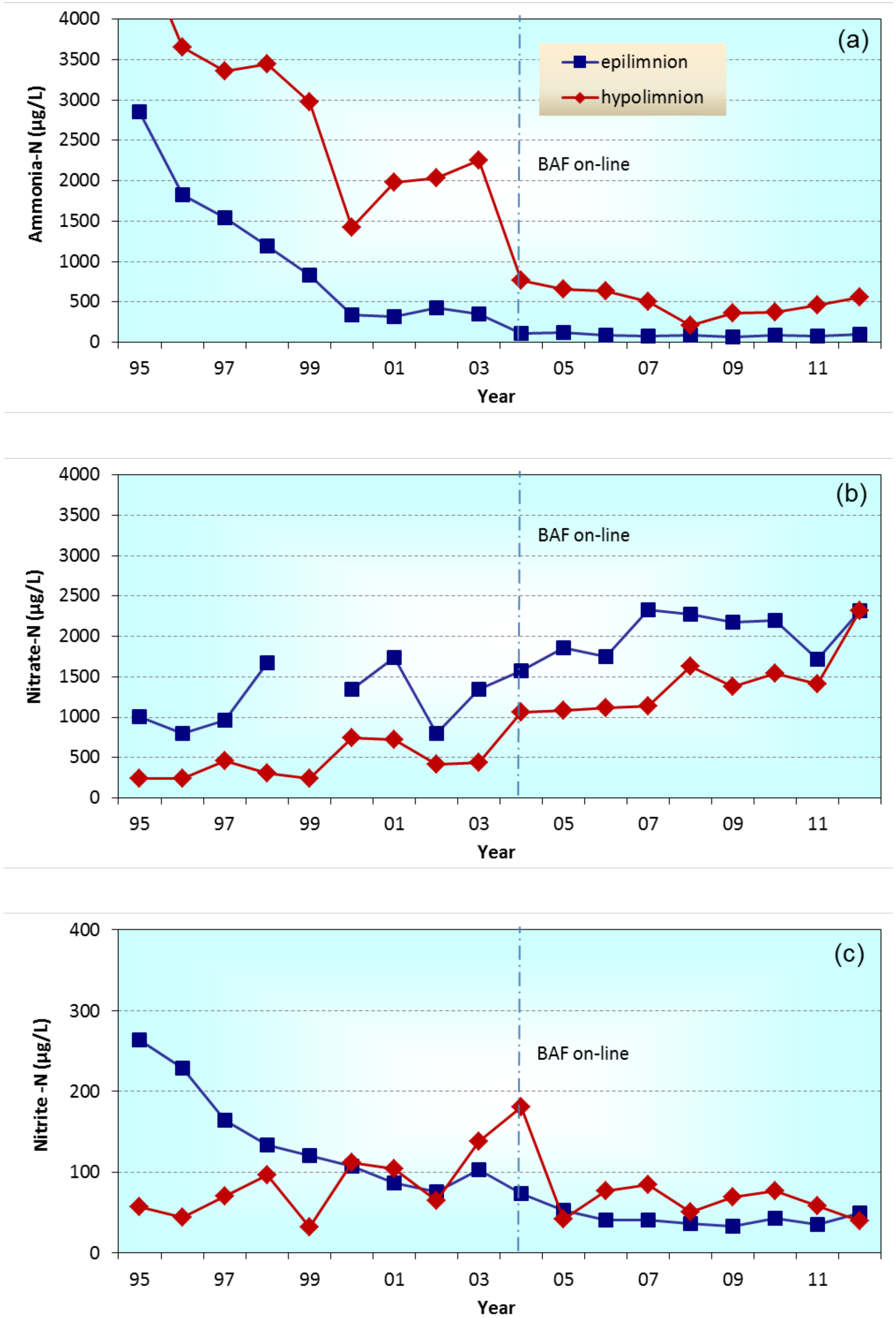


Figure 5-17. Summer average concentrations of nitrogen species in the epilimnion and hypolimnion of Onondaga Lake, 1995–2012: (a) ammonia-N, (b) nitrate-N, and (c) nitrite-N.

5.6 Recreational Water Quality

The suitability of Onondaga Lake for water contact recreation is assessed using two parameters: fecal coliform bacteria and water clarity. Substantial inputs of bacteria and turbidity (causing reductions in clarity) often occur in both urban and agricultural areas during runoff events from the wash-off of pollutants from land surfaces and overflow of combined sewers. 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. Dreissenid (zebra, quagga) mussels likely have a significant impact on water clarity in the nearshore, while zooplankton have a greater effect on clarity in offshore regions.

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.

This standard is applied here to assess bacterial contamination at nearshore locations (Figure 5-18) as well as at the open water sites North Deep and South Deep (refer to Figure 1-2). Bacteria levels in southern portions of the lake often increase following significant rainfall, and concentrations can vary by orders of magnitude due to the event-driven nature of the sources. Consequently, geometric means are appropriate for examining spatial and temporal trends. In 2012, bacteria counts at the monitoring stations were less than the fecal coliform bacteria standard at all but one nearshore location within the Class C segment at the lake's southeastern shoreline (Figure 5-18). This monitoring location, adjacent to the Metro outfall, exceeded the AWQS for fecal coliform bacteria only in the month of April. In addition, bacterial counts at the two offshore monitoring locations, North Deep and South Deep, were below the AWQS for fecal coliform bacteria throughout the 2012 assessment period.

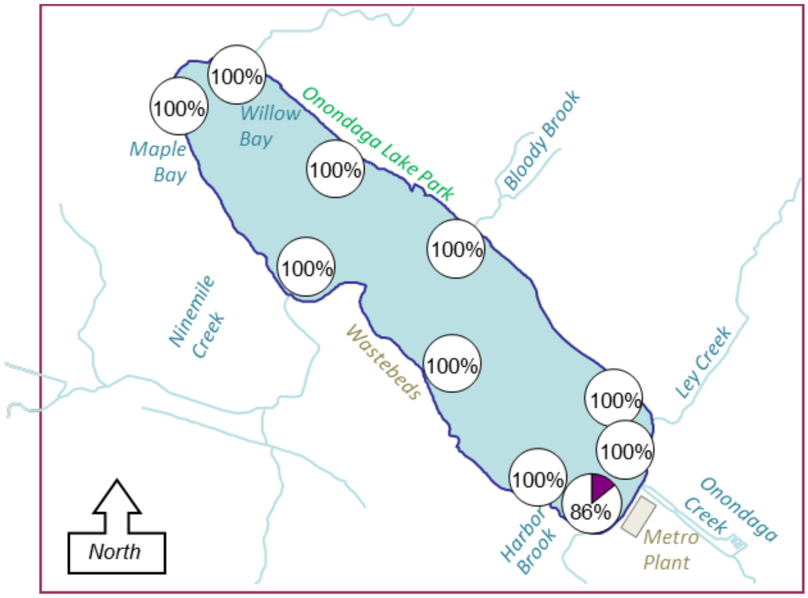


Figure 5-18. The percentage of months in compliance with the water quality standard for fecal coliform bacteria for nearshore stations in Onondaga Lake, April–October 2012.

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

Water clarity is measured at the same network of ten near shore stations. While there is no NYSDEC standard for water clarity, the NYSDOH has a swimming safety guidance value for designated bathing beaches of 4 feet (1.2 meters). The 2012 results demonstrate that the DOH swimming safety guidance value was met throughout the summer recreational period (June 1 to September 30) at eight of the ten monitored locations, including all sites within the Class B segment of the lake (Figure 5-19). Monitoring locations near the mouths of Onondaga Creek and Harbor Brook met the swimming safety guidance value on 17 of the 20 and 19 of 20 monitored days, respectively. Sediment inputs, including those from the mud boils located in upper portions of Onondaga Creek, likely contributed to the diminished water clarity in nearshore areas of the Class C segment in the southern portion of the lake. Dreissenid (zebra, quagga) mussels likely have a significant impact on water clarity in the nearshore, while zooplankton have a greater effect on clarity in offshore regions.

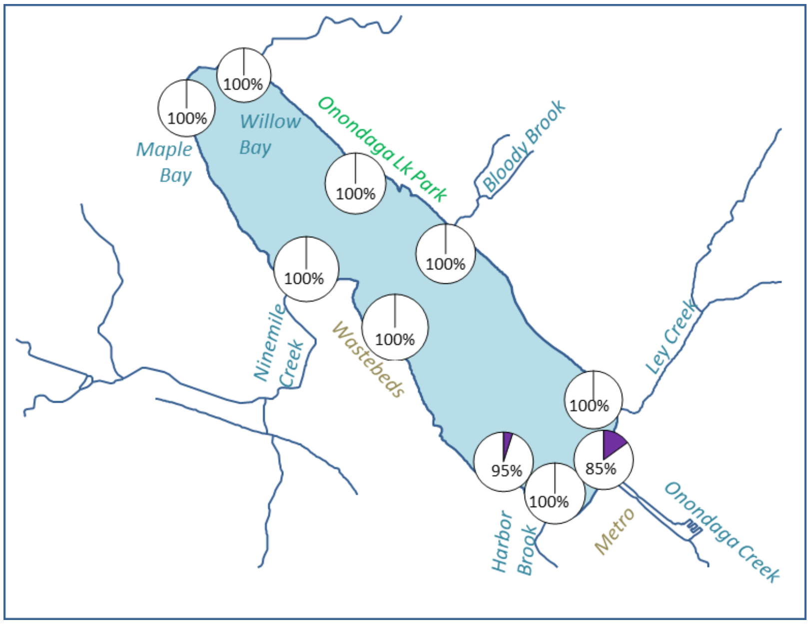


Figure 5-19. Percentage of nearshore Secchi disk transparency measurements greater than 1.2 meters (4 feet) during June–September 2012.

Note: The percent shown in figure indicates compliance with swimming safety guidance value (1.2 m), and the shaded area of pie charts indicates percent of samples where Secchi depth was below guidance value for the period June 1 through September 30.

5.7 Nearshore Trends

Onondaga County WEP has monitored near shore water quality conditions as part of the AMP since 2000. The monitoring program has included both routine sampling and sampling following storm events. Dr. William Walker completed a trend analysis of the water clarity and bacteria data through 2010. Both a full report of the analysis and a summary of the findings are included in the annual AMP report for 2010.

The data were segmented in that analysis according to runoff (wet versus dry) and portions in the lake. Noteworthy trends over the period that emerged from the analysis were (1) clarity increased in the nearshore area (but more robustly represented by turbidity decreases), (2) fecal coliform levels were distinctly higher during wet weather (especially at nearshore stations in the southern end of the lake), (3) decreases over time occurred in wet-weather fecal coliform levels at the southern stations and adjacent to the Bloody Brook inflow, and (4) an increasing dry weather trend in bacteria levels prevailed in the southern nearshore areas adjacent to Harbor Brook and the Metro outfall. Other than the two sites adjoining the Metro outfall and the mouth of Onondaga Creek, summer monthly geometric means have not exceeded the regulatory limit over the 2003–2012 (10-year) period.

5.8 Long-Term Trends in Water Quality

Improvements to the Metro treatment plant have resulted in major reductions in loading of total phosphorus, ammonia, and nitrite to Onondaga Lake. The lake has responded positively to these loading reductions, with major improvements documented for a number of key water quality parameters. In this section, long-term trends for the last 10 years (2003–2012) are evaluated statistically using the two-tailed seasonal Kendall test (Table 5-4).

5.8.1 Indicators of Primary Production

Primary production, algal biomass, and related parameters have declined in response to increased limitation to growth from decreases in phosphorus loading from Metro. Significant decreasing trends in ammonia, nitrite, total Kjeldahl nitrogen, total phosphorus, soluble reactive phosphorus, total organic carbon, and total inorganic carbon were identified for both the upper and lower layers (Table 5-4). Decreases in chlorophyll-*a* were identified for the upper waters. The significant increase in nitrate over the same period is primarily a manifestation of year-round nitrification at Metro. Honeywell's nitrate addition pilot project increased nitrate levels in the hypolimnion during 2011 and 2012. Improvements in oxygen levels of the lower waters, associated with decreases in primary production, have also been identified through these statistical analyses.

Table 5-4. Summary of statistically significant trends in lake concentrations during the 2003 to 2012 period, according to two-tailed Seasonal Kendall tests.

Note: See table footnotes for specifications of significance levels associated with the various symbols. "Upper waters" refers to the 0-3m depth interval and" lower waters" refers to the 12-18m interval.

Variables		South Basin		North Basin		Lake Outlet	
		upper waters	lower waters	upper waters	lower waters	0.6m	3.7m
Clarity	Secchi disk transparency	↑	--	○	--	--	--
Bacteria	Fecal coliforms	○	○	○	○	○	○
Nitrogen	Ammonia (NH_3-N)	↓	↓	↓	↓	↓	↓
	Nitrite (NO_2-N)	↓	↓	↓	↓	↓	↓
	Nitrate (NO_3-N)	↑	↑	↑	↑	○	↑
	Organic nitrogen as N	○	○	○	○	○	○
	Total Kjeldahl nitrogen as N (TKN)	↓	↓	↓	↓	↓	↓
Phosphorus	Total phosphorus (TP)	↓	↓	↓	↓	↓	↓
	Soluble reactive phosphorus (SRP)	↓	↓	↓	↓	↓	↓
Solids	Total solids (TS)	○	○	○	○	○	○

Table 5-4. Summary of statistically significant trends in lake concentrations during the 2003 to 2012 period, according to two-tailed Seasonal Kendall tests.

Note: See table footnotes for specifications of significance levels associated with the various symbols. "Upper waters" refers to the 0-3m depth interval and" lower waters" refers to the 12-18m interval.

Variables		South Basin		North Basin		Lake Outlet	
		upper waters	lower waters	upper waters	lower waters	0.6m	3.7m
	Total suspended solids (TSS)	↓	○	○	○	○	○
	Total dissolved solids (TDS)	○	○	○	○	↓	○
	Volatile suspended solids (VSS)	○	○	○	○	○	○
Chlorophyll	Chlorophyll-*a*	↓	○	↓	○	○	○
	Phaeophytin-*a*	↓	○	↓	○	○	↓
Carbon	Total organic carbon (TOC)	↓	↓	↓	↓	↓	↓
	Total organic carbon, filtered (TOC-F)	↓	↓	↓	↓	↓	↓
	Total inorganic carbon (TIC)	↓	↓	↓	↓	↓	↓
Other	Alkalinity as $CaCO_3$	○	○	○	○	○	○
	Calcium (Ca)	○	○	↑	○	○	○
	Chloride (Cl)	○	○	○	○	○	○
	Specific conductance	○	○	○	○	↓	○
	Dissolved oxygen (DO)	○	↑	○	↑	○	○
	Hardness	○	○	○	○	○	○
	Magnesium (Mg)	○	○	○	○	↓	○
	Sodium (Na)	○	○	○	○	○	○
	pH	○	○	○	○	↑	↑
	Dissolved Silica (SiO_2)	○	○	○	○	○	○
	Sulfate (SO_4)	↓	○	○	○	↓	↓
	Temperature	○	○	○	↑	↑	↑

Notes:
Significance level, two-tailed, seasonal Kendall test accounting for serial correlation.
↓ indicates decreasing trend ($p < 0.1$)
↑ indicates increasing trend ($p < 0.1$)
○ indicates no trend ($p > 0.1$)
- dash indicates parameter not measured at this location.

5.8.2 Phosphorus

Scatterplots of water year (October 1 to September 30) total phosphorus (TP) loading estimates and summer average (June 1 to September 30) TP concentrations for the 1999 to 2012 period depict systematic decreases in both loading and in-lake concentrations achieved by the upgrades in treatment at Metro (Figure 5-20). The water year time segmentation is more consistent with the specified summer interval of the in-lake total phosphorus guidance value than an annual load. Empirical analysis according to linear least-squares regression demonstrates that changes in Metro loads explained 78% (R^2 = 0.78) of the observed variations in the summer average total phosphorus concentration of the upper waters (Figures 5-20a). The relationship becomes substantially weaker (R^2 = 0.42) when tributary contributions are included in the independent variable (Figure 5-20b). The weaker empirical model from inclusion of tributary contributions is attributable to multiple factors, including (1) disproportionately large inputs of total phosphorus from tributaries during intervals of the year that do not contribute substantively to in-lake total phosphorus concentrations during summer, (2) large interannual variations in tributary total phosphorus loading associated with natural variations in runoff, and (3) differences in the in-lake behavior of tributary phosphorus inputs compared to those from Metro.

OCDWEP Water Quality Monitoring Buoy at Onondaga Lake, South Deep Station

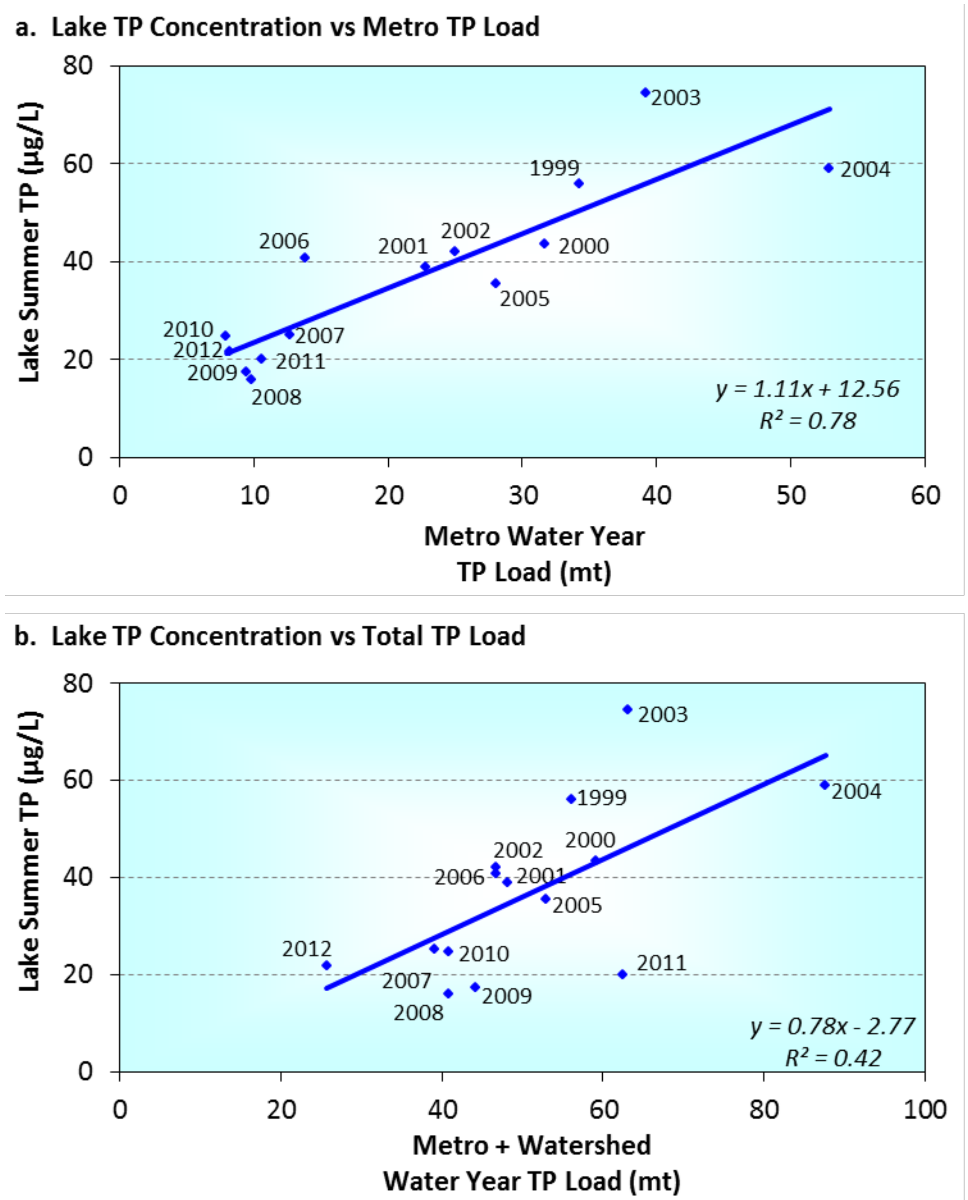


Figure 5-20. Evaluation of the relationship between summer (June–September) average total phosphorus (TP) concentration in the upper waters (0–3 meters) of Onondaga Lake and TP loading for the 1999–2012 period.

Note: Loads are presented on a water year (October 1–September 30) basis for (a) Metro, and (b) the sum of Metro and the tributaries.

5.8.3 N to P Ratio

The relative concentration of nutrients is an important determinant of the composition of the phytoplankton community. The effects of nutrient concentrations on phytoplankton speciation can have water quality management implications, particularly with respect to avoiding proliferation of cyanobacteria (blue-green algae). Cyanobacteria can cause nuisance and potentially toxic conditions when present in high concentrations. The maintenance of high nitrogen to phosphorus ratios (N:P) in the upper productive layers of Onondaga Lake has been a long-term management strategy to discourage such nuisance conditions. Data from a wide range of temperate lakes suggests that a total N to total P ratio (TN:TP) of 29:1 (by mass) differentiates between lakes with cyanobacteria dominance (TN:TP<29:1) and lakes without such dominance (TN:TP>29:1; Smith, 1983). The time series of the summer average (June 1–September 30) TN:TP ratio for the upper waters is presented for the 1998-2012 period (Figure 5-21). Total nitrogen (TN) was calculated as the sum of total Kjeldahl N (TKN; organic nitrogen plus ammonia), nitrite, and nitrate.

The TN:TP ratio has remained above the literature N:P threshold for cyanobacteria dominance for the entire 1998 to 2012 period (Figure 5-21). The higher values from 2007 to 2012 reflect the effects of systematic decreases in total phosphorus loading from Metro, with mostly unchanging TN concentrations. This representation of the N:P ratio is in fact quite conservative, as the TN pool is dominated by dissolved forms while most of the TP pool in the upper waters of the lake is in particulate form and not available to support algal growth. The common occurrence of dense populations of filamentous cyanobacteria in summer from the late 1980s to early 2000s was likely due to a combination of lower N:P ratios and higher levels of P pre-2000. Large cyanobacteria are better competitors when P levels are high both because they can get large enough to be inedible to grazers like *Daphnia*, and because they can regulate their buoyancy and better compete for light that can be limiting at high nutrient concentrations.

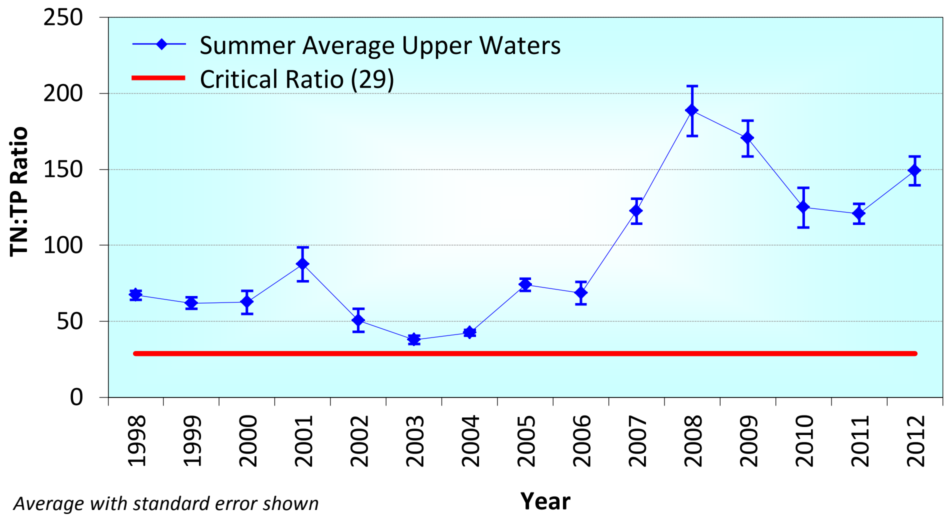


Figure 5-21. Summer average ratio of total nitrogen to total phosphorus (TN:TP, by weight) in the upper waters of Onondaga Lake, 1998–2012. Error bars represent plus and minus 1 standard error.

5.8.4 Deep Waters

The upgrades in treatment at Metro have resulted in profound changes in the lower waters of the lake, in addition to those described previously, associated with both the decreased loading of phosphorus and the increased inputs of nitrate (instead of ammonia). The improvements from reduced phosphorus loading were anticipated, following a well-established logic pattern for rehabilitation of culturally eutrophic lakes. Accordingly, reductions in phosphorus loading are expected to decrease algal growth and associated deposition, thereby decreasing the oxygen demand associated with its decay. This has been manifested as a delay in the onset of anoxia, described previously, which would be expected to translate to some reduction in the release of soluble reactive phosphorus (SRP) from the sediments. When transported to the upper waters by vertical mixing processes, SRP released from the sediments can act to augment phytoplankton growth.

Phosphorus release from the sediments has been greatly diminished by increased in-lake concentrations of nitrate (Matthews et al. 2013). In the presence of dissolved oxygen or nitrate, sediment phosphorus remains in particulate phase, tightly bound to ferric iron. When oxygen and nitrate are depleted from the surface sediments, iron is converted to the reduced ferrous form and soluble reactive phosphorus is released. Thus maintenance of high nitrate concentrations in the hypolimnion serves to effectively block the release of phosphorus from the sediments. The complete absence of sediment phosphorus release under the high nitrate concentrations of 2012 clearly demonstrates the positive effect of nitrate, even under anoxic conditions (Figure 5-22). This is in stark contrast to the high rates of phosphorus release that prevailed in years when both dissolved oxygen and nitrate were depleted from the hypolimnion (Figure 5-23).

The mass of phosphorus accumulated in the hypolimnion during the summer stratification interval has decreased by 90% since the 1990s (Figure 5-23). Note that the decrease in sediment P release has been in response to both the decrease in primary production from the Metro phosphorus treatment upgrade and the increase in nitrate from the facility's year-round nitrification. Some interannual variations are to be expected due to differences in the duration of stratification and ambient mixing associated with natural meteorological variations. Moreover, the supply of nitrate to the lower waters in summer is now being augmented by Honeywell as a test of a strategy to control sediment release of mercury. Particularly low sediment release rates of phosphorus during this three year (2011 to 2013) pilot test are a reasonable expectation (Figure 5-23).

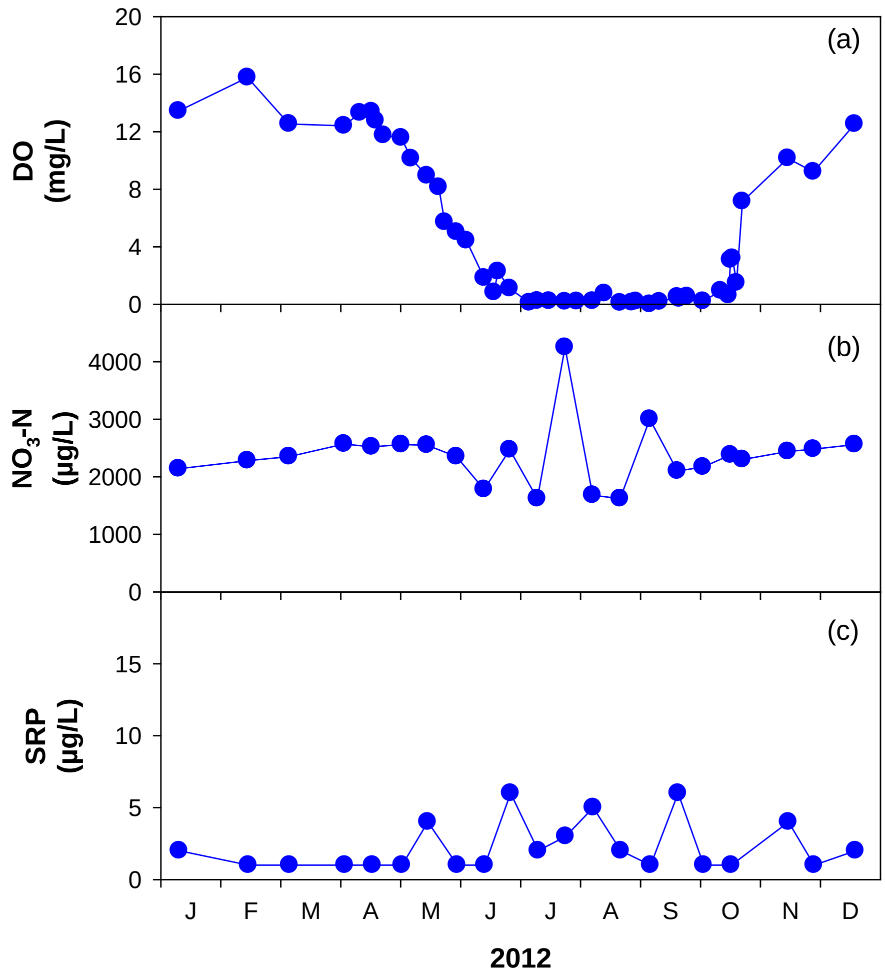


Figure 5-22. Time-series of concentration values in the deep waters of Onondaga Lake in 2012: (a) dissolved oxygen at 18 meters, (b) nitrate in the lower water layer (LWL), and (c) soluble reactive phosphorus at 18 meters.

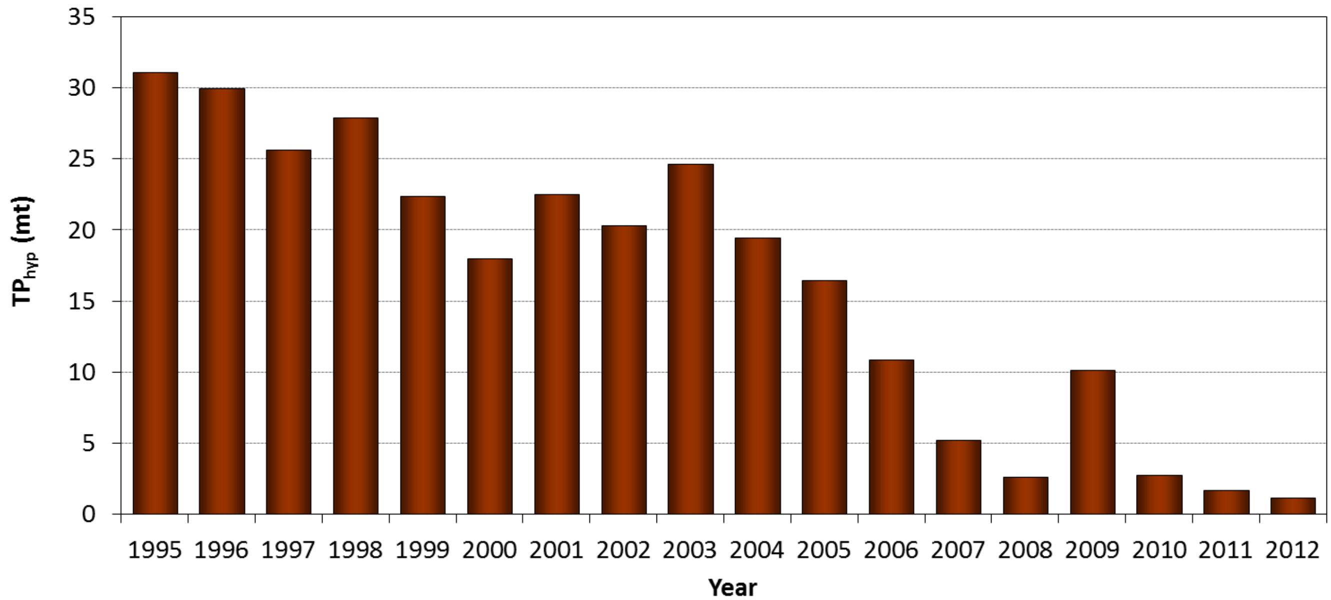


Figure 5-23. The maximum mass of total phosphorus (TP) accumulated in the hypolimnion during summer stratification, 1995–2012.

This page intentionally left blank

Section 6. Biology and Food Web: 2012 Results and Trends

In this section of the Annual Report, the extensive AMP data describing the phytoplankton, macrophyte, zooplankton, dreissenid mussel, and fish communities that form the Onondaga Lake food web are reviewed. The goals for the biological monitoring program are summarized according to program component: phytoplankton (Appendix A-8), macrophytes (Appendix A-9), zooplankton (Appendix A-10), and fish (Appendix A-11).

As phosphorus concentrations in Onondaga Lake have declined to mesotrophic levels (see Section 5.3.4) biological conditions have responded. Improved light penetration, a consequence of lower algal abundance resulting from the reduced phosphorus concentrations, has resulted in expansion of macrophyte beds. This expanded coverage of macrophytes throughout the littoral zone has improved habitat and shelter for many fish and other aquatic organisms.

6.1 Primary Producers

6.1.1 Phytoplankton

Since the late 1990s, the biomass of phytoplankton, which includes algae and cyanobacteria, in Onondaga Lake has declined rapidly, from a standing crop around 8 mg/L in 1998-99 to less than 1.5 mg/l after 2007 (Figure 6-1). The levels have remained relatively constant since then with the lowest value recorded in 2008. Phytoplankton abundance in 2012 was similar to values measured since 2007, with average algal biomass for April-October of 1.5 mg/L, below that expected for a mesotrophic lake (3-5 mg/L, Wetzel 2001) (Figure 6-1). We attribute the low algal biomass to lower phosphorus concentrations from reduced loading. Algal biomass also is affected by the degree of grazing from zooplankton and mussels and the difference between years since 2007 is associated with different densities of large zooplankton. This is discussed further below. A detailed report on lower trophic levels of Onondaga Lake can be found in Appendix F-1.

The composition of the phytoplankton community has changed from one dominated by undesirable blue-green algae (Cyanobacteria) and dinoflagellates (Pyrrhophyta) to one dominated by more desirable diatoms (Bacillariophyta) and green algae (Chlorphyta; Table 6-1; Figure 6-2). Phytoplankton biomass peaked in May during the diatom-dominated spring bloom (Figure 6-3). Biomass was low from the end of May through October. The late summer phytoplankton community consisted of a diverse assemblage including diatoms, chlorophytes, chrysophytes, and cryptophytes.

Figure 6-1. The mean April–October standing crop of phytoplankton in Onondaga Lake, 1998–2012. The heavy line is a 3 point moving average.

Table 6-1. Phytoplankton scientific and common names.

Scientific Division	Common Name
Cyanophyta (Cyanobacteria)	Blue-green algae
Pyrrhophyta	Dinoflagellates
Bacillariophyta	Diatoms
Chlorophyta	Green algae
Cryptophyta	Brown algae
Chrysophyta	Golden algae

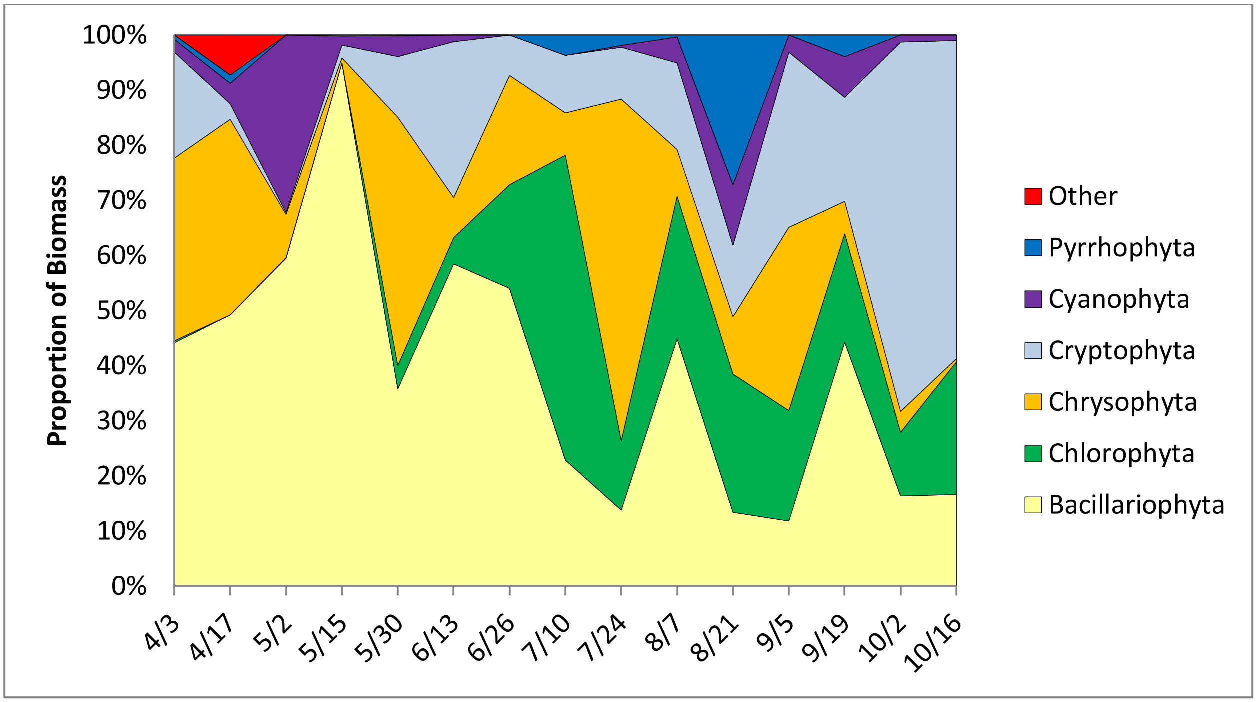


Figure 6-2. Proportional biomass of phytoplankton divisions, 2012.

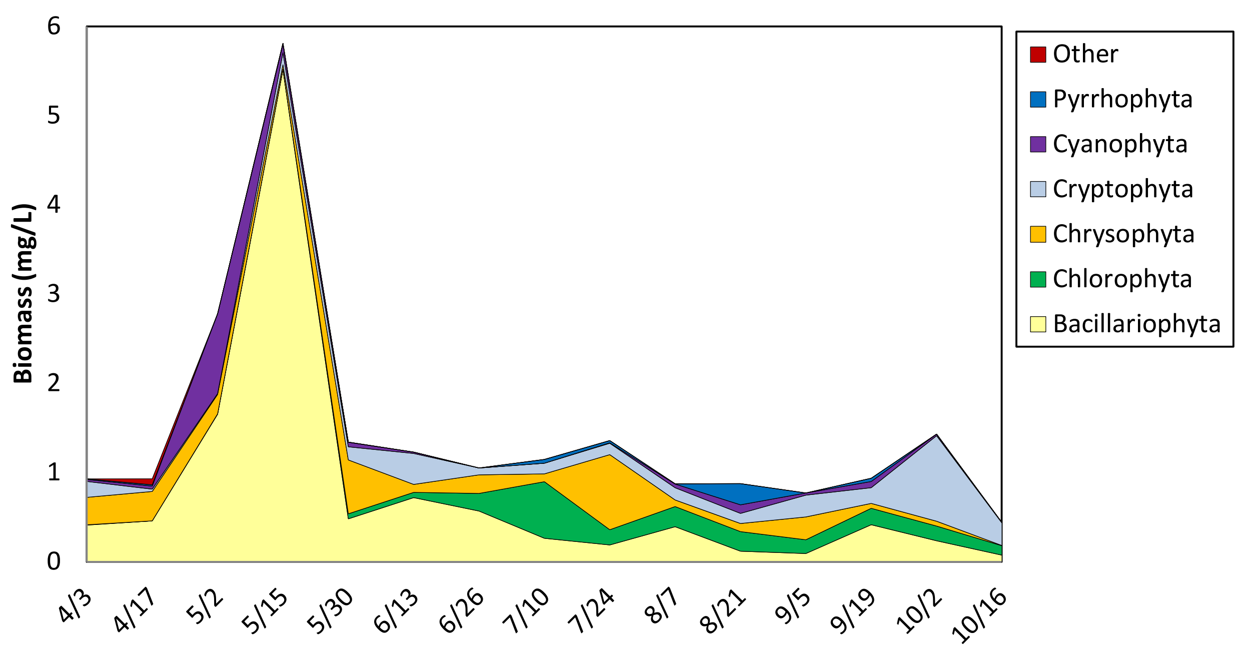


Figure 6-3. Phytoplankton community structure and biomass, 2012.

6.1.2 Macrophytes

Aquatic macrophytes

Along with phytoplankton, macrophytes also are an important component of lake ecology; the rooted plants and algae have major effects on productivity and biogeochemical cycles. Macrophytes produce food for other organisms and provide habitat for aquatic invertebrates, fish, and wildlife, and help to stabilize sediments. As part of the ACJ, the AMP included extensive sampling of the macrophyte community every five years (2000, 2005, and 2010) to document species occurrence and biomass. Aerial photographs of the littoral zone (i.e., depths 6 m or less) also were collected annually, when water clarity allowed, to determine plant distribution. A detailed report on 2012 Onondaga Lake macrophyte monitoring can be found in Appendix F-2.

Macrophyte coverage within the littoral zone in 2012 was the highest observed to date, with over 500 acres of plants covering 65 percent of the littoral zone (Figure 6-4). Approximately 64 acres in the littoral zone were not assessed in 2012 because of Honeywell's dredging activities. The 65 percent cover value reflects the calculated plant coverage area, excluding the dredged area (which is assumed to have no plants), divided by the littoral zone area of 777 acres. Macrophyte coverage has expanded to cover approximately five times more of the littoral zone in 2012 compared to a decade ago, providing more complex habitat for many aquatic organisms (Figure 6-5).

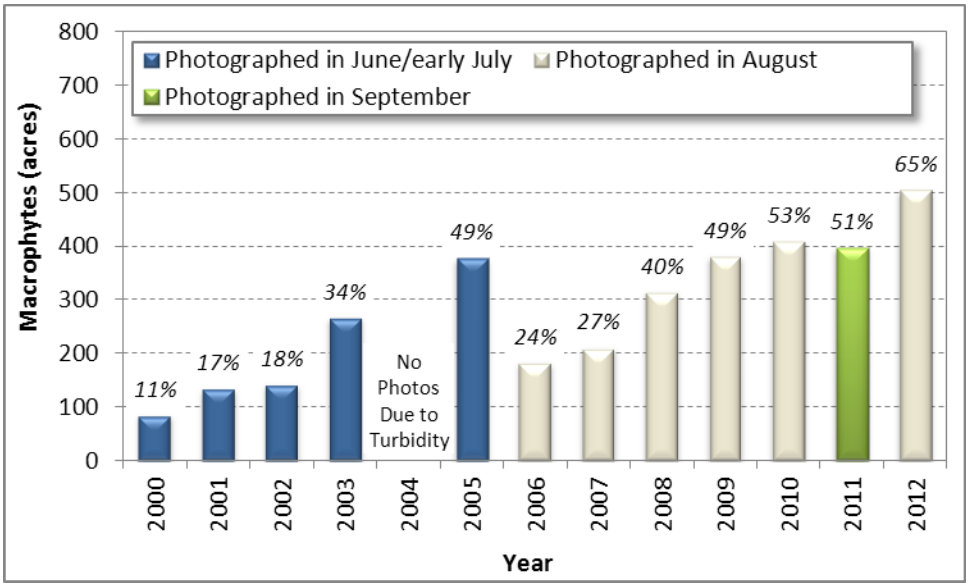


Figure 6-4. Macrophyte distribution, 2000–2012. Percentage represents coverage of the littoral zone (to depth of 6 m)

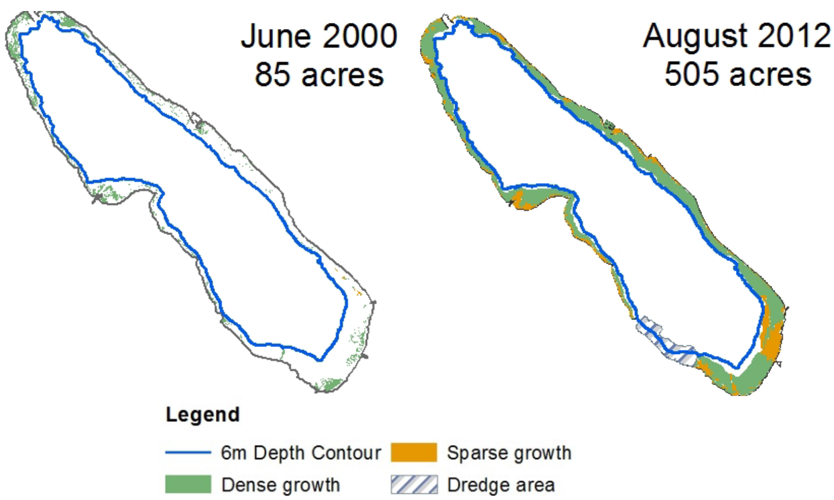


Figure 6-5. Aquatic macrophyte coverage 2000 and 2012

The annual aerial photos do not allow for species identification, only percent cover. The AMP team completes limited field surveys of the macrophyte community during the week of the aerial flights to verify the estimates of relative abundance and assess species composition. This effort in 2012 resulted in the identification of 11 plant species, with coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), and Eurasian water milfoil (*Myriophyllum spicatum*) found at 90 percent or more of the sites (although all three had low relative abundance where present). Water stargrass (*Zosterella dubia*) had the greatest overall relative abundance (35%), and sago pondweed (*Stuckenia pectinata*) the second highest abundance (18%).

6.2 Zooplankton

The zooplankton community is a central component of the lake ecosystem; these grazing aquatic animals affect the abundance and species composition of the phytoplankton community. Zooplankton, in turn, are eaten by fish and are a critical food for many species of fish, particularly in early stages of development. The size structure and abundance of the Onondaga Lake zooplankton community is tracked annually as part of the AMP. A detailed report on Onondaga Lake zooplankton monitoring results can be found in Appendix F-1. In Onondaga Lake, zooplankton and benthic mussels are the most important grazers of phytoplankton.

The size structure of the zooplankton community (i.e., the relative abundance of small and large species), is a consequence of the grazing pressure exerted on zooplankton by fish. The community composition has changed dramatically during several time periods; in late summer 2002 as alewife increased in abundance, in summer 2008 following alewife declines, and again during summer 2009 through summer 2012 when alewife abundance rebounded (Figure 6-6, Figure 6-7). Alewife preferentially feed on larger zooplankton species compared to smaller zooplankton. When alewife populations are high, the population of larger zooplankton species declines. With reduced alewife predation, the population of larger zooplankton species increases (Figure 6-6, Figure 6-7).

The average dry weight biomass of zooplankton samples collected in Onondaga Lake in 2012 was slightly higher than 2011, the lowest recorded in the AMP. Zooplankton biomass has been low since 2010 and there is an overall long-term decline. The species and size composition is similar to 2003-2007 and quite different from what was observed in 2008 and 2009 (Figure 6-7). The decrease in large daphnids and calanoid copepods in late summer 2009 was similar to the shift in the late summer 2002, when alewife became abundant in Onondaga Lake. Zooplankton species and size composition indicate high planktivory continuing in 2012, similar to 2010-2011 (Figure 6-7).

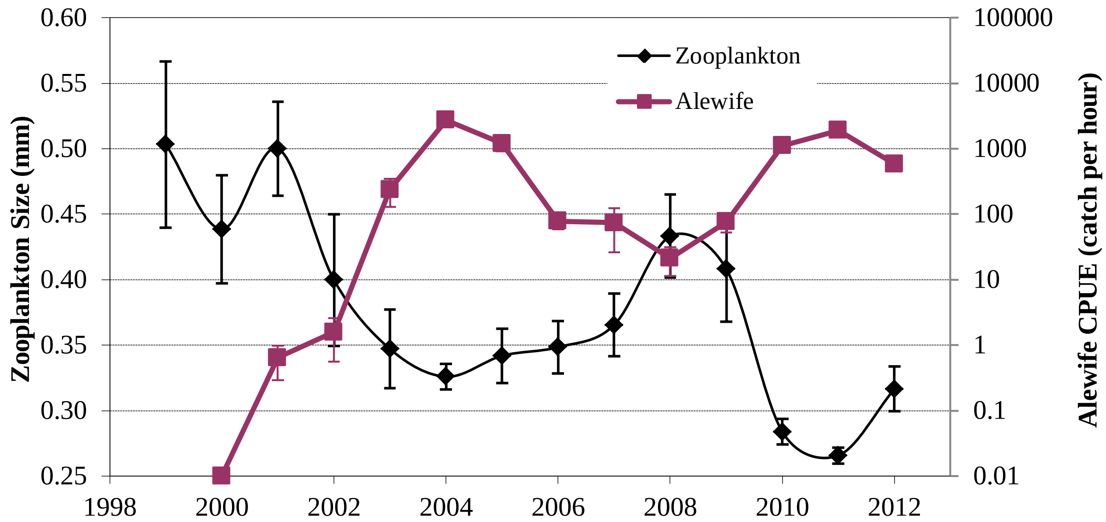


Figure 6-6. Average zooplankton size (all taxa combined) and alewife catch rates from electrofishing, growing season 2000–2012, Onondaga Lake.

Note: error bars are standard error of the mean.

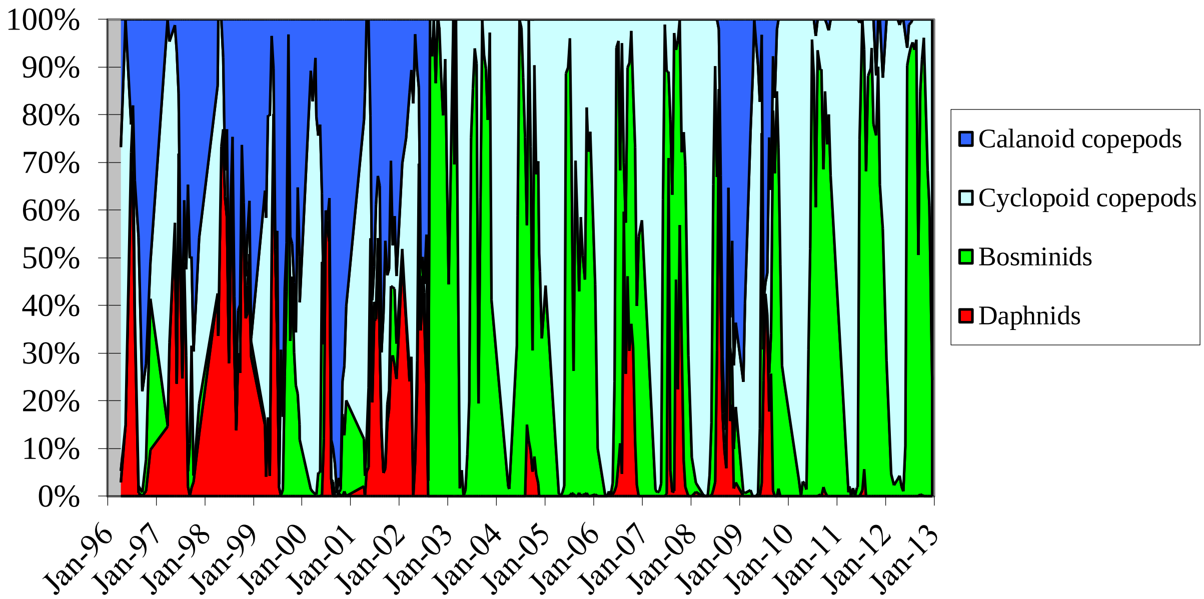


Figure 6-7. Proportion by biomass of major zooplankton groups. Calanoid copepods and daphnids are large taxa and cyclopoid copepods and bosminids are relatively small.

The low biomass of *Daphnia* from 2003 through 2007 and 2010 through 2012 is attributed to the presence of abundant alewife during these periods. *Daphnia* was abundant in 2008 and 2009, and primarily consisted of *D. mendotae* with limited biomass of *D. retrocurva* (Figure 6-8). *D. mendotae* was present from mid-July to early December 2008, and from mid-June through August 2009. All *Daphnia* species have been virtually absent in the lake since fall 2009.

Continued high alewife abundance had an important cascading effect on lower levels of the food web in 2012. Alewife feeding selectively on larger zooplankton leads to lower biomass and smaller average size of the crustacean zooplankton (Figure 6-9). Smaller zooplankton are less efficient grazers of phytoplankton than larger ones, and phytoplankton abundance increases as a result. More abundant phytoplankton results in decreased water clarity, typically measured as Secchi disk transparency. The relationship between zooplankton size and water clarity is illustrated in Figure 6-10. These top-down effects are often referred to as a “trophic cascade”, with alternating increases and decreases between adjacent levels of the food web. High water clarity and low phytoplankton biovolume was observed in 2008 and 2009 reflecting this top-down effect, as alewife abundance was lower resulting in higher abundance of large zooplankton. In 2010 to 2012, with alewife again abundant and the large zooplankton absent, water clarity was lower than the previous two years and algal biovolume was approximately twice as high as in 2008.

6.3 Dreissenid Mussels

Zebra mussels (*Dreissena polymorpha*) were introduced into the Great Lakes from Eurasia in ballast water from international shipping. They were first recorded in Onondaga Lake in 1992, although they did not become abundant until 2000 (Spada et al. 2002). A second related species, the quagga mussel (*Dreissena bugensis*), was first detected in Onondaga Lake in 2005. Their abundance and distribution has been tracked as part of the AMP using consistent methods since 2005. One modification was made in 2011 when the maximum depth sampled increased from 4.5 m to 6.0 m to determine if quagga mussels had colonized deeper areas of the lake. Assessments in 2012 included both the 0 to 4.5 m range and 0 to 6.0 m range for comparison among years. A detailed report on the 2012 dressenid mussel survey can be found in Appendix F-3. Abundance of quagga mussels was similar to abundance of zebra mussels in 2010 through 2012 (Figure 6-11). The average density of dreissenid mussels declined slightly in 2012 following a large increase in 2011, with average biomass (wet weight with shell included) continuing to decline (Figure 6-12). Including the 4.5 to 6.0 m depth range, average annual mussel biomass is slightly higher than the 0 to 4.5 m depth (445 g/m*2* compared to 336 g/m^2, respectively). This is due to the increased quagga mussel biomass at 0 to 6.0 m (797 g/m^2) compared to the 0 to 4.5 m depth (562 g/m^2). Quagga mussels dominated mussel biomass again in 2012 (90%) due to their larger average size.

The observed dreissenid mussel population variations in Onondaga Lake are difficult to attribute to any one factor. Nutrient levels, wave action, changes in water quality, macrophyte densities, and annual variability in populations are all possible contributing factors. A more detailed analysis of the dreissenid mussel data for Onondaga Lake is planned for the 2013 AMP report. Data from Oneida Lake will be compared to Onondaga Lake. The dynamics of quagga mussels replacing zebra mussels and the effects on total abundance, biomass and filtering potential in both lakes will be examined. Additionally, the effect of basin morphology and quagga mussel dominance and the potential ecosystem effects will also be reviewed.

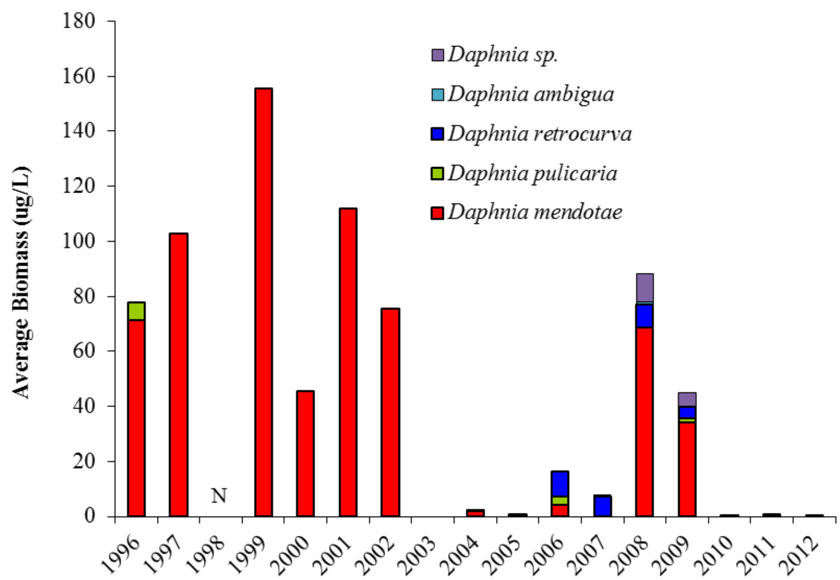
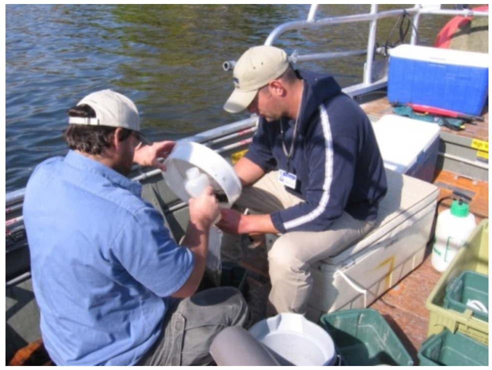


Figure 6-8. Biomass of various *Daphnia* species during the growing season in Onondaga Lake. Daphnids were almost non-existent in 2012.



OCWEP Technicians Zebra Mussel Sampling

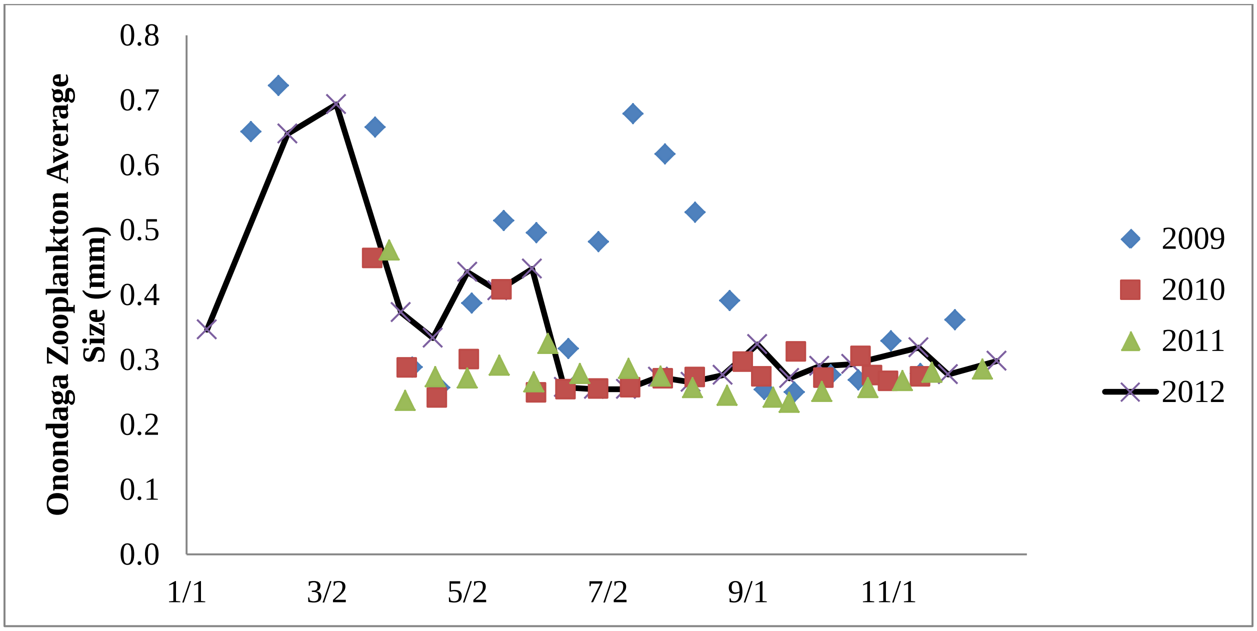


Figure 6-9. Seasonal development of average crustacean zooplankton length (mm), 2009 through 2012. Lines connect the values from 2012.

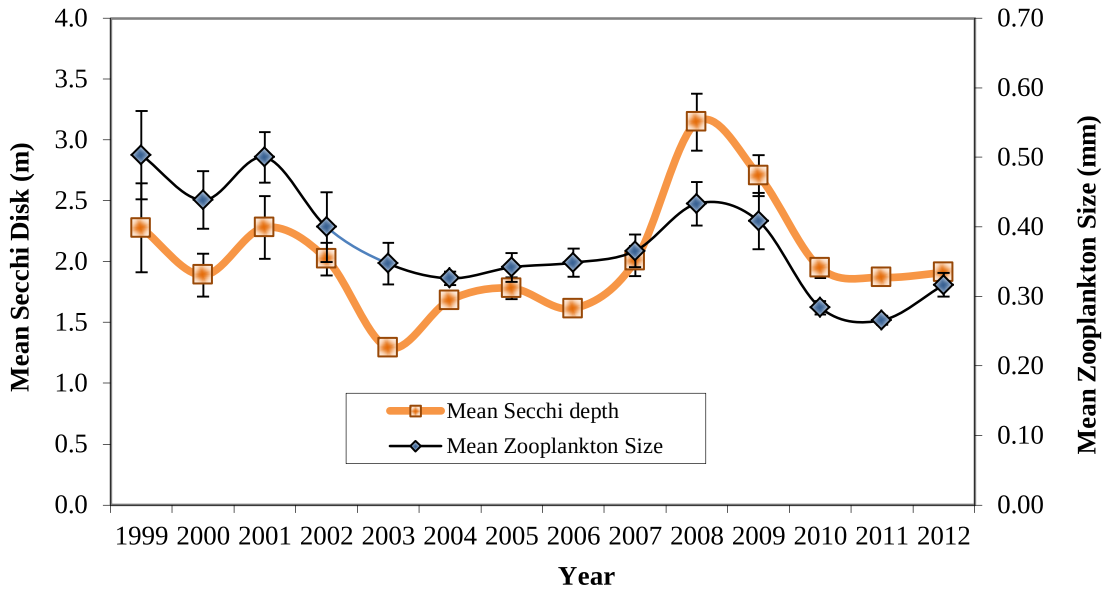


Figure 6-10. Growing season (April-October) mean (± standard error) Secchi disk depth and zooplankton size for Onondaga Lake, 1999–2012.

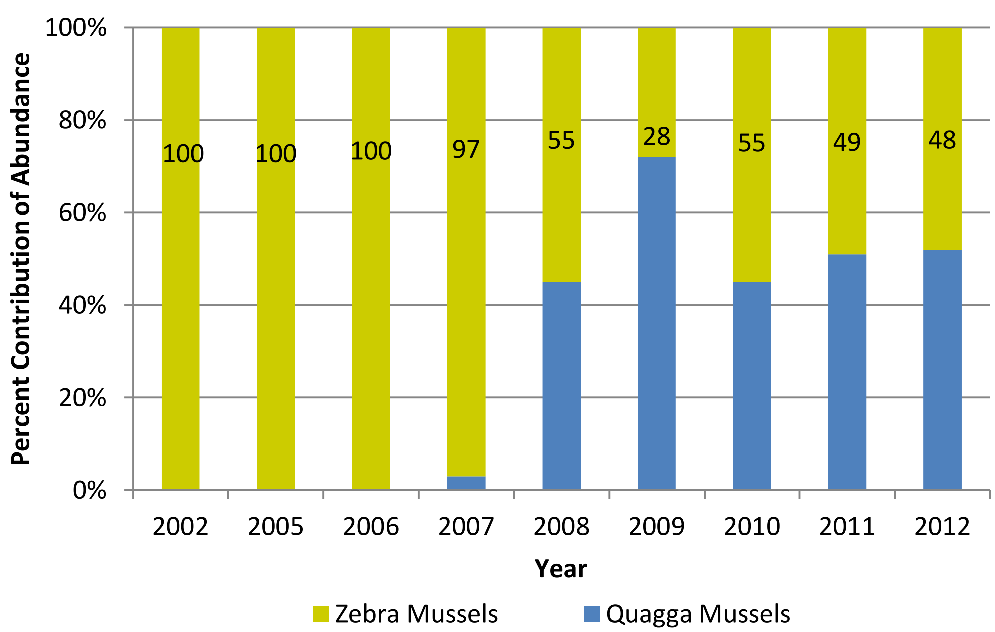
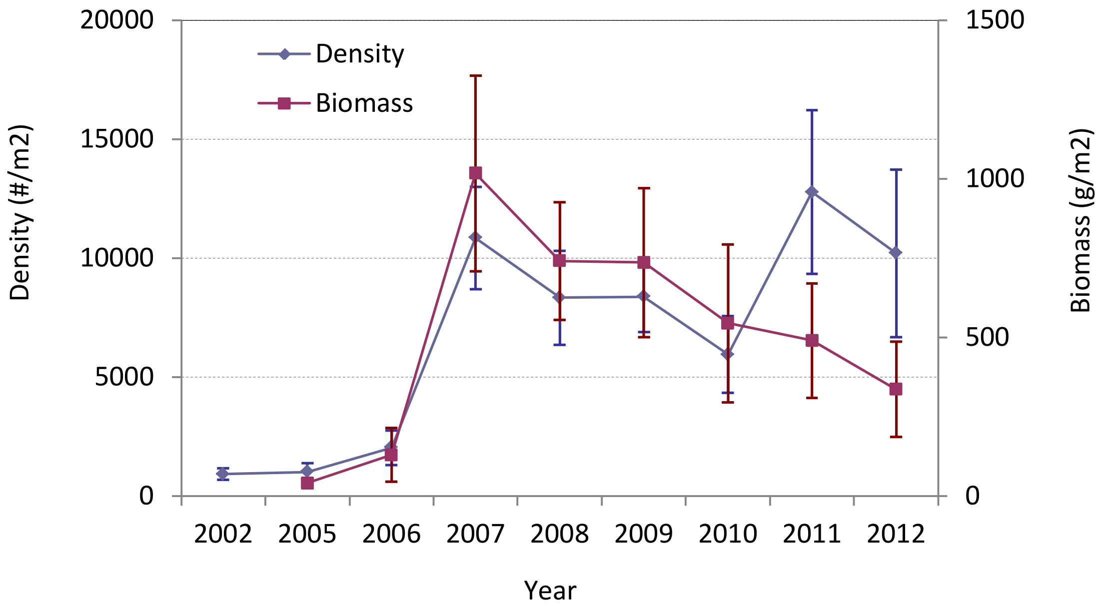


Figure 6-11. Relative abundance of dreissenid mussels, 2002–2012.



Note:
2002 biomass data were rejected.

Figure 6-12. Dreissenid mussel average density and biomass with standard errors, 2002–2012.

Note: where average quagga and zebra mussel biomass by zone were reported separately (2009-2012), the biomass of each species in each zone was averaged to obtain total average mussel biomass by zone. Average zone biomasses were then averaged, and standard deviation calculated, for the lake biomass as presented in this graphic. In 2011 and 2012, an additional depth was sampled [4.5 to 6.0 m]; these data are not included here for consistency of comparison among years.

6.4 Fish

Largemouth bass with Floy Tag

Changes in the fish community of Onondaga Lake have occurred as water quality and habitat conditions have improved. The significant reduction in ammonia and phosphorus input, resulting in the shift from eutrophic to mesotrophic conditions over the past several years, has expanded available fish habitat in both the littoral and pelagic zones. Since 2000, an extensive fisheries monitoring program has been included in the AMP, incorporating multiple types of sampling gear to assess nesting, larval, juvenile, and adult stages of the fish community. Since 2000, more than 149,000 individual fish have been captured from Onondaga Lake by Onondaga County's sampling efforts, representing fifty-three species (Table 6-2). Growth and survival of largemouth bass are summarized in a report (Appendix F-4).

Honeywell implemented a biological sampling program in 2008 to assess mercury concentration in fish tissue. As part of that program, State University of New York College of Environmental Science and Forestry (SUNY-ESF) students conduct sampling to assess the fish community and population estimates of several sport fish species. During development of Honeywell's monitoring program, project scientists conferred with County employees working on the biological programs to reduce duplication and provide complementary information to the AMP. Some of the SUNY-ESF data are incorporated into this report to provide a more holistic assessment of the overall fish community in Onondaga Lake.

The challenge in fishery data analysis and interpretation lies with the multitude of abiotic and biotic factors affecting the fish community, including annual variability in weather and climate, interactions among species, food web effects, and invasive species. The following section provides an overview of the lake's fish community in 2012, an assessment of trends observed since the onset of the AMP biological program in 2000, and a more detailed assessment of changes in the fish community that integrates data from the Honeywell program from 2008 to 2012.

Table 6-2. Fish species identified in Onondaga Lake, 2000–2012 (all gear types).

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
Brook silverside	Smallmouth bass	Emerald shiner	Round goby	Brown trout	Rudd
Brown bullhead	White perch	Fathead minnow	Shorthead redhorse	Chain pickerel	Silver redhorse
Carp	White sucker	Freshwater drum	Tessellated darter	Creek chub	Spotfin shiner
Gizzard shad	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	

6.4.1 Reproduction and Recruitment

OCDWEP Technicians Larval Seining

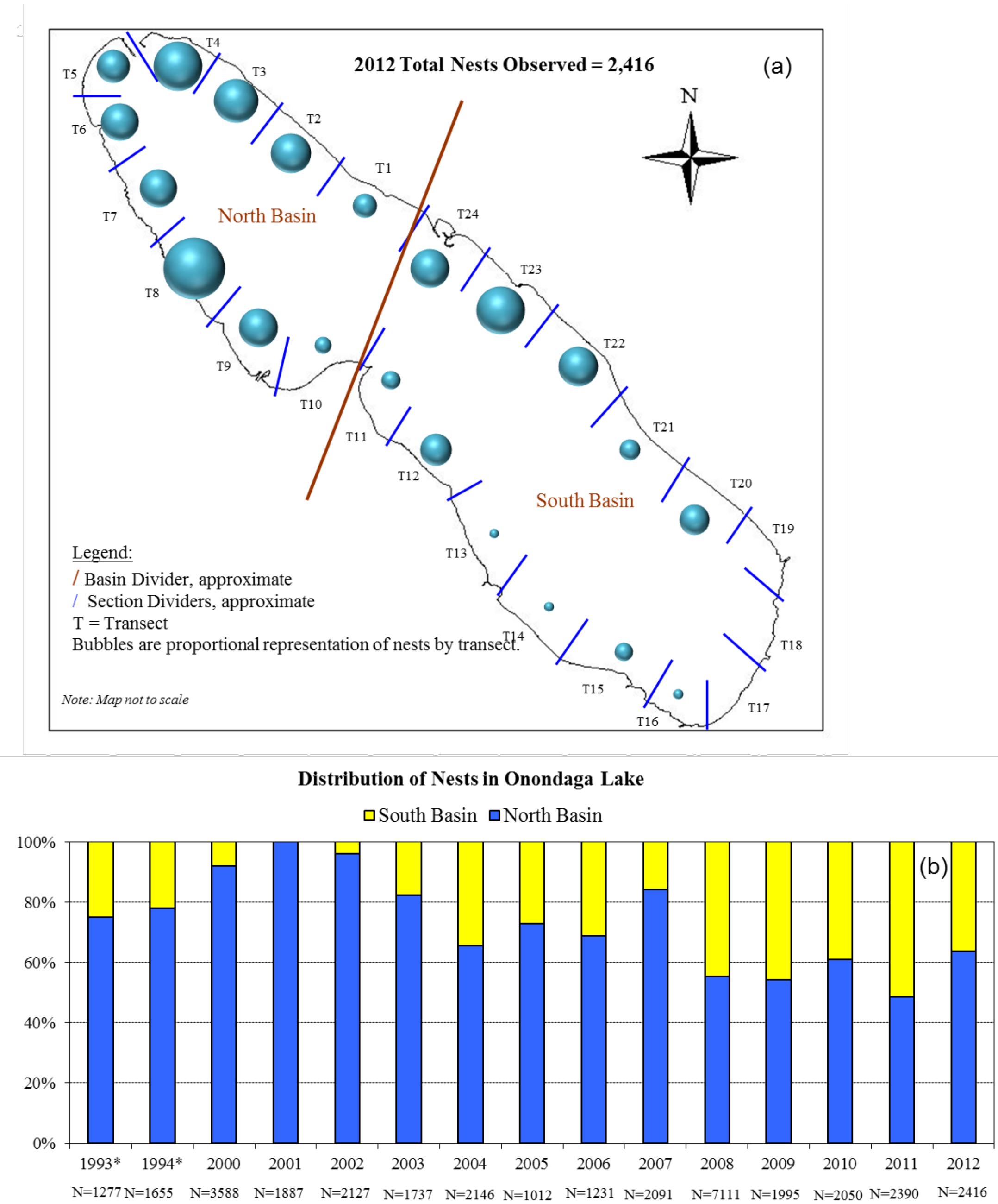
Several methods are used in the AMP to assess fish reproduction and recruitment (i.e, juvenile survival to the adult life stage), including nesting surveys and separate sampling of larval, juvenile, and adult fish. Evaluation of larval and juvenile fish provides information on the overall health of the fish community within the lake and the success of annual reproduction. Additionally, younger life stages often are less tolerant of water quality conditions such as elevated ammonia or low DO than are adults. Fish are known to have variable recruitment from year to year; environmental factors including water quality, habitat availability, wind, water level, and water temperature during and following spawning affect reproductive success. In addition, predation, disease, and competition can affect the reproductive success of many species.

6.4.1.1 Nesting

Centrarchid species (largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), pumpkinseed (*Lepomis gibbosus)*, bluegill (*Lepomis macrochirus*), and rock bass (*Ambloplites rupestris*)), and bullhead (*Ameiurus spp.*) construct nests in the littoral zone of the lake. Each year, the AMP team conducts nesting surveys to estimate the number and spatial distribution of the nests of these species. In 2012, 2,416 nests were observed (Figure 6-13), with approximately two-thirds in the North basin and one-third in the South basin (64% and 36%, respectively). The distribution of nests between the north and south basins has been more evenly distributed during the past several years, primarily due to increased numbers of nests in the south basin since 2008 (Figure 6-13). The increased nesting activity observed in the southern basin of the lake may be influenced by the increased macrophyte coverage of the littoral zone over the last decade. Dense beds of macrophytes may reduce the effects of wind-induced waves that can cover eggs with sediment and dislodge eggs from nesting areas. The majority of the nests observed in 2012 were sunfish (pumpkinseed, bluegill, and one green sunfish) accounting for 70% of the total nests identified (Table 6-3). Lesser amounts of largemouth bass (3.5%) and bullhead (0.41%) were also observed. The remaining 26% of the nests were described as unknown (nest observed without an adult fish present).

6.4.1.2 Larval, young-of-year, juvenile assessment

In response to the observed decreases in larval and juvenile fish during the past several years, OCDWEP modified its 2012 sampling program to include larval seine events, extra juvenile seine locations, and an electrofishing event to target juvenile fish. Nine species were captured during the 2012 larval seine events including pumpkinseed and bluegill, banded killifish (*Fandulus diaphanous*), brook silverside (*Labidesthes sicculus*), logperch (*Percina corrodes*), bluntnose minnow (*Pimephales notatus*), golden shiner (*Notemigonus crysoleucas*), round goby (*Neogobius melanostomus*), and yellow perch (*Perca flavescens*). *Lepomis spp*. (bluegill and pumpkinseed) larvae made up 75% of the overall catch, followed by banded killifish (11%, Figure 6-14). Larval seines were last used in 2003 when nine species were collected (*Lepomis spp*. [68% of catch]; carp (*Cyprinus carpio)* [20%], brook silverside [6%], yellow perch [4%], banded killifish [1%], golden shiner ([1%], crappie (*Pomoxis spp.)* [<1%], alewife [<1%], and unknown [1%]). Overall CPUE was higher in 2012, compared to 2000 through 2003, although the number of species was lower (Figure 6-14). Only one species (alewife) was collected in 2011, and no fish were collected in 2012 using larval trawls in the pelagic zone, indicating the change back to larval seines may be providing a better assessment of fish reproduction.

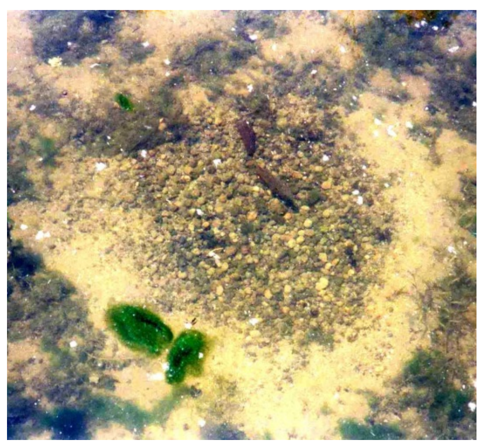


Year	1993*	1994*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
North Basin	75%	78%	92%	100%	96%	82%	66%	73%	68.9%	84.1%	55.4%	54.4%	61.0%	48.5%	63.6%
South Basin	25%	22%	8%	0%	4%	18%	34%	27%	31.1%	15.9%	44.6%	45.6%	39.0%	51.5%	36.4%
Nest count by basin															
North Basin	958	1291	3301	1887	2042	1430	1409	739	848	1759	3941	1085	1250	1159	1537
South Basin	319	364	287	0	85	307	737	273	383	332	3170	910	800	1231	879
Historic nest distribution. 1993 and 1994 data from Arrigo 1998.															

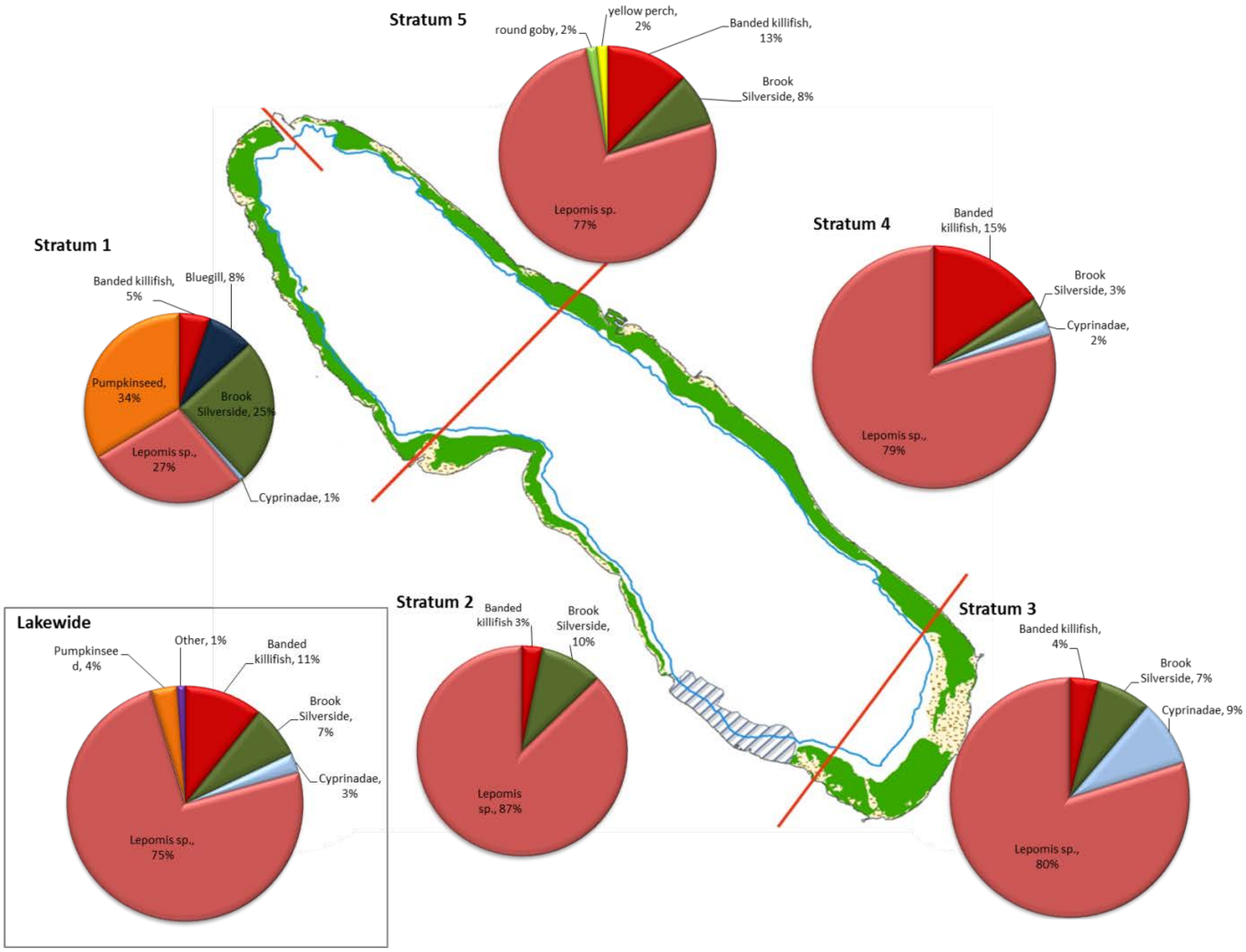
Figure 6-13. Nesting survey map (a) and comparison of north vs. south 1993–2012 (b).

Table 6-3. Fish species nesting in Onondaga Lake, 2012.

Species	Total Number of Nests	Percent of Total
Bullhead (species unknown)	10	0.4%
Bluegill	55	2.3%
Green sunfish	1	0.05
Pumpkinseed	1194	49.4%
Lepomis spp.	441	18.3%
Largemouth bass	85	3.5%
Other	630	26.1%



Centrarchid Nests



Year	2000	2002	2003	2012
Overall CPUE	38.64	47.33	47.7	194.73
Richness	20	12	9	9

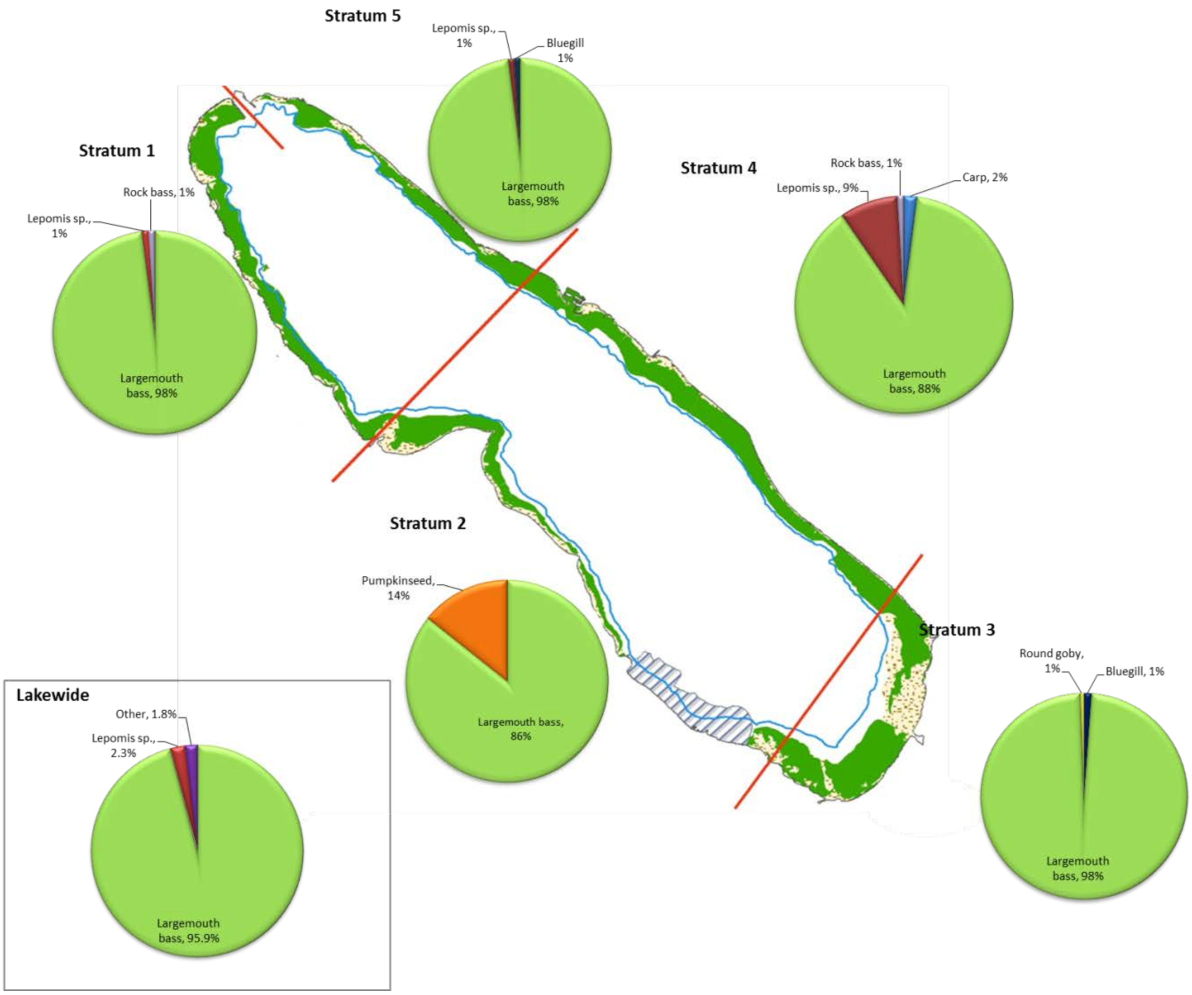
Figure 6-14. 2012 larvae relative abundance by stratum and species (fish collection by larval seining).

Note: The area of each pie is not proportional to its total.

Littoral zone seining is conducted every three weeks during the summer and early fall to assess young-of-year and juvenile (age 1+ or greater, not yet mature) abundance and diversity. Young-of-year bluegill, pumpkinseed, common carp, largemouth bass, smallmouth bass, rock bass, and round goby were captured in 2012. During all the events combined (total of 75), 488 young-of-year fish representing 7 species were captured. Largemouth bass young-of-year dominated the catch (96 percent) with one to a few individuals of the other species represented (Figure 6-15). The extra juvenile seine sweep conducted at each location during each event (total of 25 additional sweeps) did not result in any additional species or increased catch per unit effort. Overall, 783 fish were collected, the majority of which were adult banded killifish (66 percent). An additional 113 young-of-year fish were collected in the five events, 111 (98 percent) of those were largemouth bass. Generally, young-of-year abundance has been lower in recent years (2009 to 2012) in comparison to early in the monitoring program (early 2000s) with fewer species captured in the littoral seines. The number of young-of-year fish species has steadily declined since 2008 when 13 species were caught.

Juvenile abundance was evaluated based on the life stage description of "juvenile" in the littoral electrofishing and seining events with 871 individuals identified. The overall number of species representing the juvenile catch was approximately double the number of young-of-year species with 15 juvenile species identified in 2012. Alewife, pumpkinseed, largemouth bass, and gizzard shad (*Dorosoma cepedianum*) juveniles each represented approximately 20 percent of the overall catch (Figure 6-16).

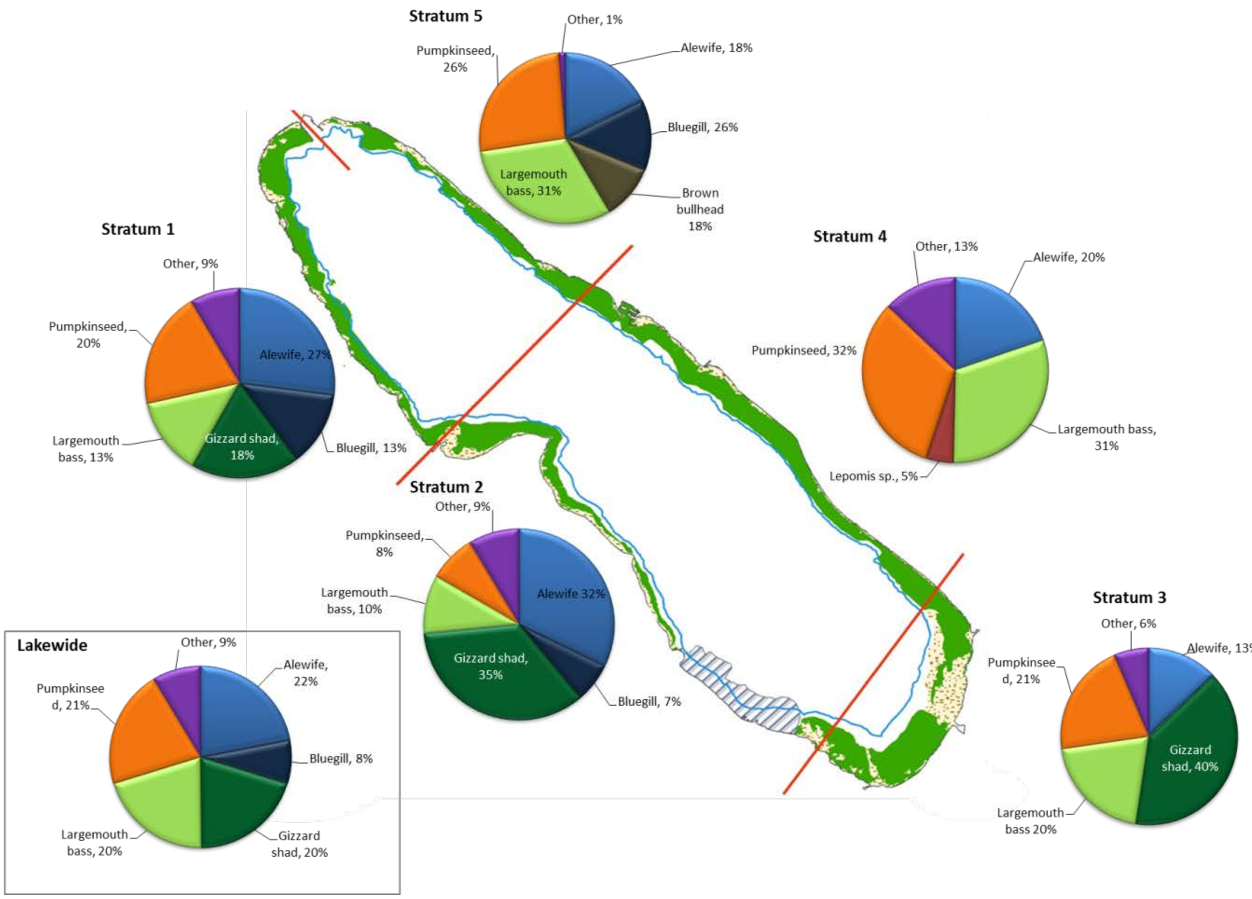
OCDWEP Technicians Juvenile seining



Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Overall CPUE	17.4	127.0	23.1	36.3	27.6	57.5	9.9	16.4	16.9	2.5	5.8	4.2	6.5
Richness	14	13	14	9	9	12	5	8	13	10	9	9	7

Figure 6-15. 2012 young-of-year relative abundance by stratum and species. Sampling by seining.

Note: The area of each pie is not proportional to its total.



Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Overall CPUE	(#/seine sweep)	1.75	9.15	53.54	3.16	0.49	21.36	3.06	4.74	3.69	1.71	3.01	0.94	2.61
	(#/hour)	15.34	15.52	24.95	22.10	24.16	21.01	29.77	19.66	40.65	84.07	104.64	67.54	57.35
Richness		18	20	16	14	11	14	13	11	14	15	14	16	15

Figure 6-16. 2012 juvenile relative abundance by stratum and species. Life stage indicated as juvenile during seining and electroshocking (YOY excluded).

Note: The area of each pie is not proportional to its total.

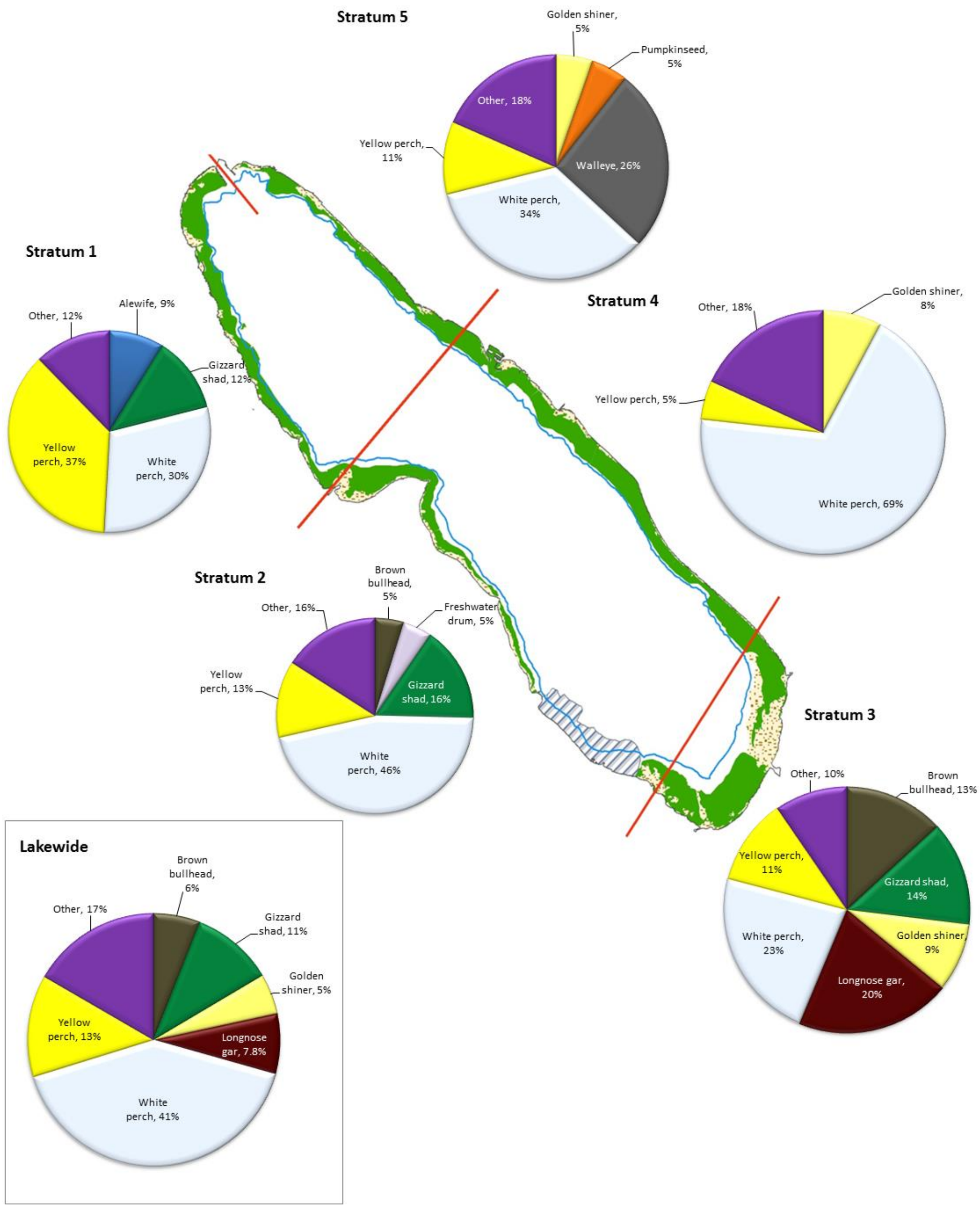
The electrofishing event conducted in mid-July targeted juvenile fish and was used to evaluate whether or not this technique might produce different results from littoral seining given the increased macrophyte distribution and abundance in the littoral zone. However, the data generated from the electrofishing effort were similar to those resulting from the littoral seining. Electrofishing catch was dominated by young-of-year largemouth bass (37%) and adult banded killifish (20%); only one other young-of-year species was collected, represented by one brown bullhead (0.5% of catch).

6.4.2 Fish Community

6.4.2.1 Abundance

The relative abundance of the adult fish community has been assessed by the sampling program. Pelagic adults are sampled using experimental gillnets in the deeper littoral zone and pelagic zone, while littoral adults are sampled by boat electrofishing in the littoral zone. Some adults, particularly the smaller species (minnows and killifishes) are captured during the littoral juvenile seining as well. In 2012, pelagic adults were collected from each strata with 21 species identified. White perch (*Morone americana*) and yellow perch were the most abundant species collected together comprising 54% of the total catch. Lesser amounts of gizzard shad, longnose gar (*Lepisosteus osseus*), brown bullhead (*Ameirus nebulosus*), and golden shiner comprising 11%, 7.8%, 6%, and 5% were collected respectively (Figure 6-17). Overall catch per unit effort (CPUE) was higher than rates seen in previous years (Figure 6-17). The number of littoral adult species (28) captured in 2012 tied the record high (2009, 2010) observed since the program began (Figure 6-18). Gizzard shad and alewife dominated the lakewide catch. Yellow perch and pumpkinseed were the next most abundant species collected followed by brown bullhead. Overall CPUE was lower than in 2011, but was one of the higher rates observed over the entire program (Figure 6-18).

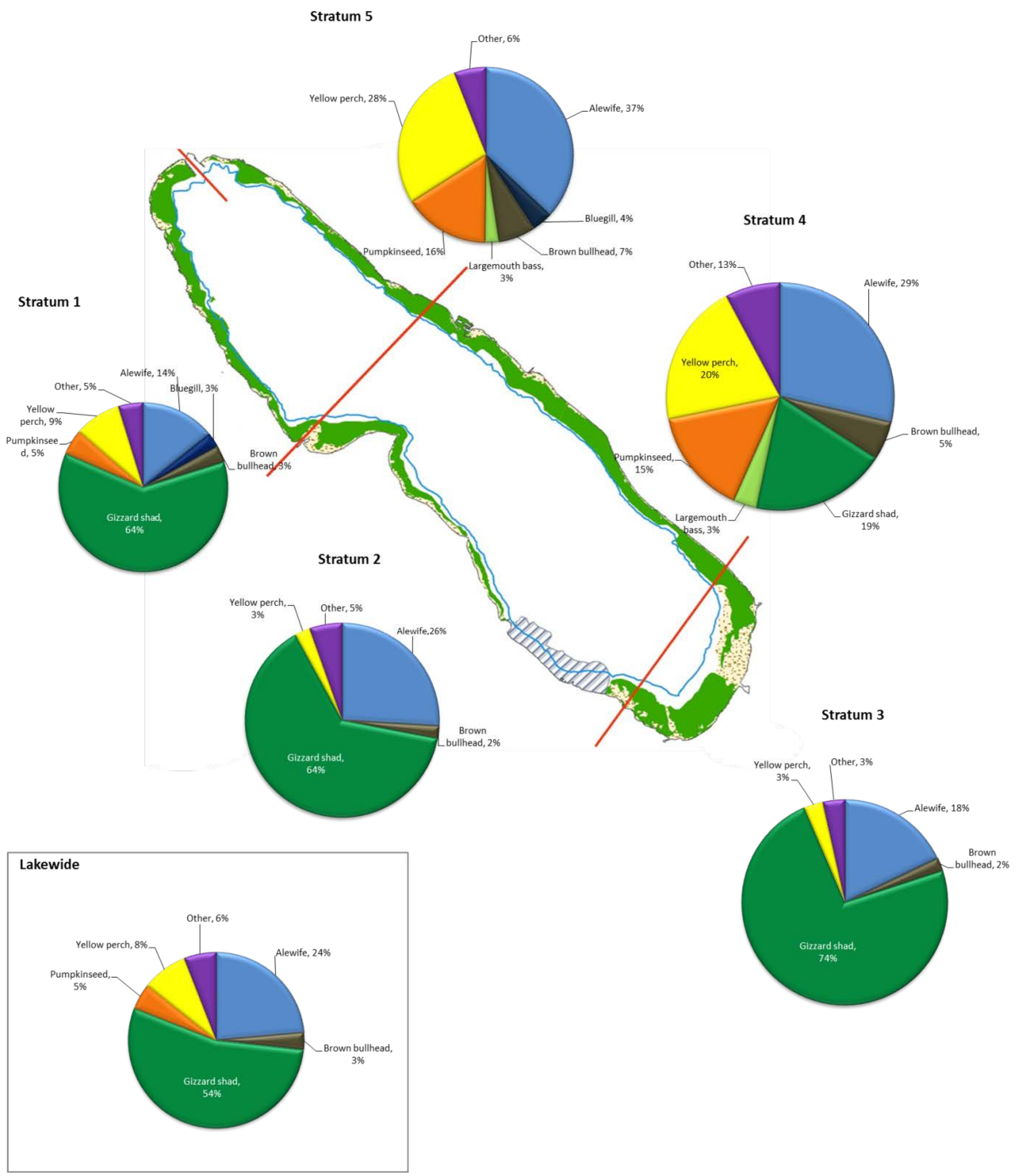
OCDWEP Technicians Electrofishing



Year	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Overall CPUE	0.31	4.7	7.6	12.53	13.25	7.26	6.09	3.72	2.74	5.69	6.05	12.62
Richness	9	10	12	11	16	11	16	12	11	15	16	21

Figure 6-17. 2012 pelagic adult relative abundance by species and stratum. Sampling by gill net.

Note: The area of each pie is not proportional to its total.

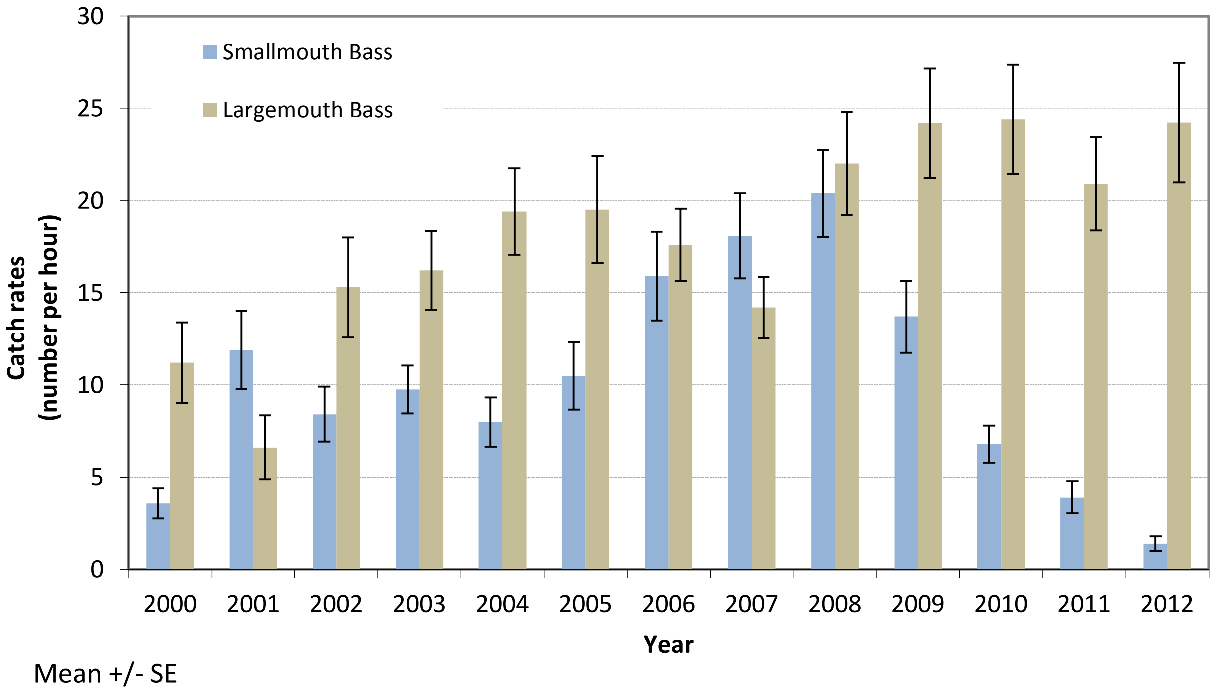


Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Overall CPUE	254.2	196.47	634.23	519.93	2098.24	1158.47	371.19	471.3	802.03	814.06	1297.65	2344.99	1668.34
Richness	23	21	25	21	26	25	25	21	24	28	28	25	28

Figure 6-18. 2012 littoral adults relative abundance by species and stratum (based on "counts" only; counts and estimates for gizzard shad and alewife only).

Note: The area of each pie is not proportional to its total.

The black bass population is increasingly dominated by largemouth bass in both adult and young-of-year life stages (Figure 6-19). Smallmouth bass catch rates continue to decline, likely indicative of the changing conditions in the littoral zone with increased macrophyte coverage more suitable for largemouth bass (Stuber et al. 1982, Edwards et al. 1983). Increases in the relative abundance of largemouth over smallmouth bass also have occurred in Oneida Lake and Canadarago Lake, two other New York lakes with increasing macrophyte coverage (Jackson et al. 2012, Brooking et al. 2012).



Mean CPUE, entire year

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Smallmouth Bass	3.57	11.9	8.41	9.75	7.99	10.5	15.9	18.1	20.4	13.7	6.8	3.9	1.39
Largemouth Bass	11.2	6.61	15.3	16.21	19.4	19.5	17.6	14.2	22	24.2	24.4	20.9	24.2

Figure 6-19. Trend in annual average catch rates (number per hour) from two electrofishing events (spring and fall) of largemouth and smallmouth bass combined in Onondaga Lake from 2000 to 2012.

Overall trends in catch rates have varied by species since 2000 (Figure 6-20). Several species have increased recently, including largemouth bass, gizzard shad, brown bullhead, and yellow perch; while catch rates of smallmouth bass, bluegill, pumpkinseed, white perch, and carp have declined (Figure 6-20). These patterns reflect the changing habitats in the lake including increased macrophyte coverage, increased mussel abundance, and changes in the fish community associated with alewife. Decreased nutrient levels and open water production also could play a role as we may expect carp to decline and yellow perch to increase as the lake's overall productivity has declined from eutrophic to mesotrophic conditions (Krieger et al. 1983). However, other changes, such as an increase in gizzard shad and largemouth bass and decrease in smallmouth bass, are not consistent with this explanation. It is likely that the reasons for changes in abundance are more complex and species-specific reflecting changes in overall lake productivity as well as increased littoral zone habitat diversity.

6.4.2.2 Richness and Diversity

In Onondaga Lake, adult fish species richness (i.e., number of species) has gradually increased since 2000. In 2012, a total of 37 adult species were captured during electrofishing, gill netting, and seining surveys (Figure 6-21). Onondaga Lake is part of the Seneca River system, which provides a corridor for fish movement between the lake and the waterways connected to the Seneca River as evident based on tag returns since 1987 (Gandino 1996, Siniscal 2009). Since the monitoring program started in 2000, fifty adult species have been identified in the lake (Figure 6-21).

Fish community diversity fluctuates in response to changes in seasonal and environmental variables and inter-species competition, among other factors. In Onondaga Lake, changes in diversity are highly influenced by periodic peaks and crashes of two species of clupeid (herring family), alewife and gizzard shad. Abundance of these two species is highly variable because Onondaga Lake is near the northern edge of their range, and both populations periodically exhibit significant winter mortality. Extremes in recruitment are seen as well; both fish periodically produce very strong year classes that dominate the catch for years, as alewife can live to ten years and gizzard shad even longer. Shannon-Weiner diversity (H'), an index that considers richness and relative abundance, has fluctuated over the past 12 years due largely to shifts in abundance of clupeids, with the highest value (2.53) observed in 2007 and the lowest value (1.66) observed in 2009. The 2012 value was 2.20 (Figure 6-21).

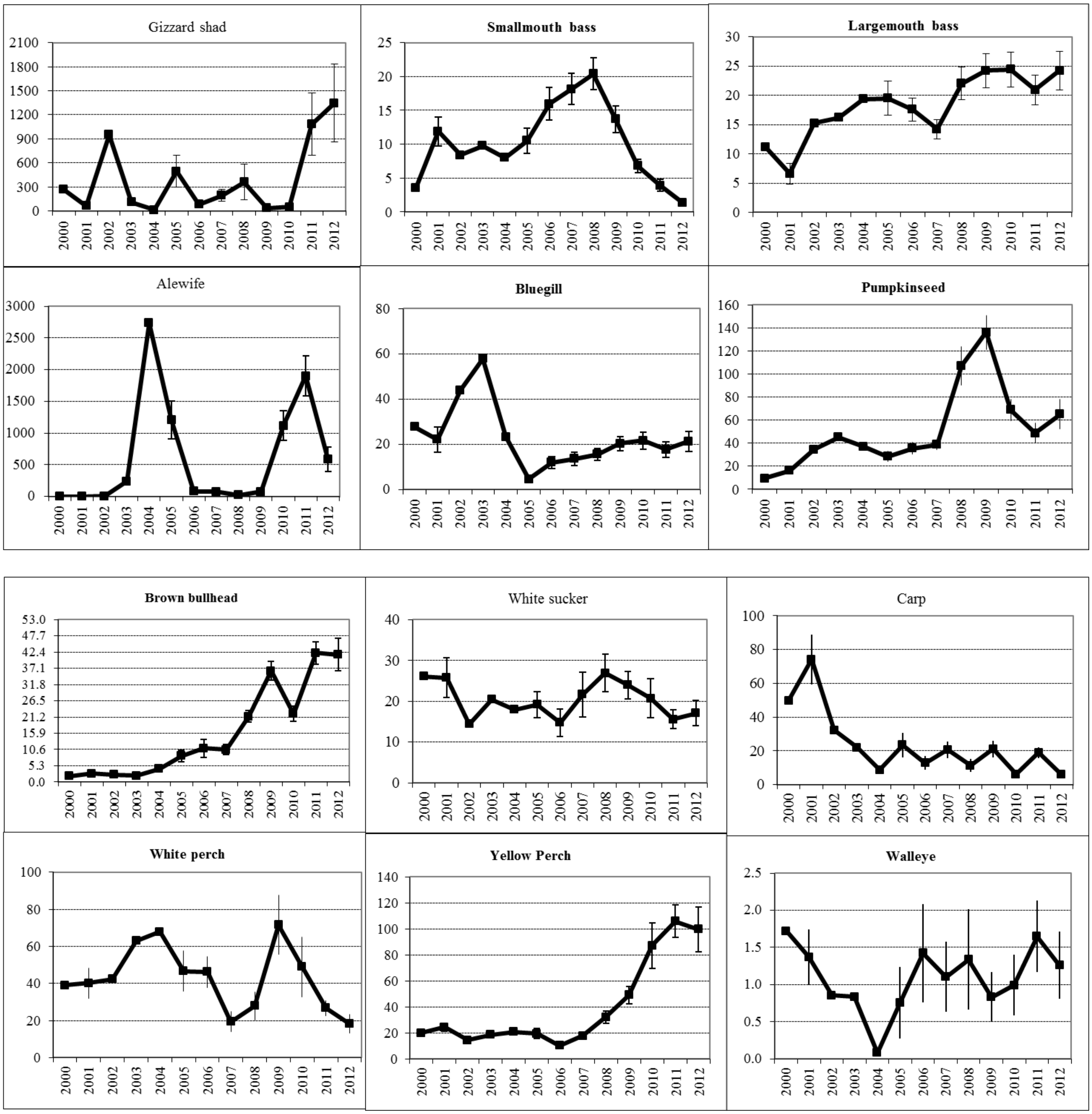
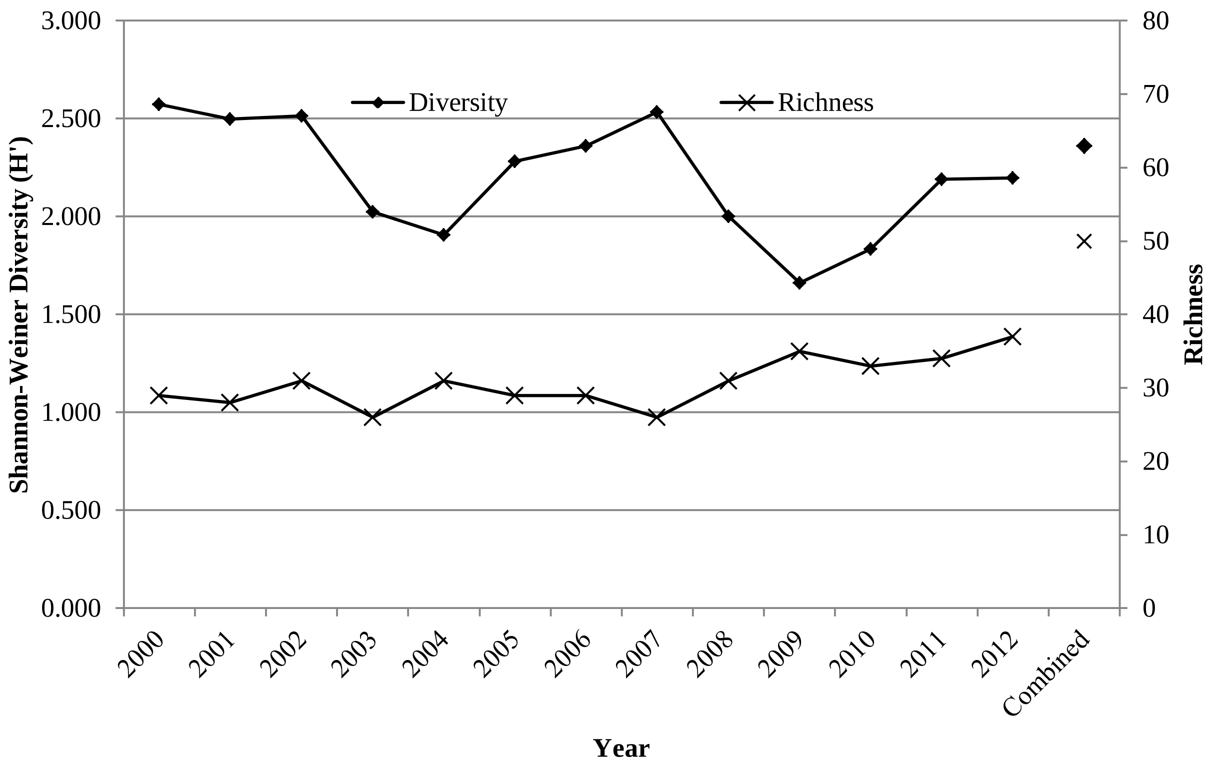


Figure 6-20. Trends in catch per unit effort (CPUE) of select species captured by electrofishing 2000–2012.

Note: CPUE for gamefish (bolded) is calculated from all 24 transects. CPUE for non-gamefish are calculated from only the one-half of the transects where all fish are collected (every other transect). Because of the difficulty in netting clupeids (shad and alewives), the CPUE for these species is calculated from a combination of fish that are boated and estimates of the number of fish missed. Because of their large size carp are not boated, instead carp within netting distance are counted while still in the water. Note: Y-axis differs for each species.



Notes: OCDWEP Based on fish counts only and life stage=adult. Fish from gill netting, electroshocking, and seining data sets.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Combined
SW Diversity (H')	2.57	2.50	2.51	2.02	1.91	2.28	2.36	2.53	2.00	1.66	1.83	2.19	2.20	2.36
Richness	29	28	31	26	31	29	29	26	31	35	33	34	37	50

Figure 6-21. Trends in adult fish Shannon-Weiner diversity (H’) and richness 2000–2012.

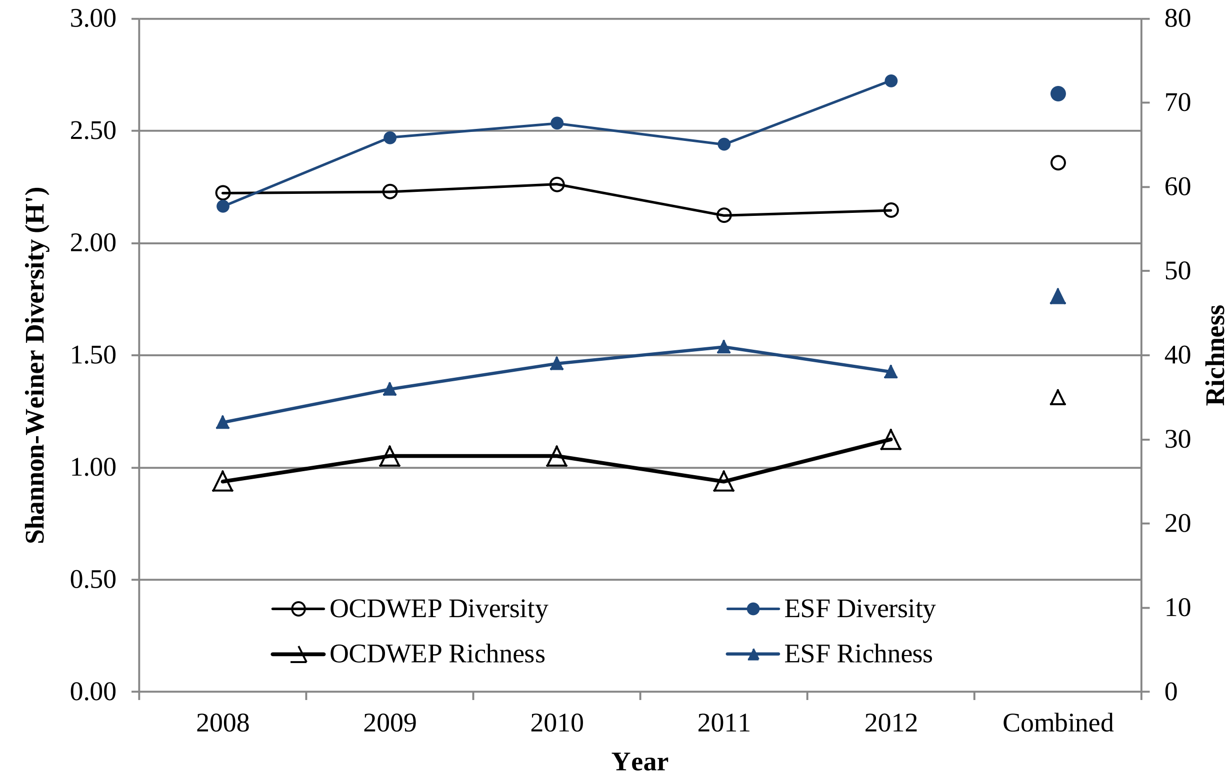
Diversity and richness estimates from 2008 through 2012 were compared with the SUNY-ESF trap net and gill net data. As part of the Honeywell monitoring program, monthly trapnet and gillnet sampling is conducted by SUNY-ESF students from May through October at ten locations around the lake. Trap nets are set overnight at each location once per month (total approximately 60 sets per year), while gill net sampling is conducted during the overnight hours with approximately one hour net sets at each location (total sets approximately 55 per year). Only the AMP electrofishing and gill netting data were used for comparison because they were collected to assess littoral and pelagic abundance and richness, respectively; all life stages were included in the analysis because the life stage is not included in the SUNY-ESF data set and juveniles and young-of-year are typically collected in the trap nets. Diversity was generally similar over the five years, with the SUNY-ESF diversity slightly higher, except in 2008 (Figure 6-22). SUNY-ESF richness was higher, with SUNY-ESF consistently catching more species than OCDWEP in all five years. However, this may be the result of more small fish typically being passively captured in the trap nets, while electrofishing and gill netting target larger fish. In addition, the monthly sampling by SUNY-ESF is more intensive than the spring and fall electrofishing and gill netting efforts conducted by OCDWEP and would be expected to capture more species. The combination of the two data sets allows for a more complete assessment of the overall fish community in Onondaga Lake.

Comparison of relative abundance by species indicates similar trends in overall abundance and dominance by certain species each year (Figure 6-23). Pumpkinseed sunfish are prevalent in both data sets with a noticeable decline between 2008 and 2012. The increase in clupeids (alewife and gizzard shad) also is apparent in both sampling programs from 2010 through 2012. Differences in abundance between the two programs also are noted with yellow perch being more abundant in the OCDWEP data and bluegill in the SUNY-ESF data. This likely reflects differences in vulnerability between species to different sampling methods.

6.4.3 Population Estimates of Centrarchids

As part of the Honeywell program, SUNY-ESF samples bass and sunfish to calculate population estimates based on mark recapture methods. In 2012, the sampling was modified slightly to conduct the mark recapture sampling within a shorter time period to account for potential movement between the Seneca River and Onondaga Lake during the summer and reduce the variability of these estimates.

During 2012, 929 pumpkinseed with total lengths of 100 mm or greater were captured and marked during four electrofishing sampling events in June; 10 pumpkinseed were recaptured. Using the Schnabel mark recapture method, the lakewide pumpkinseed population in 2012 was estimated at 28,655 with a 95 percent confidence interval of 18,328 to 65,641 fish.



Note: ESF data collected using gillnets and trapnets, includes all sizes; OCDWEP includes counts only from electroshocking and gillnetting, all sizes. Combined is the overall value for 2008 to 2012.

		2008	2009	2010	2011	2012	Overall
OCDWEP	SW Diversity	2.22	2.23	2.26	2.12	2.15	2.36
	Richness	25	28	28	25	30	35
ESF	SW Diversity	2.16	2.47	2.53	2.44	2.72	2.67
	Richness	32	36	39	41	38	47

Figure 6-22. Fish Shannon-Weiner Diversity (H') based on all gears sampled each year, comparison with SUNY-ESF results.

ESF Relative Abundance of species in trapnet and gill net samples	OCDWEP Relative Abundance of species in electroshocking and gill netting samples	OCDWEP/ESF Combined

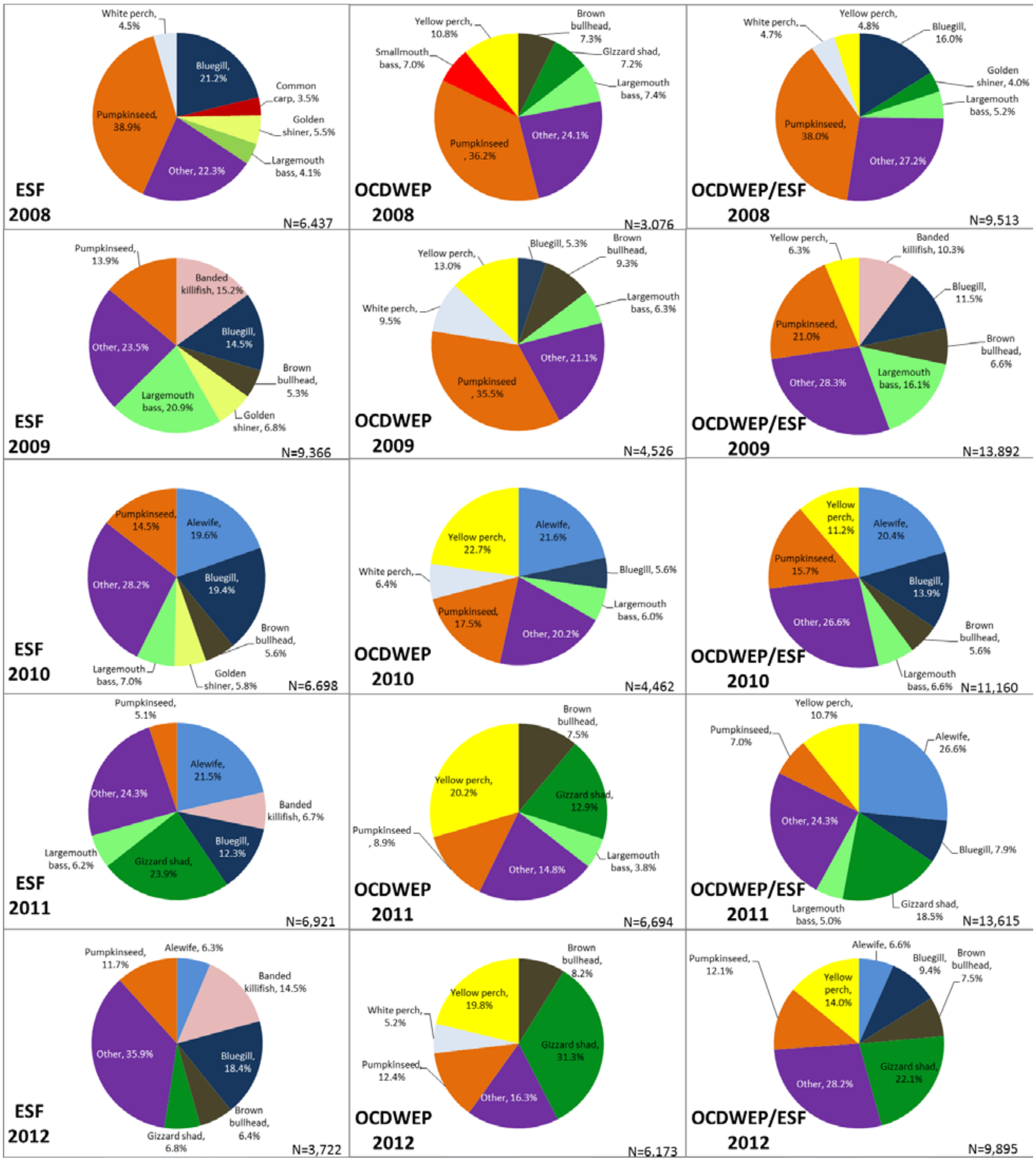


Figure 6-23. Comparison of relative abundance of fish collected in Onondaga Lake by OCDWEP and SUNY-ESF. OCDWEP data includes fish counts from all life stages in noted gear.

Note: For each analysis the top 6 most abundant were used and all others combined into "other" category

A total of 833 bluegill with total lengths of 100 mm or greater were captured and marked during four sampling events in June; six bluegill were recaptured. The lakewide bluegill population in 2012 was estimated using the Schnabel mark recapture method to be 36,415 with a 95 percent confidence interval of 21,600 to 115,920 fish.

A total of 286 largemouth bass with total lengths of 300 mm or greater were captured and marked during four sampling events in June; 14 largemouth bass were recaptured. The lakewide largemouth bass population in 2012 was estimated using the Schnabel formula at 1,930 with a 95 percent confidence interval of 1,297 to 3,777 fish.

6.4.4 Fish Abnormalities

The occurrence of physical abnormalities in fish captured during AMP sampling is monitored using a standardized protocol of identifying Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies (DELTFM). Data are used for trend analysis and to compare fish collected from Onondaga Lake to those collected in other areas. Fish abnormalities can result from chemical contamination; biological agents such as bacteria, viruses, or fungi; or interactions among multiple stressors.

Brown bullhead with lesions

DELTFM abnormalities showed an overall increase from 2003 to 2009, but have decreased since then. DELTFM abnormalities were found in 0.6% of adult fish from Onondaga Lake in 2003, increased to 4.1% in 2005, decreased slightly to approximately 3% in 2006 and 2007, and then increased steadily to 7.7% in 2009. DELTFM abnormalities began declining in 2010 and have steadily decreased to 5.4% in 2012 (Figure 6-24). The majority of abnormalities in the Onondaga Lake fish community in 2012 were lesions (69%), followed by deformities (24%). Erosions, tumors, malignancies, and fungal infections were rare (7% combined).

Eighteen species of adult fish were found with DELTFM abnormalities in 2012, similar to 2011 and recent previous years. The species contributing the most to the DELTFM total in 2012 were brown bullhead (29% of total), gizzard shad (29%), largemouth bass (12%), pumpkinseed (9%), and bluegill (7%).

The incidence of lesions and tumors in brown bullhead in Onondaga Lake from 2000 to 2012 was compared with similar data from waters in the Chesapeake Bay watershed, Great Lakes, and Cape Cod area (Baumann et al. 2008, Pinkney et al. 2004; Figure 6-25). Prior to 2007, occurrences of lesions and tumors in Onondaga Lake brown bullhead were within the range associated with reference sites (typically <5% incidence). Data from 2007-2009 indicated a shift in occurrence to levels associated with contaminated sites from regional waters. The cause of this shift is not known, but may have been due to several recently identified pathogens affecting brown bullhead in Onondaga Lake. The incidence of lesions and tumors in brown bullhead in Onondaga Lake has continued to decline since 2008, suggesting a recovery of the population from these pathogens. The incidence of lesions and tumors in brown bullhead in Onondaga Lake in 2012 fell to 6% and is again approaching the range associated with regional reference sites (Figure 6-25).

6.4.5 Coolwater and Coldwater Habitat

Dissolved oxygen and water temperature largely determine the amount of habitat available for the different species that make up the Onondaga Lake fish community. The Data Visualization Tool (DVT) provides insight into the habitat available for coolwater and coldwater fish communities, or "fish space". The fish space metric is useful for tracking changes in habitat based on DO and water temperature, two variables that determine the ability of coolwater and coldwater species to maintain a population. Optimal DO and water temperature requirements differ for coldwater and coolwater fish species as shown on Figures 6-26 and 6-27, respectively.

Available habitat for the coldwater fish community is calculated as a percent of the theoretical total, using volume-days as the measurement. For example, if half the lake's water volume had suitable DO and temperature conditions for half of the selected time period, the percent available habitat is 25% for a given year. The 6-month period from May 15 through November 15 (185 days) is used 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. Moreover, the Onondaga County monitoring probes are deployed over this period and high frequency data are available. In Figures 6-26 and 6-27, the blue color represents the depth and timing of water temperatures and DO concentrations that are suitable for coldwater and coolwater fish habitat, respectively. Yellow represents where and when temperatures are out of range, and green represents where and when DO is out of range. Orange represents conditions where and when both temperature and DO are out of the range.

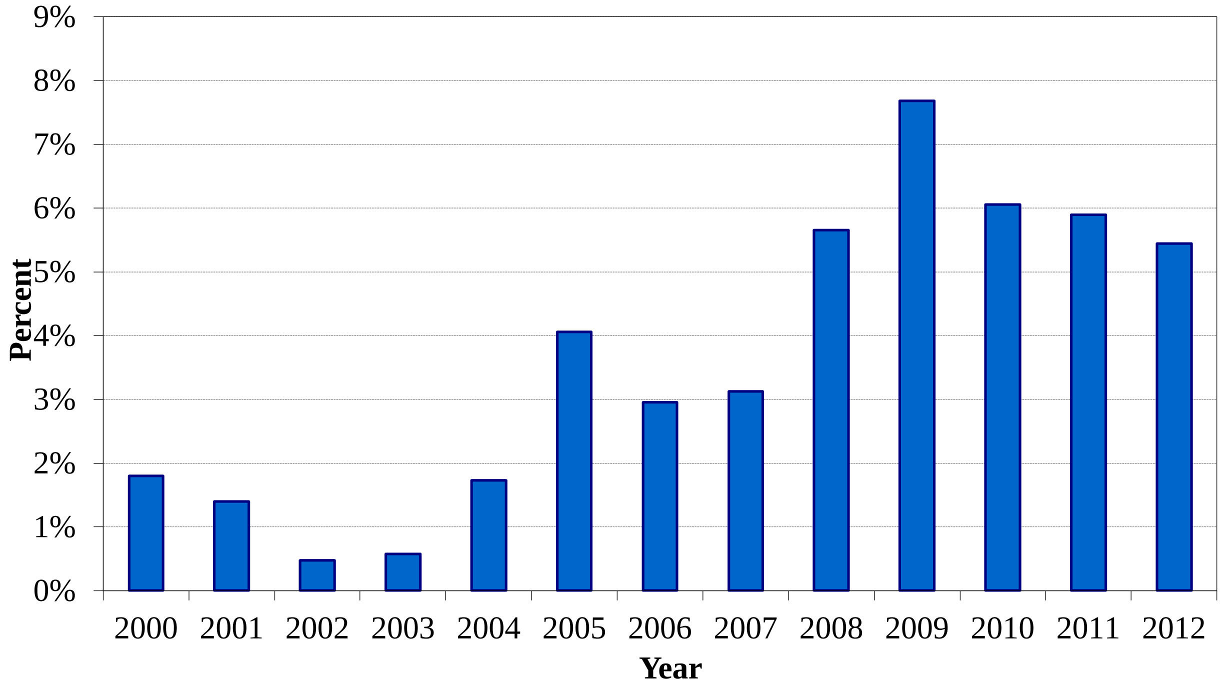


Figure 6-24. Percent of adult fish captured during AMP sampling with DELTFM abnormalities.

Note: DELTFM are defined as Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies. The increase in recent years is mostly due to an increase in the brown bullhead catch and a higher proportion of those brown bullhead having skin lesions. Analysis by Cornell University of Onondaga Lake bullhead in 2008 found a variety of pathogens including: Trichodina, Saprolegnia, Digenean infestations, Micrococcus luteus, and Aeromonas sobria.

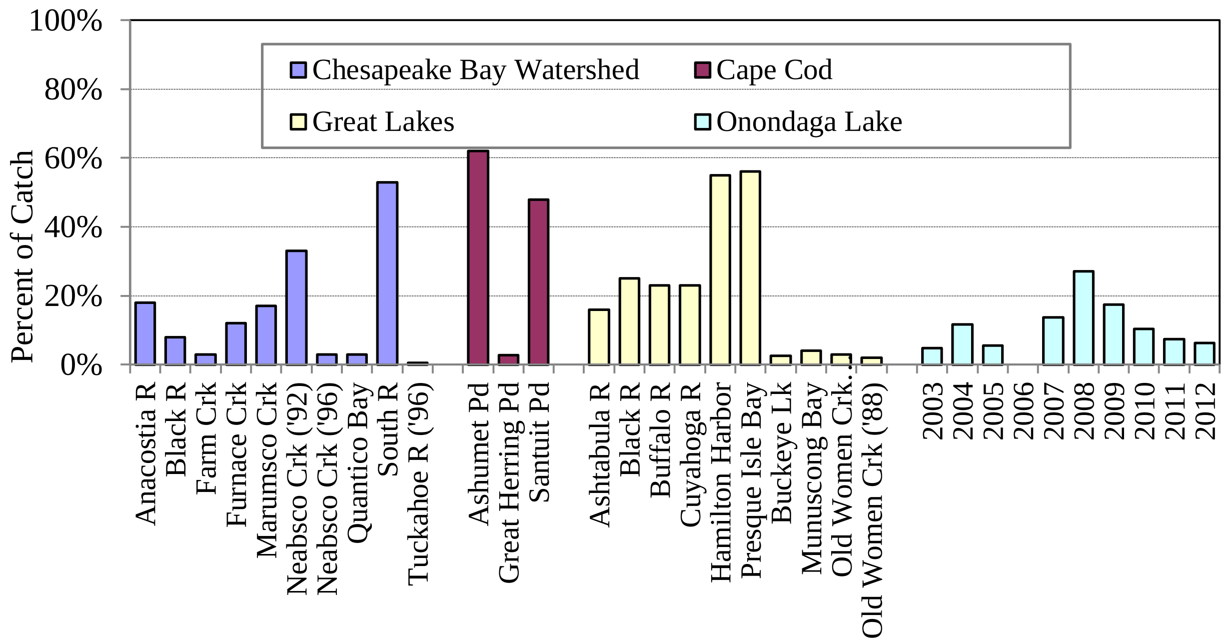


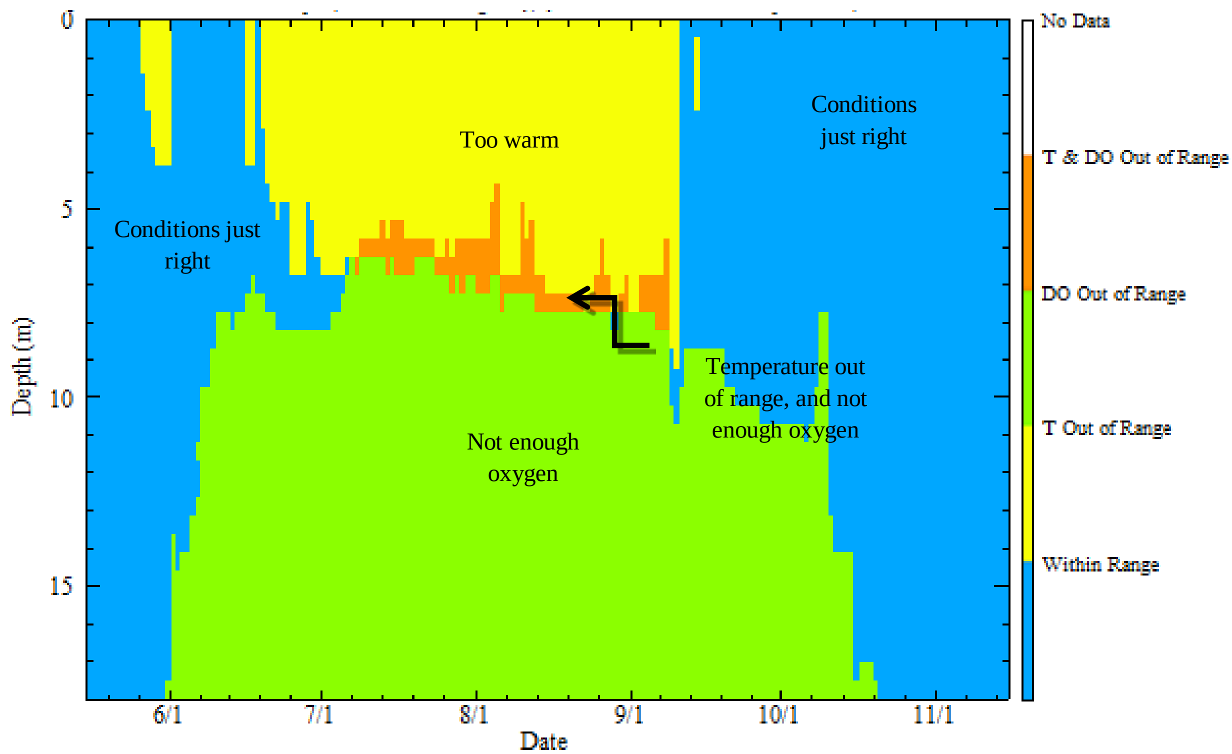
Figure 6-25. Occurrence of lesions and tumors in brown bullhead from Onondaga Lake and other regional waters.

Note: Onondaga Lake brown bullhead data includes Lesions, Tumors and Malignancies, and does not include Deformities, Erosions or Fungal Infections. The following locations were identified as reference sites in the cited reports: Cape Cod – Great Herring Pond and Santuit Pond; Great Lakes: Buckeye Lake, Munuscong Bay, and Old Women Creek.

Sources:

1. *Baumann, P.C., LeBlanc, D.R., Blazer, V.S., Meier, J.R., Hurley, S.T., and Kiryu, Yasu, 2008, Prevalence of tumors in brown bullhead from three lakes in southeastern Massachusetts, 2002: U.S. Geological Survey Scientific Investigations, Report 2008–5198, 43 p., available online at http://pubs.usgs.gov/sir/2008/5198.*

2. *Pinkney, A E (AE); Harshbarger, J C (JC); May, E B (EB); Melancon, M J (MJ); Tumor prevalence and biomarkers of exposure in brown bullhead (Ameiurus nebulosus) from Back River, Furnace Creek, and Tuckahoe River, Maryland. Archives of environmental contamination and toxicology (Arch Environ Contam Toxicol), published in United States. 004-May; vol 46 (issue 4) : pp 492-501*



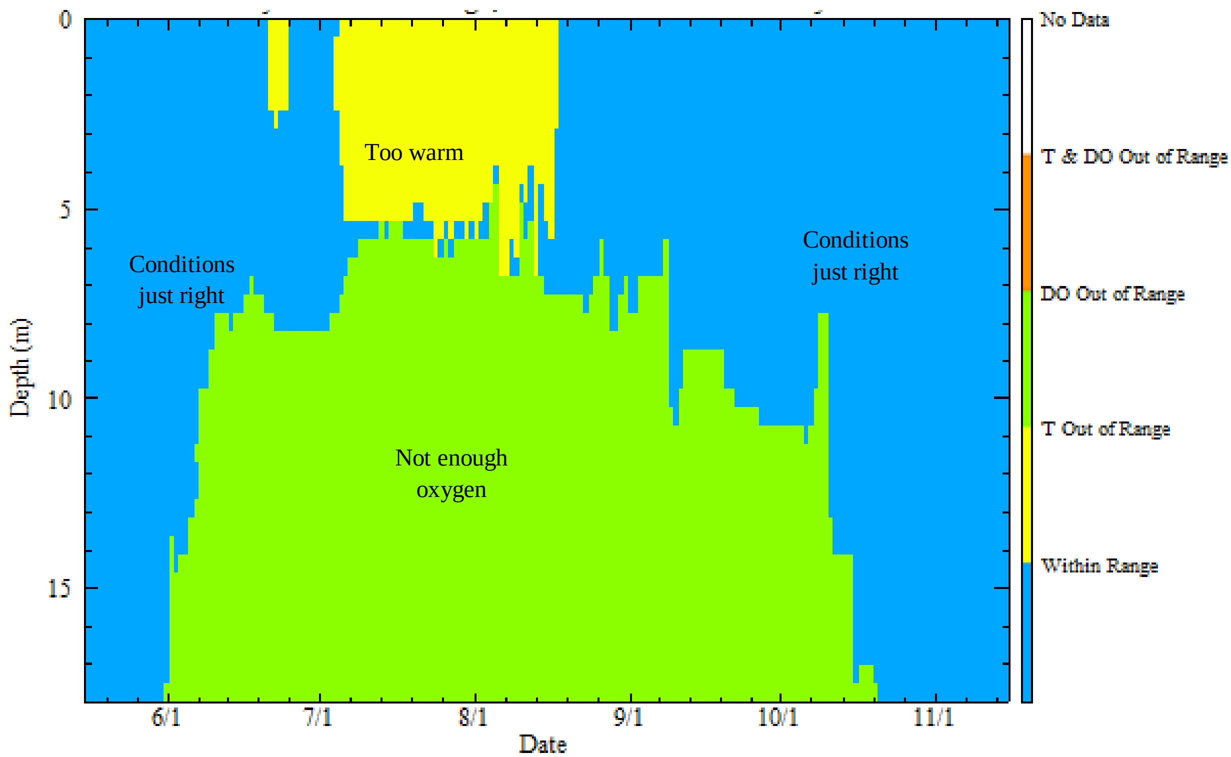
Year	% Avail. Habitat[2]	Total # Days in Range (max 185)[3]	# Consec. Days in Range (max 185)[3]	Year	% Avail. Habitat[2]	Total # Days in Range (max 185)[3]	# Consec. Days in Range (max 185)[3]
2000	33	145	50	**2007**	36	138	65
2001	33	140	72	**2008**	40	124	67
2002	30	95	49	**2009**	47	156	80
2003	31	125	47	**2010**	45	142	71
2004	32	161	67	**2011**	37	131	77
2005	34	115	59	**2012**	40	119	68
2006	39	131	80				

[1] Default DVT criteria: temperature ≤ 22ºC and DO ≥ 6 mg/L between May 15 and November 15.

[2] Assumes entire volume of the lake (May 15 to November 15) is available.

[3] Number of days where temperature and DO are within range in at least a 1 meter vertical section of the lake.

Figure 6-26. Coldwater fish habitat in Onondaga Lake in 2012 and trends in habitat availability 2000–2012.



Year	**% Avail. Habitat[2]**	**Total # Days in Range (max 185)[3]**	**# Consec. Days in Range (max 185)[3]**	**Year**	**% Avail. Habitat[2]**	**Total # Days in Range (max 185)[3]**	**# Consec. Days in Range (max 185)[3]**
2000	46	185	185	**2007**	49	184	102
2001	46	185	185	**2008**	53	185	185
2002	40	153	67	**2009**	56	185	185
2003	39	172	87	**2010**	55	180	95
2004	45	185	185	**2011**	46	172	106
2005	43	162	89	**2012**	46	155	94
2006	47	179	101				

[1] Default DVT criteria: temperature ≤ 25ºC and DO ≥ 5 mg/L between May 15 and November 15.

[2] Assumes entire volume of the lake (May 15 to November 15) is available.

[3] Number of days where temperature and DO are within range in at least a 1 meter vertical section of the lake.

Figure 6-27. Coolwater fish habitat in Onondaga Lake in 2012 and trends in habitat availability 2000–2012.

Overall, there has been a general lack of trends in coldwater and coolwater habitat in the past few years, despite the improvement in overall water quality. The summer of 2012 was warm and surface water temperatures within the lake exceeded preferred conditions for both coldwater and coolwater species for a majority of the summer (Figures 6-26, 6-27). In addition, conditions in the metalimnion appeared to be less suitable for both temperature and DO for a longer period of time than has been observed previously (i.e., more orange in figures). If warm summer temperatures continue in the future, it would be expected that favorable conditions for coldwater and coolwater species may become more limiting, unless DO conditions improve in the hypolimnion.

6.5 Integrated Assessment of the Food Web

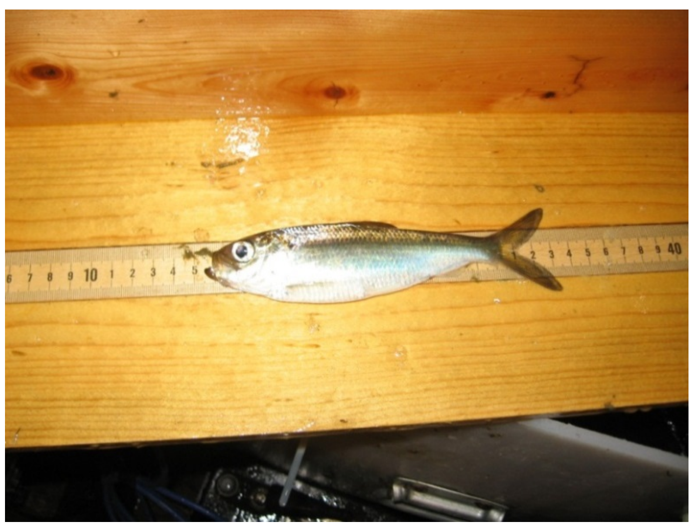
The Onondaga Lake ecosystem is continuing to change, although overall nutrient status and indicators have stabilized over the past few years (i.e., ammonia and phosphorus concentrations have remained relatively consistent since 2006). The reduced phosphorus and ammonia concentrations have resulted in a decrease in algal productivity and virtual elimination of nuisance blue-green algal blooms. Alewife have had several successful year classes which have reduced the large *Daphnia*, resulting in less grazing on phytoplankton thereby shifting Secchi disk transparency values to more typical of eutrophic conditions. A detailed report on alewife abundance in Onondaga Lake in 2012 can be found in Appendix F-5. However, zebra mussel and quagga mussel filtering phytoplankton may have dampened this effect. Increased macrophyte coverage has expanded nearshore habitat for many fish and presumably other aquatic animal species.

6.5.1 Influence of Alewife and Dreissenid Mussels

Understanding Onondaga Lake's recovery is complex and reductions in nutrients do not account for all of the changes observed in recent years. Phytoplankton biomass in the lake has declined as a result of reduced phosphorus loading from Metro, but differences between years are affected by the abundance and efficiency of grazing organisms. The size structure of the zooplankton community is directly affected by alewife. Analysis of the 2012 data indicates alewife abundance is still high and large zooplankton had been virtually eliminated. Water clarity was lower in 2012 compared to 2008 and 2009. Total phosphorus was similar to 2011 and slightly greater than the targeted 20 µg/L, although loading from Metro was unchanged; chlorophyll-*a* was similar to 2011. This pattern is consistent with a cascading effect of alewife on phytoplankton through the elimination of large zooplankton (Carpenter et al. 1985). Dreissenid mussel populations remain high in the littoral zone and may impact algal abundance. These mussels are filter feeders and have a top-down effect on phytoplankton abundance similar to that of the zooplankton. However, dreissenid mussel grazing does not appear to be as important as the effect of alewife predation controlling the larger zooplankton and associated increase in algal abundance.

In years of high alewife abundance, including 2012, fish with pelagic larvae (such as pumpkinseed, bluegill, yellow perch, and white perch) have shown reduced recruitment, which may be due to alewife predation on the larvae. Nesting surveys and the subsequent capture of larvae indicate centrarchids are reproducing in the lake; however, the reduced abundance of pumpkinseed and bluegill young-of-year indicates high mortality between the egg stage and the juvenile stage. Largemouth bass dominated the young-of-year catch; this species defends the nest and young for several weeks, and the young remain in the littoral zone after leaving the nest, potentially providing some protection from predation by alewife and other species.

Alewife are preyed on by larger, fish-eating species such as smallmouth and largemouth bass, northern pike (*Esox lucius*), and walleye (*Sander vitreum*). For smallmouth bass, the availability of alewife as forage in pelagic habitats, as well as the increased macrophyte coverage in the littoral zone (less preferred habitat), may be facilitating a shift to deeper, offshore habitat from shallower, littoral habitat resulting in the lower abundance observed over the past couple years. Smallmouth bass are collected as part of the Honeywell tissue monitoring; deep water gillnet sampling is the most effective method to capture these samples. If an offshore shift has occurred, this would reflect a change in adult smallmouth bass foraging from a littoral-based food web to a pelagic-based food web. A secondary explanation may be that smallmouth bass are moving more throughout the watershed, with the lake outlet and Seneca River providing suitable habitat as well, although there are little data to evaluate this explanation.



Alewife

The proliferation of zebra and quagga mussels in the lake following reductions in ammonia levels may be helping to support the increased abundance of several species by providing an abundant food source. Pumpkinseed, freshwater drum, yellow perch, common carp, lake sturgeon, and round goby feed on mussels and are likely benefitting from the increasing abundance of these mussels. Consumption of mussels by multiple fish species provides a connection between the benthic-based food web and the pelagic-based food web. The increasing complexity of the overall food web in Onondaga Lake is an important sign that the lake is recovering from past environmental perturbations.

6.5.2 Macrophyte Coverage and Implications for Fishery

Macrophyte coverage in Onondaga Lake was the highest recorded with 65 percent of the littoral zone covered. Increased macrophyte coverage presumably has resulted in a substantial increase in production of phytophilous (plant eating) macroinvertebrates in the littoral zone. The increased macrophytes should result in increases in the littoral zone fish species that use these areas for foraging, including largemouth bass, pumpkinseed, yellow perch, and brown bullhead among others. Abundance of largemouth bass, yellow perch, and brown bullhead adults has been increasing the past several years; pumpkinseed abundance increased slightly in 2012 following large declines since 2009. The impact of the increased coverage of macrophytes needs to be more fully considered on the overall trophic dynamics in the lake. Macrophytes provide habitat for zooplankton, aquatic macroinvertebrates, and numerous fish species, as well as stabilizing sediments and maintaining water clarity (Valley et al. 2004).

Largemouth and smallmouth bass together make up one of the most important sportfishery in Onondaga Lake and central New York. Over the past ten years, tournament angling has become increasingly popular, with several large scale bass tournaments held on Onondaga Lake in 2007 and 2008. The increase in largemouth bass may be a result of increased macrophyte coverage over the past several years because largemouth bass habitat is strongly linked to macrophyte cover. Literature sources estimate optimum macrophyte coverage for largemouth bass between 36 percent and 60 percent of the littoral zone (Stuber et al. 1982, Wiley et al. 1987). Based upon these relationships it appears that macrophyte coverage in Onondaga Lake is currently slightly above the ideal range for largemouth bass. How this increase in vegetation may be impacting largemouth bass growth and survival should be evaluated further if macrophyte coverage remains high.

6.5.3 Fish Community Dynamics Since 2005

Overall, there has been an increase in the quantity and quality of habitat available to fish species in Onondaga Lake since 2005. The number of fish species collected from the lake continues to increase, with 38 species documented in 2012. Since 2000, 53 species have been documented in the lake by Onondaga County.

Smallmouth bass

There has been an apparent shift in dominance with yellow perch, largemouth bass, and brown bullhead adults steadily increasing over the past few years, and smallmouth bass declining. This pattern is consistent with the increasing macrophyte coverage, which is not a preferred habitat for smallmouth bass. The limited abundance of young-of-year fish from nesting species is not completely understood, but predation on the larval stage is likely a factor. The increase in yellow perch adults may be attributed to movement into the lake from the Seneca River; largemouth bass currently dominate juvenile recruitment, based on current sampling efforts. In addition, the increased macrophyte coverage of the littoral zone may be leading to less effective sampling of the fish in this area of the lake. While the additional seining event within each strata, as well as the electrofishing event targeting smaller fish, did not result in the collection of more species or individuals; the effectiveness of the sampling and potential limitations due to increased macrophyte coverage cannot be ruled out as a potential factor in understanding recruitment.

The warmwater and coolwater fishery continues to provide plenty of angling opportunities for our community. The improved water quality, increased plant coverage, changing plankton community, and the invasion by dreissenid mussels have altered the trophic dynamics within the lake. The fish community is still adapting to the various changes and will need to be monitored to more fully understand the trophic structure of the lake and how this may affect sportfishing opportunities in the future.

This page intentionally left blank

Section 7. Water Quality in the Three Rivers System

The Three Rivers System consists of the Seneca, Oneida, and Oswego rivers, which connect Cross Lake, Onondaga Lake, and Oneida Lake with Lake Ontario (Figure 7-1). The Seneca River, which drains the Finger Lakes region and Onondaga Lake, joins the Oneida River, which drains Oneida Lake, to form the Oswego River, the second largest inflow to Lake Ontario. The rivers are used for recreation, navigation, and waste discharge. They receive nutrient inputs from agricultural activities and wastewater treatment plants (WWTP), including four operated by Onondaga County (Baldwinsville-Seneca Knolls, Brewerton, Oak Orchard, Wetzel Road). The Metro WWTP effluent enters Onondaga Lake, which flows to Seneca River via its outlet (Figure 7-1). The Seneca River is listed as an impaired water body by NYSDEC because of low dissolved oxygen concentrations during summer low flow periods. The metabolism of invasive dreissenid mussels (zebra and quagga mussels) contributes importantly to this oxygen depletion. Physical alterations of the rivers to support navigation, including locks and dams, channelization, and maintenance of a minimum depth of 4.5 meters have eliminated much of the natural turbulence and associated reaeration capacity, further compromising oxygen resources. Water quality conditions of the Three Rivers System are of concern to protect the multiple uses of the rivers and downstream Lake Ontario.

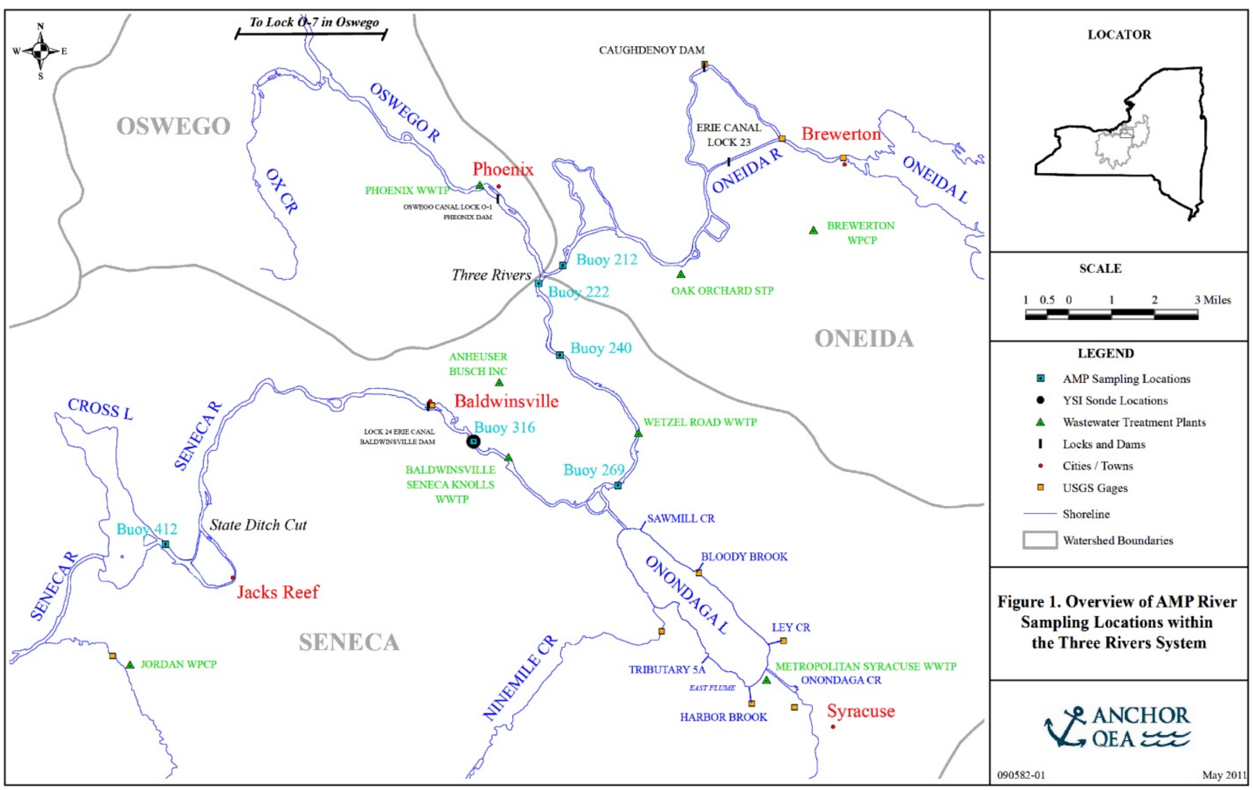


Figure 7-1. The Three Rivers System, with AMP sampling locations and wastewater treatment plants identified.

The Three Rivers monitoring program was developed and implemented to support the detailed mathematical modeling study of the system. These modeling efforts were conducted by Anchor QEA and finalized in May 2012 with the issuance of the *Final Phase 3 Model Validation and Application Report, Onondaga Lake Water Quality Modeling Project*. In a memorandum dated February 26, 2013, Anchor QEA recommended discontinuing the annual diurnal monitoring at Buoy 316 within the Seneca River. Annual low-flow surveys are sufficient to: (1) provide the data needed to monitor the water quality trends within the Three Rivers System; and (2) update the modeling framework in the future, if deemed necessary.

On July 19, 2012 a synoptic survey of water quality conditions in the Three Rivers System was conducted by OCDWEP. During this survey, which targeted critical low flow conditions, samples were collected from 1 meter below the water surface and 1 meter above the sediments at six locations (Buoys #212, 222, 240, 269, 316, 412; Figure 7-1) and analyzed for a suite of water quality parameters, including forms of phosphorus, nitrogen and carbon, chlorophyll-*a*, dissolved oxygen (DO), and turbidity. In addition, measurements of temperature, DO, pH, and salinity were made at 15-minute intervals using a YSI sonde deployed at Buoy 316 (upstream of the Baldwinsville-Seneca Knolls WWTP).

Flow rates in the Seneca and Oneida Rivers were near or below long-term median flows for much of 2012 (Figure 7-2). Median flows for Seneca River at Baldwinsville are based on 35 years of measurements (1978–2012) and median flows for Oneida River at Euclid are based on 17 years of measurements (1996–2012). Flows were particularly low in March, April, and November. Relative to historic conditions, flows in the Seneca River were elevated in January and February. The Oneida River experienced elevated flows during May and early June. The summer average (July–September) flow in the Seneca River was 735 cubic feet per second (cfs), less than one-half the long-term summer average of 1,634 cfs. Summer average flow in the Oneida River was 356 cfs in 2012, 72% lower than the long-term summer average of 1,261 cfs. The lowest 7-day average flow that occurs on average once every 10 years (7Q10) is a commonly used statistic for identifying critical low flow conditions in rivers and streams. Flows in the Seneca River were below the 7Q10 of 374 cfs on 10 days during the summer of 2012. Only on July 1 did flow in the Oneida River fall below the 7Q10 of 237 cfs. Flows during the July 19 survey were 948 cfs for the Seneca River and 357 cfs for the Oneida River, both above critical low flow conditions.

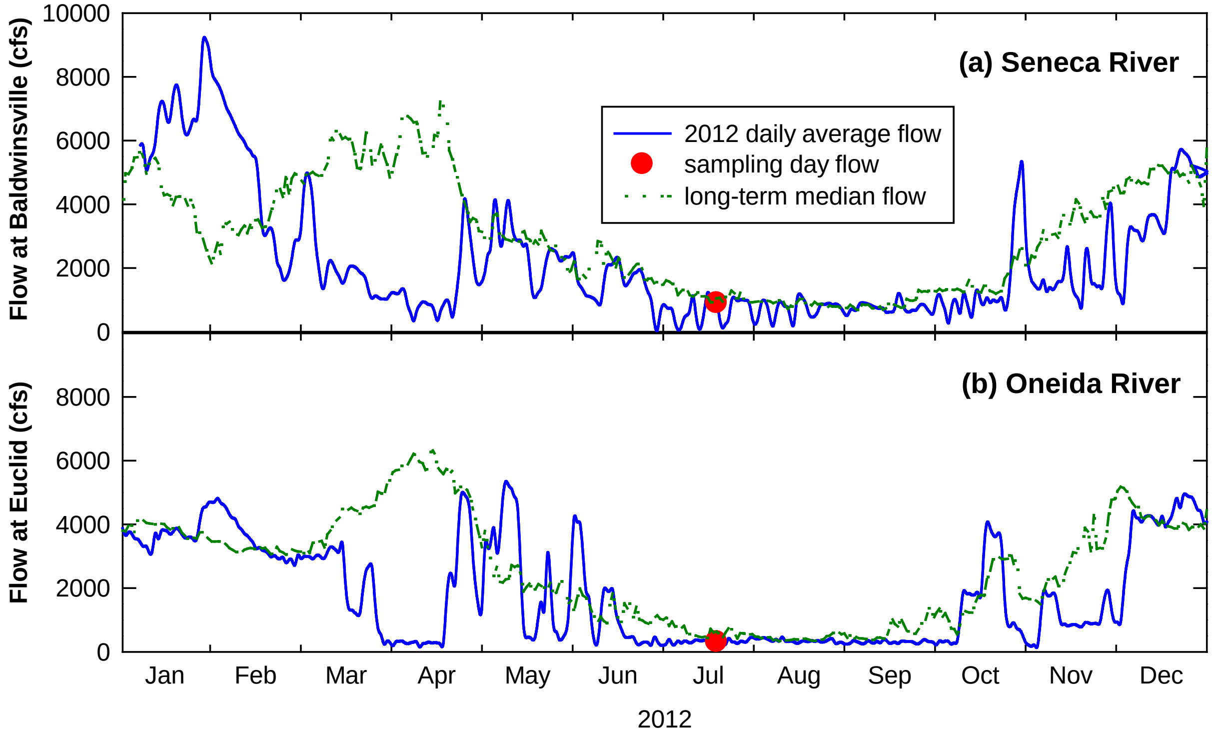


Figure 7-2. Daily average flows for 2012 compared to long-term median flows: (a) Seneca River at Baldwinsville and (b) Oneida River at Euclid.

The outlet of Onondaga Lake and nearby portions of the Seneca River experience density stratification, particularly during periods when flow in the river is low. This phenomenon is unusual for rivers and is caused by the more saline and therefore denser waters of the lake flowing beneath the comparatively less dense waters of the river. During the July 19, 2012 survey, conspicuous vertical gradients in the Seneca River were apparent for various water quality parameters, including temperature, specific conductance, dissolved oxygen, and nitrate (Figure 7-3, Figure 7-4). A number of factors likely contributed to these observations, including influx of Onondaga Lake water to the river, limited vertical mixing, and possibly inflow of groundwater downstream of the lake outlet. Distinct vertical gradients are not observed during high flow conditions when levels of turbulence and vertical mixing are sufficient to overcome stratification.

Zebra mussels were first observed in the Seneca River in 1991, and dense populations had developed by 1993. These invasive, filter-feeding bivalves have had a considerable impact on water quality in the Three Rivers System since their introduction in the early 1990s. Water quality changes have been particularly well-documented for the Seneca River near Baldwinsville

(Effler et al. 2004). The dreissenid mussel invasion has converted the Seneca River at Baldwinsville from a low clarity, phytoplankton rich, nutrient depleted system, with nearly saturated oxygen concentrations, to a system with increased clarity, low phytoplankton levels, highly enriched in dissolved, nutrients, with substantially undersaturated oxygen concentrations. These changes reflect at least three features of the metabolism of the invader, including respiration (decreases in dissolved oxygen and pH), filter feeding (decreases in chlorophyll-*a* and increases in Secchi disk), and excretion (increases in soluble reactive phosphorus and ammonia). Increased water clarity has led to a major expansion in macrophyte coverage in many areas of the Three Rivers System. Conspicuous signatures of dreissenid mussels were observed in the 2012 survey data, including decreases in turbidity dissolved oxygen, and chlorophyll-*a*, and increases in ammonia and soluble reactive phosphorus concentrations from Cross Lake to the Onondaga Lake outlet (Figure 7-3, Figure 7-4, Figure 7-5).

OCDWEP Technicians Monitoring the Seneca River

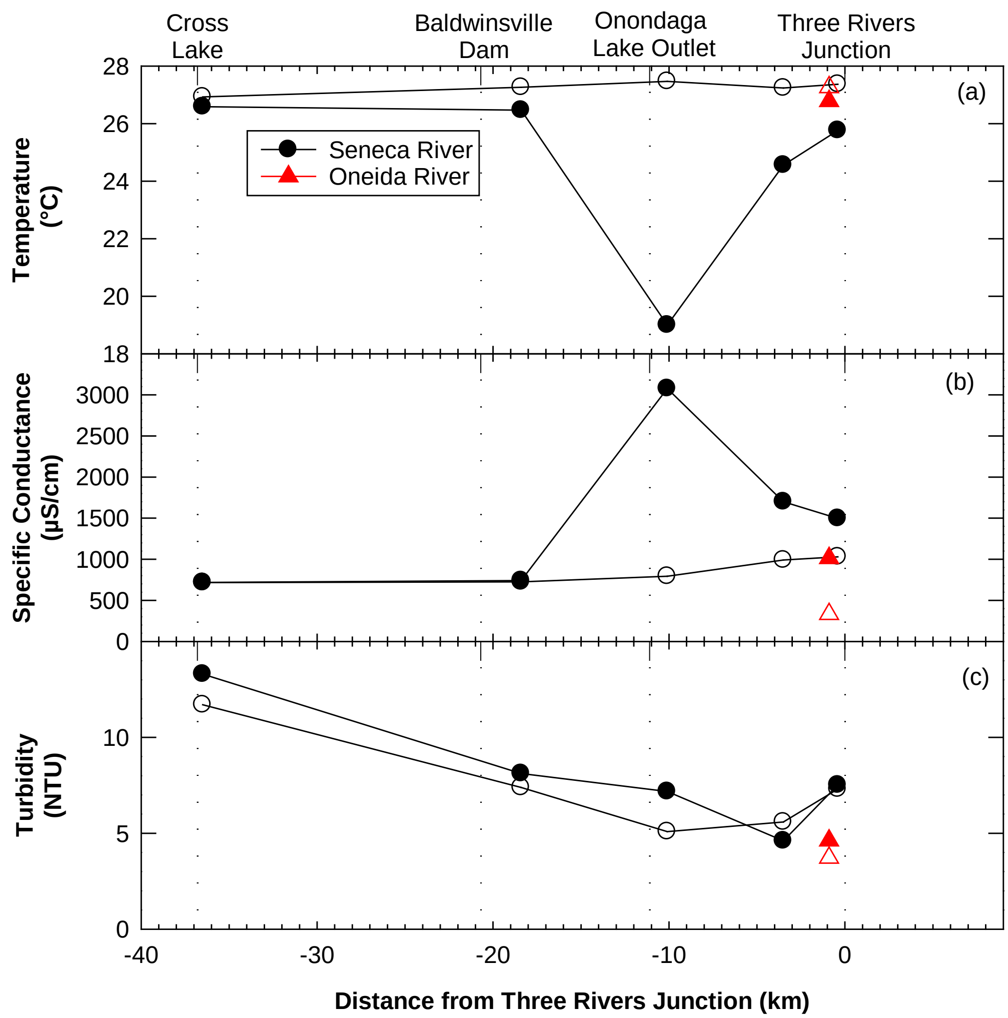


Figure 7-3. Longitudinal profiles of water quality parameters in the Three Rivers System on 7/19/12: (a) temperature, (b) specific conductance, and (c) turbidity.

Note: Surface samples are represented by open symbols and bottom samples are represented by closed symbols. One sample collected at mid-depth for buoy 269 is represented by a filled circle with cross hairs.

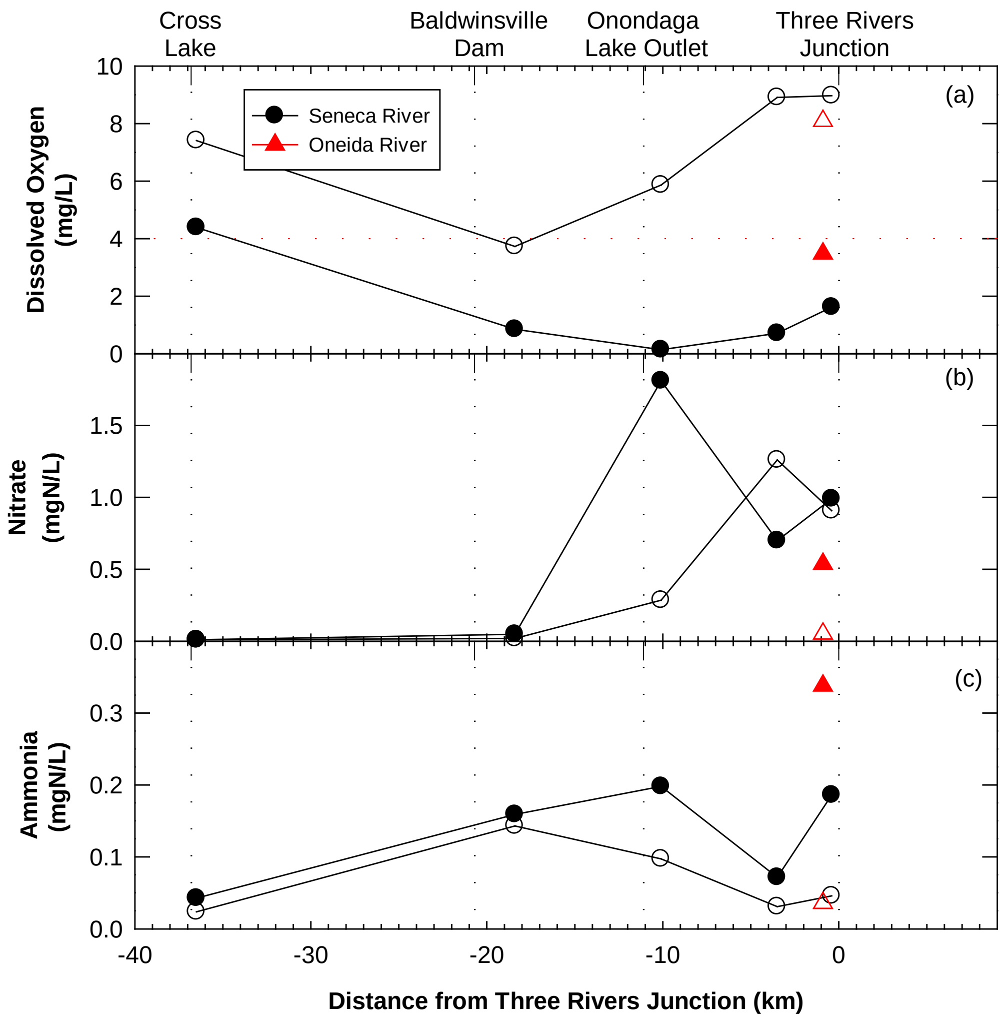


Figure 7-4. Longitudinal profiles of water quality parameters in the Three Rivers System on 7/19/12: (a) dissolved oxygen, (b) nitrate, and (c) ammonia.

Note: Surface samples are represented by open symbols and bottom samples are represented by closed symbols. One sample collected at mid-depth for buoy 269 is represented by a filled circle with cross hairs. Red dashed line on panel (a) represents the NYS instantaneous DO standard.

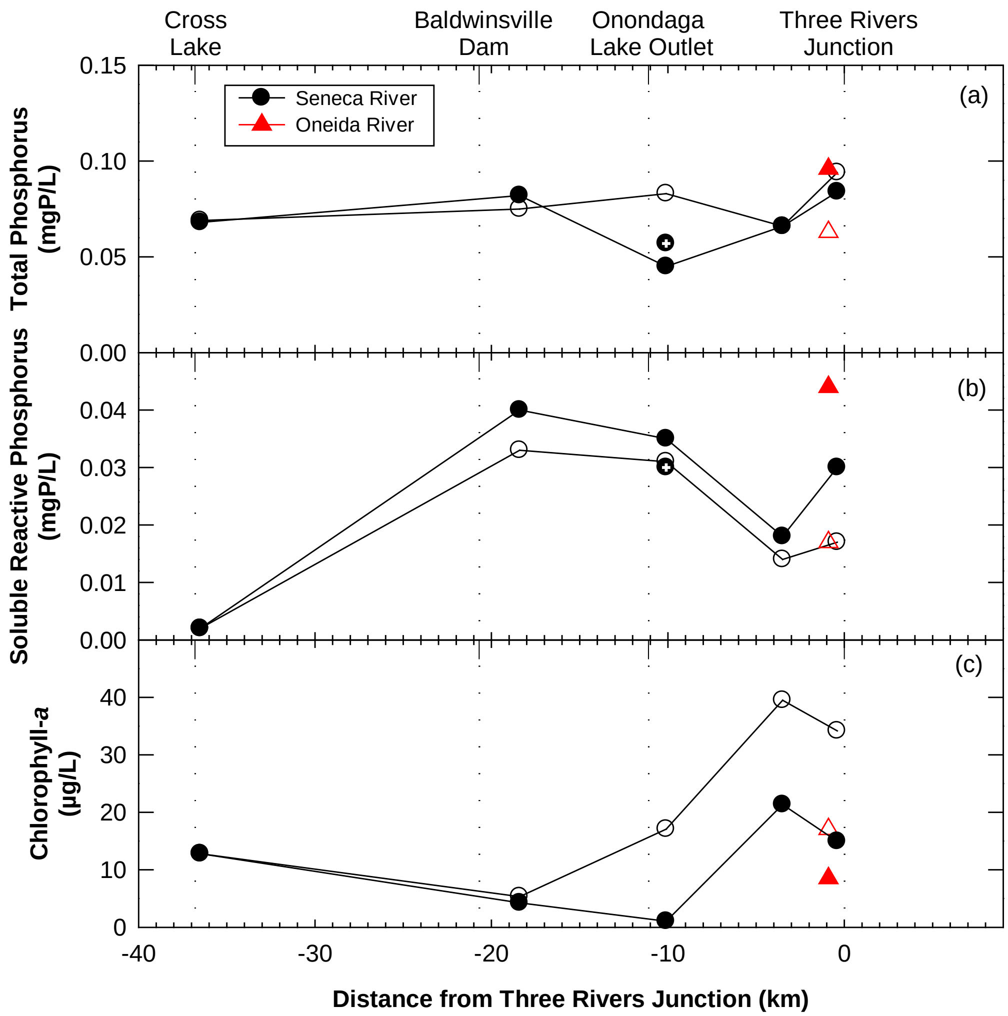


Figure 7-5. Longitudinal profiles of water quality parameters in the Three Rivers System on 7/19/12: (a) total phosphorus, (b) soluble reactive phosphorus, and (c) chlorophyll-*a*.

Note: Surface samples are represented by open symbols and bottom samples are represented by closed symbols. One sample collected at mid-depth for buoy 269 is represented by a filled circle with cross hairs.

Contraventions of the NYSDEC instantaneous minimum dissolved oxygen standard of 4 mg/L were documented at all six locations monitored during the July 19 survey (Table 7-1). At five of the six locations dissolved oxygen concentrations were extremely low (0.1-0.3 mg/L) in the lower portion of the water column, suggesting widespread anoxic conditions. Only at Buoy #316 did dissolved oxygen concentrations less than 4 mg/L extend into the upper portion of the water column. There were no documented exceedances of the ambient water quality standards for nitrite or ammonia during the 2012 field program.

Table 7-1. Summary of compliance with the ambient water quality standard for dissolved oxygen in the Three Rivers System on 7/19/2012.

Parameter	Location	Depths Out of Compliance (m)	Values Out of Compliance (mg/L)
Dissolved Oxygen (Instantaneous Compliance Criteria = 4 mg/L)	Buoy #412	5.5-6.0	0.1-2.7
	Buoy #316	0.0-6.0	0.2-3.8
	Buoy #269	6.5-9.0	0.2-1.3
	Buoy #240	4.0-6.0	0.2-2.2
	Buoy #222	3.5-5.5	1.5-1.8
	Buoy #212	4.0-5.0	0.3-3.5

High frequency measurements of dissolved oxygen made during the June to November period of 2012 provide information on the frequency and duration of low dissolved oxygen conditions in the Seneca River at Buoy 316, downstream of Baldwinsville (Figure 7-6). Contravention of both minimum dissolved oxygen standards (less than 5 mg/L as a daily average and less than 4 mg/L for instantaneous measurements) were documented at this location (Table 7-2). Based on measurements made 1 meter above the bottom, dissolved oxygen concentrations less than the 5 mg/L standard occurred on 42% (59 of 140) of the days for which measurements were available. The 4 mg/L standard was contravened on 35% (49 of 140) of the days in the monitoring period. Contraventions of the dissolved oxygen standards were less frequent in the upper portion of the water column (Figure 7-6, Table 7-2), which is further from the major sink for dissolved oxygen (dreissenid mussels) and closer to the primary source (the atmosphere). In 2011, the frequency of contravention of the 5 mg/L and 4 mg/L standards at Buoy #316 was 17% and 8%, respectively. The apparent worsening of dissolved oxygen conditions in 2012 was likely a result of much lower summertime flows in 2012 (average = 735 cfs) compared to 2011 (average = 2,528 cfs).

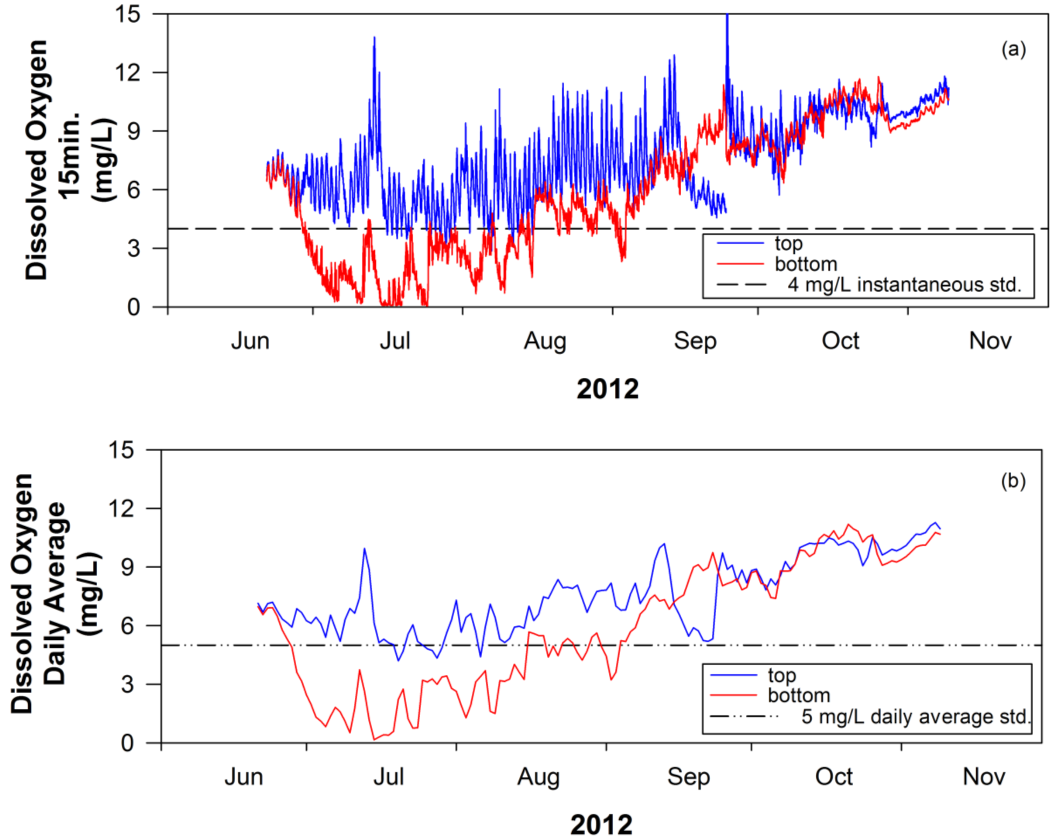


Figure 7-6. Dissolved oxygen patterns in the Seneca River (Buoy 316) and comparisons to instantaneous and daily average water quality standards: (a) high frequency (15 min.) measurements, and (b) daily average values.

Table 7-2. Summary of 15-minute dissolved oxygen (DO) concentrations measured by YSI sondes deployed at Buoy #316 in 2012.

Sonde Location	Deployment Dates[1]		Operation (days)[2]	DO < 5 mg/L (days)[3]	DO < 4 mg/L (days)[4]
	Start	End			
Buoy 316 (TOP)	6/21/12	11/9/12	140	7	0
Buoy 316 (Bottom)	6/21/12	11/9/12	140	59	49

Notes:
[1] only full days included in analysis.
[2] number of days when DO measurements were made.
[3] reported value represents number of days in which the daily average calculated from the 15-minute data was below the 5 mg/L standard.
[4] reported value represents the number of days in which one or more of the 15-minute readings was below the 4 mg/L standard.

Onondaga Lake Outlet

Section 8. Emerging Issues and Recommendations

The AMP continues to evolve in response to new information and emerging issues affecting Onondaga Lake, its tributaries, and the Three Rivers System. Each year, the Onondaga County Department of Water Environment Protection (OCDWEP), New York State Department of Environmental Conservation (NYSDEC), Atlantic States Legal Foundation (ASLF), and members of Onondaga Lake Technical Advisory Committee (OLTAC) review the monitoring program design and recommend modifications in light of changing objectives. In recent years there has been a shift toward greater focus on water quality conditions in the Onondaga Lake tributaries. This shift is appropriate given the great progress that has been made with respect to lake water quality and the remaining issues in the streams. The County seeks to balance additional monitoring of the tributaries with a reduction in ancillary monitoring that has not contributed significantly to our understanding of the Onondaga Lake ecosystem or its response to environmental improvements.

On February 28, 2013, OCDWEP submitted the 2013 Annual AMP sampling work plan to NYSDEC. A number of revisions were proposed for the Onondaga Lake, Tributary, and River sampling programs. With the completion of advanced wastewater treatment at Metro, which became operational in 2005, several notable water quality improvements have been realized in the lake. In addition several major milestones have recently been achieved, including successful completion of the Onondaga Lake Water Quality Modeling Project related efforts in 2012 and the NYSDEC's issuance of the Final Onondaga Lake TMDL for Phosphorus, dated May 2012. The proposed scope of the 2013 AMP reflects these important accomplishments.

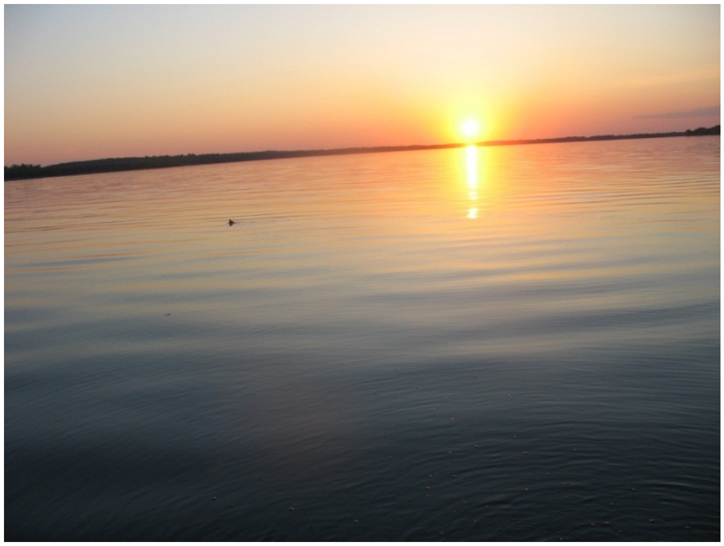
A detailed re-evaluation of the sampling program was undertaken, based on defining program objectives in relation to the collection of meaningful data. This evaluation was completed taking into consideration future data collection needs, effort to reduce data redundancy and completion of additional data analysis used in supporting these modifications. An AMP technical workgroup was convened on February 5, 2013, with participation by several members of OLTAC, who have extensive knowledge of the AMP. Based on input and feedback received during this session from members of the workgroup relating to sampling program locations, parameters, protocol and depths, modifications for 2013 were proposed and justifications provided. Program modifications implemented in 2013 included:

- Discontinuation of sampling at Allied East Flume – Manhole #015, which contributes ~0.2% of the inflow to Onondaga Lake.
- Replaced the depth-integrated sampling protocol with grab samples because there are no demonstrable benefits from this onerous sampling technique.
- Discontinued measurements of arsenic, cadmium, chromium, copper, nickel, lead, and zinc in the tributaries because long-term, consistent compliance with ambient

water quality standards has been established. Added analysis of dissolved total mercury.

- Revised sampling program at North Deep to comply with the phosphorus TMDL follow-up monitoring requirements and discontinued other parameters at this site.
- Replaced composite sampling of the upper mixed layer (UML) and lower water layer (LWL) with discrete samples collected from 3 meter and 15 meter depths.
- Discontinued measurements of arsenic, cadmium, chromium, copper, nickel, lead, and zinc in Onondaga Lake because long-term, consistent compliance with ambient water quality standards has been established. Added analysis of dissolved total mercury.
- Utilized data from the Honeywell funded monitoring buoy at South Deep and discontinued deployment of the Onondaga County buoy.
- Discontinued LiCor Underwater Illumination profiles in the lake and river. Secchi disk transparency is used to assess compliance, trophic status, aesthetics, and use attainment.
- Discontinued special Fall Turnover sampling because dissolved oxygen concentrations during fall have met New York State ambient water quality standards consistently for more than a decade.

These modifications support a focused sampling program that will produce the data needed to continue assessment of compliance with AWQS, track progress toward use attainment, and support future management decisions. The program will continue to incorporate flexibility and allocate resources in response to assessing additional chemicals or potential sources as needed during the course of the year. It is OCDWEP’s goal to ensure that all elements of the AMP provide meaningful data in a scientifically defensible and cost-effective manner.



Baby Duck and Sunset on Onondaga Lake

Section 9. Literature Cited

Brooking, T.E., J.R. Jackson, L.G. Rudstam, and N.D. McBride. 2012. Fisheries surveys of Canadarago Lake, New York. New York State Department of Environmental Conservation, Albany, NY.

Callinan, C.W. 2001. Water quality study of the Finger Lakes. New York State Department of Environmental Conservation.

Canadarago Lake, New York. New York State Department of Environmental Conservation, Albany, NY.

Carpenter, S. R., J. F. Kitchell, and J. R. Hodgson. 1985. Cascading trophic interactions and lake productivity. BioScience 35: 634-639.

Cooke, G. D., E. B. Welch, S. A. Peterson and S. A. Nichols. 2005. Restoration and management of lakes and reservoirs. 3rd Edition. CRC Press, Boca Raton, FL. 591 p.

CR Environmental, Inc. 2007. Onondaga Lake Phase 1 Pre-design Investigation Geophysical Survey Report. Prepared for Parsons, Syracuse, NY. East Falmouth, MA. 167 p.

Edwards, E.A., G. Gebhart, and O.E. Maughan. 1983. Habitat suitability information: Smallmouth bass. U.S. Dept. Int. Fish. Wildl. Serv. FWS/OBS-82/10.36.

Effler, S. W., M. T. Auer, F. Peng, M. G. Perkins, S. M. O'Donnell, A. R. Prestigiacomo, D. A. Matthews, P. A. DePetro, R. S. Lambert and N. M. Minott. 2012. Factors diminishing the effectiveness of phosphorus loading from municipal waste effluent: Critical information for TMDL analyses. Water Environment Research 84(3):254-264.

Effler, S. W.; O'Donnell, S. M.; Matthews, D. A.; Matthews, C. M.; O'Donnell, D. M.; Auer, M. T.; Owens, E. M. (2002). Limnological and Loading Information and a Phosphorus Total Maximum Daily Load Analysis for Onondaga Lake. Lake and Reservoir Management 18:87-108.

Effler, S. W., R. K. Gelda, M. G. Perkins, F. Peng, N. G. Hairston and C.M. Kearns. 2008. Patterns and modeling of the long-term optics record of Onondaga Lake, New York. Fundamental and Applied Limnology 172:217-237.

Effler, S. W., Matthews, D. A., Matthews (Brooks), C. M., Perkins, M. G., Siegfried, C. A. & Hassett, J. M., 2004: Water quality impacts and indicators of metabolic activity of the zebra mussel invasion of the Seneca River. Journal of the American Water Resources Association 40:737-754.

Gandino, C. 1996. Community structure and population characteristics of fishes in a recovering New York lake. M.S. thesis SUNY-ESF. Syracuse, NY.

Helsel, D.R. and R. M. Hirsch (2002). Statistical Methods in Water Resources, Techniques of Water Resources Investigations, Book 4, Chapter A3. U.S. Geological Survey. 522 pages.

Jackson, JR, LG Rudstam, TE Brooking, SD Krueger, KT Holeck, C Hotaling, and JL Forney. 2012. The Fisheries and Limnology of Oneida Lake 2000-2011. New York State Department of Environmental Conservation, Albany, NY.

Kishbaugh, S.A. 2009. NY State Citizens Statewide Lake Assessment Program (CSLAP): Interpretive Summary: Cazenovia Lake 2008.

Krieger, D. A., J. W. Terrell, and P. C. Nelson. 1983. Habitat suitability information: Yellow perch. U.S. Fish Wildl. Servo FWS/OBS-83/10.55. 37 pp.

Matthews, D. A., D. B. Babcock, J. G. Nolan, A. R. Prestigiacomo, S. W. Effler, C. T. Driscoll, S. G. Todorova and K. M. Kuhr. 2013. Whole-lake nitrate addition for control of methylmercury in mercury-contaminated Onondaga Lake, NY. Environmental Research 125: 52-60.

Rudstam, L. G. 2013. Limnological data and depth profile from Oneida Lake, New York, 1975-2011. Knowledge Network for Biocomplexity.Available: http://knb.ecoinformatics.org/knb/metacat/kgordon.35.49/default.

Siniscal, A. C. 2009. Characterization of the fish community of a recovering ecosystem, Onondaga Lake, New York. MS Thesis. State University of New York College of Environmental Science and Forestry, Syracuse, N.Y. 108 pp.

Smith, V. H. 1983. Low N to P favor dominance by blue-green algae in lake phytoplankton. Science 225:669-671.

Spada, M. E., N. H. Ringler, S. W. Effler and D. A. Matthews. 2002. Invasion of Onondaga Lake, New York, by the zebra mussel (Dreissena polymorpha) following reductions in N pollution. Journal of the North American Benthological Society 21(4):634-650.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: Largemouth bass. U.S. Dept. of Interior, Fish and Wildl. Service. FWS/OBS-82/10.16.

Valley, R.D., T.K. Cross, and P. Radomski. 2004. The role of submersed aquatic vegetation as habitat for fish in Minnesota lakes, including the implications of non-native plant invasion and their management. Minnesota Department of Natural Resources Special Publication 160. 25 p.

Walker, W.W. (1998). A Statistical Framework for the Onondaga Lake Ambient Monitoring Program. Prepared for Onondaga County Department of Water Environment Protection. July 13, 1998. 14 pages.
http://wwwalker.net/onondaga/Statistical%20Framework%20July%2098.PDF
Other statistical framework reports: http://www.wwwalker.net/onondaga

Walker, W.W. and J.D. Walker (2011). Trends in Onondaga Lake Nearshore Monitoring Data Onondaga Lake Ambient Monitoring Program – 2011 Report. Prepared for Ecologic, LLC and Onondaga County Department of Water Environment Protection. July 2011. 19 pages. http://wwwalker.net/onondaga/olamp_nearshore_trends_www_draft_070611.pdf

Wang, R. W., L. G. Rudstam, T. E. Brooking, D. J. Snyder, M. A. Arrigo, and E. L. Mills. 2010. Food web effects and the disappearance of the spring clear water phase in Onondaga Lake following nutrient loading reductions. Lake and Reservoir Management 26:169-177.

Wetzel R. G. 2001. Limnology, Lake and River Ecosystems. Third Edition. Academic Press NY.

Wiley, M.J., P.P. Tazik, and S.T. Sobaski. 1987. Controlling aquatic vegetation with triploid grass carp. Circular 57. Ill. Nat. History Surv., Champaign, IL

List of Acronyms

AMP	Ambient Monitoring Program
ACJ	Amended Consent Judgment
ASLF	Atlantic States Legal Foundation
AWQS	Ambient Water Quality Standards
BAF	Biological Aerated Filter
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CBUD	Continuous Backflow Upwelling Dual Filters (Phosphorus Filtration Stage III)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFU	Colony Forming Units
CPUE	Catch Per Unit Effort
CSO	Combined Sewer Overflow
DAIP	Data Analysis and Interpretation Plan
DO	Dissolved Oxygen
DVT	Data Visualization Tool
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HRFS	High Rate Flocculated Settling
ISD	Impact Source Determination
METRO	Metropolitan Syracuse Wastewater Treatment Plant
MRL	Method Reporting Limit

N	Nitrogen
NYCRR	Official Compilation of the Rules and Regulations of the State of New York
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priority List
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OCDWEP	Onondaga County Department of Water Environment Protection
OLP	Onondaga Lake Partnership
OLTAC	Onondaga Lake Technical Advisory Committee
OLWQM	Onondaga Lake Water Quality Model
PWL	Priority Waterbodies List
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RSE	Relative Standard Error
SPDES	State Pollution Discharge Elimination System
SRP	Soluble Reactive Phosphorus
SSO	Sanitary Sewer Overflow
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TRWQM	Three Rivers Water Quality Model
TSS	Total Suspended Solids
UFI	Upstate Freshwater Institute
USGS	United States Geological Survey

GLOSSARY OF TERMS

Term	Abbreviation	Definition
303(d List)	--	the list of impaired and threatened waters (stream/river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval every two years on even-numbered years. The states identify all waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards, and establish priorities for development of TMDLs based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors (40C.F.R. §130.7(b)(4)).
Ambient Monitoring Program	**AMP**	Onondaga County's comprehensive program to evaluate the quality of the waterways [in Onondaga County] and track changes brought about by the improvements to the wastewater collection and treatment infrastructure and reductions in watershed sources of nutrients.
Amended Consent Judgment	**ACJ**	A legal finding or ruling. In this case, in 1998, an Amended Consent Judgment (ACJ) between Onondaga County, New York State and Atlantic States Legal Foundation was signed to resolve a lawsuit filed against Onondaga County for violations of the Clean Water Act. The lawsuit alleged that discharges from the Metropolitan Syracuse Wastewater Treatment Plant (Metro) and overflows from the combined sewer system (CSOs) precluded Onondaga Lake from meeting its designated best use. The ACJ obligates the County to undertake a phased program of wastewater collection and treatment improvements that will extend though the year 2012, monitor water quality response, and report annually on progress towards compliance.

Term	Abbreviation	Definition
Ambient Water Quality Standard	**AWQ**	Enforceable limits on the concentration of pollutants designed to protect a designated use of the waterbody. Standards are promulgated by NY State and approved by the U.S. Environmental Protection Agency.
ammonia-N	**NH_3-N**	An important form of nitrogen that is the end product of the decomposition of organic material; it is used by phytoplankton for growth.
assimilative capacity	**--**	The capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects to its designated use (e.g., without damage to aquatic life or humans who consume the water).
AUTOFLUX	**AUTOFLUX**	A customized software package developed by Dr. William Walker and used by Onondaga County WEP staff to estimate loading of water quality constituents (nutrients) to Onondaga Lake. The program uses continuous flow data and less frequent (often biweekly) tributary water quality samples to estimate annual loading rates.
biochemical oxygen demand 5 day	**BOD_5**	The amount of oxygen a water sample's chemical and biological composition will consume over a 5 day incubation period. The higher the BOD_5, the more oxygen used by the sample. Generally, the higher BOD_5 means lower water quality
Biological Assessment Profile	**BAP**	An index or score of overall impact to the macroinvertebrate (aquatic insects) community of a water body. It is comprised of seven benthic macroinvertebrate community metrics used for water quality assessment. The lower the score, the more impacted the community.

Term	Abbreviation	Definition
Biological Aerated Filter	**BAF**	A combination standard filtration with biological treatment of wastewater. BAF usually includes a reactor filled with a filter media either in suspension or supported by a gravel layer. The dual purpose of this media is to support highly active microbes which remove dissolved nutrients from wastewater and to filter particulates.
Best Management Practices	**BMPs**	A combined group of activities designed minimize the amount of pollution that reaches a body of water. BMPs can be applied to agricultural, urban, and/or industrial areas as preventative measures to protect water quality.
bicarbonate	**HCO_3^-**	Serves a crucial biochemical role in the physiological pH buffering water in natural systems and thereby minimize the disturbance of biological activities in these systems
calcium	**Ca**	A nutrient required by aquatic plants and some algae for proper metabolism and growth. Calcium, normally as calcium carbonate, is also a common contributor to water hardness.
chloride	**Cl**	A halogen element usually associated with metallic elements in the form of salts.
chlorophyll-*a*	**Chl**	A pigment used by plants and algae for photosynthesis. Chlorophyll concentration in lakes is used as a surrogate for estimating the amount of algae present.
combined sewer overflows	**CSOs**	A discharge of untreated sewage and stormwater to a water body; CSOs occur when the capacity of a combined storm/sanitary sewer system is exceeded by storm runoff.
conductivity	**--**	The measure of the ability of water to conduct electricity
cultural eutrophication	**--**	An increase in a water body's biological production due to human activities. Cultural eutrophication usually results in negative water quality impacts such as loss of clarity, increased algal blooms, decreased oxygen resources, and

Term	Abbreviation	Definition
		accumulation of reduced species
Data Analysis and Interpretation Plan (DAIP)	**DAIP**	A document created to guide managers and advisors on how numerous environmental and biological measurements, specific to Onondaga Lake, will be analyzed and interpreted in order to assess biological and water quality status and changes from remediation effort.
dissolved oxygen	**DO**	Dissolved form of oxygen, (dissolved in water) an indicator of the quality of water to support fish and aquatic organisms.
ecosystem	**--**	An interrelated and interdependent community of plants, animals, and the physical environment in which they live
Environmental Protection Agency	**EPA**	The federal agency responsible for the conservation, improvement, and protection of natural resources within the US.
eutrophic	**--**	Systems with high levels of productivity
fecal coliform bacteria	**FC**	Microscopic single-celled organisms found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation or for consumption. Their presence indicates contamination by the wastes of warm-blooded animals and the possible presence of pathogenic (disease producing) organisms.
frustules	**--**	Silica-rich external cell walls of diatoms.
guidance value	**--**	Best professional judgment of the maximum concentration of certain pollutants that will protect a designated use.
High-Rate Flocculated Settling	**HRFS or Actiflo®,**	An advanced process used in the treatment of municipal wastewater. Actiflo™ is a compact process that operates with microsand (Actisand™) as a seed for floc formation. Actisand™ provides surface area that enhances flocculation and also acts as a ballast or weight to aid a rapid settlement.

Term	Abbreviation	Definition
Hilsenhoff Biological Index	**HBI**	An index that uses species-defined pollution tolerance levels to assess the overall tolerance level of a community of organisms, and is an indicator of water quality.
hypolimnion	**--**	Deep, cold waters of a stratified lake; portion of the lake volume that remains isolated from atmospheric exchange during periods of thermal stratification
hypoxia	**--**	Low dissolved oxygen conditions of a water body which is detrimental to aerobic organisms.
indicator bacteria	**--**	Bacteria used to indicate the potential presence of pathogenic (disease-causing) microorganisms in water (see also fecal coliform bacteria).
interrelatedness	**--**	The degree to which organisms in an ecosystem interact and are influenced by other organisms. Pathways of interaction between species in an ecosystem
littoral zone	**--**	Shallow water zone at the edges of lakes, where light reaches the sediment surface
magnesium	**Mg**	A metallic element required by algae for the production of chlorophyll.
metrics	**--**	Quantifiable physical, chemical and/or biological attributes of an ecosystem that responds to human disturbances; also, measurable attributes of the ecosystem that indicate whether a desired state has been achieved. Good metrics are cost-effective to measure, associated with low uncertainty, relevant to stakeholders and sensitive to anticipated changes.
mercury	**Hg**	A trace metal element that is toxic to aquatic life and humans.
mesotrophic	**--**	Systems with mid-levels of productivity; between eutrophic and oligotrophic
Metropolitan Syracuse Wastewater Treatment Plant	**Metro**	The wastewater treatment plant that treats the municipal waste from the City of Syracuse and large portions of Onondaga County, located in Syracuse, NY near Onondaga Lake.

Term	Abbreviation	Definition
New York State Department of Environmental Conservation	**NYSDEC**	The state agency responsible for the conservation, improvement, and protection of natural resources within the state of New York.
New York State Department of Health	**NYSDOH**	
nanograms per liter	**ng/L**	A concentration unit. One billionth of a gram per liter or 10^{-9} g per liter
nitrate-N	**NO_3-N**	A form of nitrogen used by phytoplankton for growth; the end product of nitrification. In addition, the final stages of wastewater treatment at Metro produces large quantities of nitrate-N that is discharged to Onondaga Lake.
nitrite-N	**NO_2-N**	A form of nitrogen formed in the intermediate step of nitrification. Accumulation of nitrite-N can be toxic to aquatic organisms.
nitrogen	**N**	A common element required by algae for growth. In aquatic ecosystems, nitrogen is usually in abundance and does not limit algal growth in most freshwater systems.
oligotropic	**--**	Systems with low levels of productivity
Onondaga Lake Technical Advisory Committee	**OLTAC**	
particulate phosphorus	**PP**	The non-dissolved fraction of total phosphorus.
pelagic zone	**--**	Any water in the sea of a lake that is not near the bottom or the shore.
pH	**pH**	The negative log of the hydrogen ion concentration commonly used to quantify the acidity of a waterbody. pH is an important regulator of chemical reactions in ecosystems.
phosphorus	**P**	A common element required by algae for growth. In freshwater aquatic ecosystems, phosphorus is usually the nutrient limiting phytoplankton production. Increases in phosphorus can result in accelerated eutrophication.
photic zone	**--**	Upper layer of the water column where light penetration is sufficient for

Term	Abbreviation	Definition
		photosynthesis (algal growth).
phytoplankton	**--**	The community of algae and cyanobacteria present a water body.
percent model affinity	**PMA**	A measure of similarity of a sampled community to a model non-impacted community, using percent abundance of 7 major groups to quantify the community structure. The closer the similarity of the sampled community structure is to the model non-impacted community structure, the more likely that the sampled community is non-impacted.
potassium	**K**	A common alkali metal element necessary for proper growth and functioning of aquatic organisms.
profundal	**--**	The deep zone in an inland lake below the range of effective light penetration, typically below the thermocline
organic nitrogen	**--**	The total amount of nitrogen in a water sample, associated with total (particulate and dissolved) organic matter.
oxidation-reduction potential	**Redox or ORP**	A measure (in volts) of the affinity of a substance for electrons. The value is compared to that for hydrogen, which is set at zero. Substances that are more strongly oxidizing than hydrogen have positive redox potentials (oxidizing agents); substances more reducing than hydrogen have negative redox potentials (reducing agents). In Onondaga Lake's hypolimnion, ORP declines as organic material is decomposed.
Secchi disk	**SD**	A round disk, 25 cm in diameter, with alternating quadrants of black and white commonly used in limnology to quantify the clarity of surface waters. The disc is lowered through the water column on a calibrated line, and the depth at which it is no longer visible is recorded; thus indicating water clarity.
silica	**Si**	A metallic element used by phytoplankton for construction of cellular structures

Term	Abbreviation	Definition
soluble reactive phosphorus	**SRP**	A dissolved form of phosphorus that is most readily used by algae for growth.
sodium	**Na**	A common metallic element in aquatic ecosystems usually associated with chloride, NaCl a common form of salt
sonde	**--**	A compact monitoring device that includes one or more sensors or probes to measure water quality parameters, such as temperature, pH, salinity, oxygen content, and turbidity directly, eliminating the need to collect samples and transport them to a laboratory for analysis.
specific conductance	**SC**	Conductivity normalized to 25°C.
species diversity	**--**	A common ecological measure of the abundance and relative frequency of species in an ecosystem.
stoichiometric	**--**	The ratio of required elements needed for a chemical reaction; in this context, refers to the ratio of N and P required by phytoplankton for metabolism.
sulfate	**SO_4^{2-}**	A compound in abundance in Onondaga Lake due to the large quantities of gypsum (naturally occurring geological formation) in the lake's watershed. SO_4^{2-} can be converted to hydrogen sulfide when oxygen is depleted.
total dissolved phosphorus	**TDP**	A dissolved form of phosphorus that is used by algal for growth. TDP is not as readily available as SRP.
total dissolved solids	**TDS**	A common measure of the amount of salts in a water body.
total inorganic carbon	**TIC**	The total amount of carbon in a water sample, not associated with organic matter.
total Kjehldahl nitrogen	**TKN**	A measure of the concentration of organic nitrogen and ammonia in a water sample.
Total Maximum Daily Load	**TMDL**	An allocation of the mass of a pollutant that can be added to a water body without deleterious effects to its designated use.
total organic carbon	**TOC**	The total amount of carbon in a water sample, associated with total (particulate and dissolved) organic matter
total nitrogen	**TN**	The total amount of nitrogen in a water sample, associated with particulate and

Term	Abbreviation	Definition
		dissolved organic and inorganic matter.
total organic carbon filtered	**TOC_f**	The total amount of carbon in a water sample, associated with dissolved organic matter.
total phosphorus	**TP**	The total amount (dissolved plus particulate) of phosphorus in a water sample. TP is a common metric of water quality of aquatic ecosystems and an important water quality standard in Onondaga Lake is determined using surface water TP concentration during the summer months.
total suspended solids	**TSS**	The amount of particulate material in a water sample.
trophic state	**--**	The status of a water body with regard to its level of primary production (production of organic matter through photosynthesis)
micrograms per liter	**µg/L**	A concentration unit. One millionth of a gram per liter or 10^{-6} g per liter
milligram per liter	**mg/L**	A concentration unit. One thousandths of a gram per liter or 10^{-3} g per liter
volatile suspended solids	**VSS**	The total amount of organic particulate matter in a water sample (a fraction of TSS).
volume days of anoxia	**--**	A metric that integrates the volume of the lake water affected by low dissolved oxygen (DO) conditions over the duration of the low DO.
water year	**--**	The continuous 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 2010, is referred to as the 2010 water year.
watershed	**--**	The area of land that drains into a body of water
Water Environment Protection	**WEP**	The agency in Onondaga County, NY responsible for wastewater and storm water treatment as well as the monitoring and protection of all water resources in the county.