January 3, 2005

Executive Summary Onondaga Lake 2003

Onondaga Lake Ambient Monitoring Program Executive Summary

2003 Annual Report

ACKNOWLEDGMENTS

The Onondaga County Department of Water Environment Protection (DWEP) is responsible for implementing the Ambient Monitoring Program (AMP), as required by the Onondaga Lake Amended Consent Judgment. Funds for the Ambient Monitoring Program are provided primarily by Onondaga County. The Onondaga Lake Technical Advisory Committee (OLTAC) has been assembled to provide technical assistance to the County. OLTAC members include:

Dr. Raymond Canale (EnginComp Software, Inc.): modeling, Seneca River
Dr. Charles Driscoll (Syracuse University): water and sediment chemistry, mercury
Dr. James Hassett (SUNY-ESF): water resources engineering and hydrologic modeling
Dr. Edward Mills (Cornell University): food web, phytoplankton and zooplankton
Dr. Elizabeth Moran (EcoLogic, LLC): monitoring program, limnology
Dr. Lars Rudstam (Cornell University): food web, fish community
Dr. Kenton Stewart (SUNY Buffalo): physical limnology
Dr. William Walker, Jr. (Environmental Engineer): statistical design, mass-balance modeling

Many agencies provide oversight and technical assistance to the County, including:

- New York State Department of Environmental Conservation
- United States Environmental Protection Agency
- New York State Attorney General, Environmental Protection Bureau
- United States Army Corps of Engineers
- Onondaga Lake Partnership
- United States Geological Survey
- Atlantic States Legal Foundation

Joseph J. Mastriano of DWEP administers the AMP. Jeanne C. Powers oversees program implementation. In 2003, Mr. Mastriano and Ms. Powers were supported by DWEP staff members Nicholas Capozza (field program leader and biological program oversight), Michael Gena (director of Onondaga County's state-certified Environmental Laboratory), Janaki Suryadevara (water quality program oversight) and Antonio D. Deskins (data compilation, calculations, and plotting).

EcoLogic LLC, Quantitative Environmental Analysis LLC (QEA), Dr. William Walker, Jr., and Dr. Edward Mills prepared sections of the 2003 Annual Report. This Executive Summary was prepared by EcoLogic, LLC.

November 2004

The Onondaga County Department of Water Environment Protection is responsible for collecting and treating wastewater from homes and businesses throughout the County. As Commissioner, I am proud to lead a talented and dedicated staff under a name that reflects our strong commitment to protecting the water resources we all share.

The Department performs an intensive survey of water quality conditions in the Onondaga Lake watershed each year. This publication is a summary of the findings of the 2003 Onondaga Lake Ambient Monitoring Program (AMP), the 34th year of County monitoring of the lake and adjacent waters. Current conditions and trends in water quality and the lake's biological community are highlighted in this summary document. A complete report of the 2003 monitoring effort will be posted on the Onondaga County web site and is available from the Department upon request.

Onondaga County is required by State and Federal regulations to monitor Onondaga Lake and its tributary streams. The January 1998 Amended Consent Judgment (ACJ) required the Department to develop and implement an ambient monitoring program to measure water quality conditions and assess progress towards compliance with state and federal standards.

Employees of the Department sample Onondaga Lake, streams flowing into the lake, and the Seneca River. Water samples are analyzed in the County's state-certified environmental laboratory and results are used to calculate the annual input of sediment, chemicals, and bacteria. Results of the monitoring program are used to track how Onondaga Lake and the Seneca-Oneida-Oswego River system respond to pollution abatement activities. The data are compared with applicable water quality standards developed to protect the aquatic ecosystem and ensure that the waters are safe for recreational uses.

In 1998, the County's annual monitoring program was redesigned to focus specifically on the water quality and ecological improvements brought about by the required improvements to the Syracuse Metropolitan Wastewater Treatment Plant (Metro) and Combined Sewer Overflows (CSOs) that are underway. Results of the monitoring program will help the New York State Department of Environmental Conservation (NYSDEC) and the federal Environmental Protection Agency (EPA) determine whether further actions are needed to meet community goals and standards.

Comments on this report are encouraged and may be directed to Joseph J. Mastriano, Operations Manager, at 315-435-2260.

Very truly yours,

Richard L. Elander, P.E.
Commissioner

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Introduction to the Ambient Monitoring Program

Onondaga County and its federal and state partners are investing in the future of Onondaga Lake, a natural resource that has undergone years of abuse and neglect. Improvements to the wastewater collection and treatment system serving six towns, two villages, and the City of Syracuse are currently under construction. These improvements will result in improved water quality conditions in Onondaga Lake and its tributary streams. Projects to reduce the **Combined Sewer Overflows (CSOs)** and provide a higher level of treatment at the **Syracuse Metropolitan Wastewater Treatment Plant (Metro)** began in 1998 with the signing of the **Amended Consent Judgment (ACJ)**. The ACJ outlines a 15-year program for Onondaga County to complete. This program has three major elements: CSO abatement projects, Metro treatment improvements, and the **Ambient Monitoring Program (AMP)** to track improvements in water quality.

The AMP is designed to provide data and information needed to assess the effectiveness of improvements to Metro and CSO abatement. The monitoring program includes field and laboratory components to identify sources of materials (nutrients, sediment, microorganisms, and chemicals) to the lake, evaluate in-lake water quality conditions, and examine the interactions between Onondaga Lake and the Seneca River. Biological programs encompass much of the ecosystem of the lake and its watershed, including zebra mussels, insects and worms living in sediments, aquatic plants, phytoplankton and zooplankton, and fish.

Onondaga County's trained technicians collect water quality and biological samples at a number of key locations in the watershed. Streams flowing into Onondaga Lake are monitored to estimate the annual input of water and materials including nutrients, sediment, salts, and bacteria. Samples are collected upstream of the lake to help pinpoint sources of pollution. Accurate estimates of inflows are a critical component of the AMP, since they underlie many of the management decisions facing Onondaga County. Monitoring of Onondaga Lake and the Seneca River is conducted during the ice-free period. When conditions allow, winter sampling is conducted as well.

Sampling along the Onondaga Lake shoreline.

INDICATORS AND TRENDS

The AMP generates thousands of observations each year. It is challenging to organize and communicate these data in a way that retains integrity of the scientific information and makes it useful for all stakeholders. To help meet this challenge, a series of indicators have been proposed to summarize water quality and habitat conditions with respect to specific uses. These indicators share several properties: they relate directly to an impairment of the lake or watershed; they relate to a resource of interest; they correspond to a published standard that, in turn, reflects the requirements of public health or the aquatic biota; and they can be measured and interpreted with relative ease. Indicators can help answer basic questions such as: "is the lake getting better?" and "is it safe for my family to swim here?"

Indicators are used to track progress towards lake improvement or compliance with ambient water quality standards. The major indicators are summarized in Table 1.

Table 1. Major indicators of water quality for Onondaga Lake.

Desired use	Measured by:
Water contact recreation	Bacteria concentrations
	Nearshore water clarity
Aesthetics	Phosphorus concentrations (narrative standard)
	Algal blooms: intensity, frequency, and duration
	Relative abundance of blue-green algae
	Nearshore macroalgae (algal mats)
Aquatic life protection	Dissolved oxygen concentrations
	Ammonia N concentrations
	Nitrite N concentrations
Recreational angling	Habitat quality: aquatic plant growth
	Nesting success
	Presence of early life stages of target species
	Presence of adult fish sensitive to pollution
	Mercury content of fish

The 2003 results provide a snapshot of "The State of the Lake" and help managers assess how conditions during this year met the goals for a swimmable, fishable lake. Throughout the community, there is deep interest in how the lake has changed over time. The County is closely tracking changes in water quality and relating these changes to the improvements in the wastewater collection and treatment system that are underway. As part of the AMP, water quality data collected each year are analyzed for trends. The trend analysis helps gauge how the lake is changing in response to the substantial public investment in improvements to the wastewater collection and treatment system. Trends in lake water quality conditions and the fish community are summarized in Table 2. Baseline fishery data from 2000—2003 are compared to historical data as available.

Table 2. Trends in water quality conditions and the biological community of Onondaga Lake

Indicator	Trend
Phosphorus concentration	Decreased through the 1990s, relatively unchanged since 2000.
Water clarity	Variable. In 2003, summer algal blooms signaled the return of diminished water clarity.
Algal blooms	Variable. After years of reduction, summer of 2003 was characterized by algal blooms.
Ammonia concentration	Decreased in response to improvements at Metro, relatively unchanged since 2000.
Nitrite concentration	Decreased with Metro improvements, relatively unchanged since 2000.
Chloride concentration	Declined with closure of AlliedSignal facility in mid-1980s, now stable.
Dissolved oxygen	Increased levels at fall mixing, shorter duration of anoxia.
Aquatic plant growth	Increased during the 1990s. This has improved aquatic habitat and helped stabilize shallow sediments.
Fish community structure	Increased number of species; increased number of species sensitive to pollution.
Fish reproduction	Evidence of more fish and better survival. Spawning smallmouth and largemouth bass.
Fish contaminant levels	Fish advisory remains in place based on mercury concentrations.
Bacteria concentration	Elevated levels persist in southern nearshore area following storms. Outlook good as controls on combined sewers are implemented.

As illustrated in Table 2, the water quality and habitat conditions of Onondaga Lake have improved over the past decade. Phosphorus and ammonia concentrations have decreased due to improved wastewater treatment. In response, the levels of dissolved oxygen have increased throughout the water column. Improved water clarity has allowed the beds of aquatic plants to expand; this has provided for improved nesting and nursery habitat for the lake's resident warmwater fish community.

The trend analysis examines changes in materials entering the lake (loading from tributaries and Metro), the quality of the lake's upper and lower waters, and materials flowing from the lake at the outflow to the Seneca River. A ten-year window has been identified as the appropriate time scale to track trends in Onondaga Lake's water quality. The lake has a relatively short water retention time and a dynamic history. With a longer period, results could be strongly influenced by historical data that are not representative of current conditions with respect to municipal and industrial wastewater inputs. With shorter time period, trends are more difficult to detect because of the influence of year-to-year variation in rainfall, stream flows, and temperature.

The main outfall pipe from Metro discharges to the surface of Onondaga Lake.

ONONDAGA LAKE AND ITS WATERSHED

The Onondaga Lake drainage basin encompasses approximately 738 square kilometers (285 square miles) and lies almost entirely in Onondaga County. The drainage basin includes six natural sub-basins: Ninemile Creek, Harbor Brook, Onondaga Creek, Ley Creek, Bloody Brook, and Sawmill Creek (Figure 1). The outlet of Onondaga Lake flows north to the Seneca River and ultimately into Lake Ontario.

Land use in the watershed is a mixture of agriculture (32%), forests (43%), and urban areas (22%). Urban areas of two towns, two villages, and the City of Syracuse border the lake. Sediment and pollutants from the large watershed make their way to the lake.

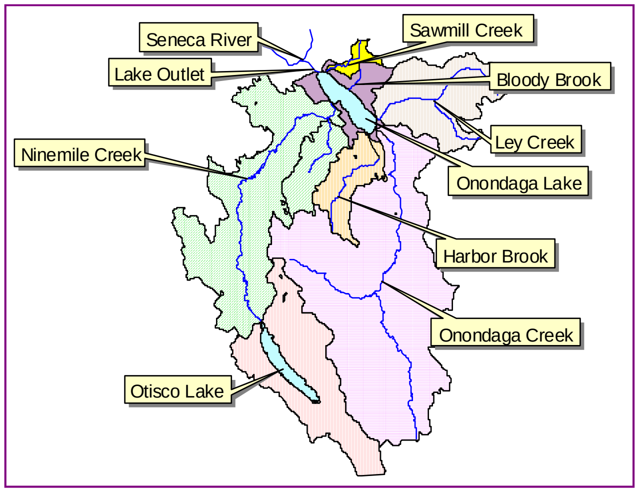

Figure 1. Onondaga Lake watershed.

Onondaga Lake is relatively small, especially compared with the nearby Finger Lakes and Oneida Lake. The shoreline is highly regular, with few bays. Much of the shoreline is owned by Onondaga County and is maintained as part of a popular park and trail system. The lakeside park is used for recreational activities such as jogging, biking, roller-blading, shoreline fishing, and cultural entertainment. The lake is used for secondary water contact recreation such as boating. Fishing derbies were held on Onondaga Lake in 2001, 2002 and 2003, attracting thousands of anglers to the lake and its shoreline.

Fishing was banned in the lake in 1972 because of mercury contamination. The ban was lifted in 1986 and modified into a "catch and release fishery"; that is, recreational fishing was permitted but possession of lake fishes was not. In 1999, the New York State Department of Health (NYSDOH) revised its advisory regarding consumption of gamefish from Onondaga Lake. The current recommendation is to eat no walleye from the lake and restrict consumption of all other fish species to no more than one meal per month. The fish advisory continues to be based on mercury levels in fish flesh. As in all New York waters with health advisories, the Health Department advises that women of childbearing age, infants, and children under the age of 15 eat no fish from these waters.

NYSDEC is responsible for managing water resources throughout the State. Lakes and streams are classified according to their designated best use (for example, water supply, swimming, recreational fishery, and/or aesthetic enjoyment). Monitoring results are evaluated regularly to determine if designated uses are supported. Because water quality and habitat conditions limit their use for swimming and ability to support aquatic life, Onondaga Lake and the Seneca River are among the State's top priorities for water quality improvement.

Metro is a major point source of pollution to Onondaga Lake, contributing nitrogen, phosphorus, bacteria, and organic (oxygen-demanding) material. Metro is an advanced secondary treatment plant, operated to enhance conversion of ammonia to nitrate during warm weather (in a process known as nitrification) and removal of phosphorus. The plant is being upgraded to tertiary treatment and will provide year-round nitrification and filtration to increase removal of ammonia, phosphorus, and oxygen-demanding material. An ultra-violet disinfection system will kill microorganisms without using chlorine; this system will be able to treat up to 126.3 million gallons per day (mgd). Metro can provide primary treatment to 240 mgd.

Nonpoint sources (such as runoff from agricultural, suburban, and urban areas) also contribute pollutants to Onondaga Lake. Nutrients, sediment, bacteria, metals, and pesticides reach surface water and groundwater from these diffuse sources. Industrial residuals in the watersheds of individual tributaries, such as PCBs in the Ley Creek basin and the AlliedSignal waste beds in the Ninemile Creek basin, continue to enter the lake through surface runoff and infiltrating groundwater. Lake sediments contain elevated concentrations of mercury and organic chemicals.

AMP 2003 Results: Inflows (Tributaries and Metro)

Program Summary

Loading estimates are needed to understand the relationships between pollutants entering the lake and the resulting water quality conditions. NYSDEC and others will use these relationships to set an acceptable level of treatment for Metro and the CSOs.

Stream monitoring provides a basis for estimating the relative importance of sources of phosphorus. Understanding the role of the watershed in contributing phosphorus to the lake from various sources, such as urban stormwater and agriculture, will help managers clarify the need for additional treatment or relocation of the Metro effluent to meet water quality and aesthetic goals for the lake.

Collecting stream samples during rainstorms and snowmelt is an important component of the tributary monitoring program. Monitoring has documented that most of the pollutants enter the lake during these infrequent high flow periods. Although challenging for the field and laboratory staff, the storm event monitoring program is collecting valuable data to assess the effectiveness of the CSO remediation program. Storm event monitoring is designed around the construction schedule for the major CSO facilities that will collect and treat overflows on Onondaga Creek, Harbor Brook, and Ley Creek. Monitoring data will be used to verify mathematical models of the relationship between storm intensity and contaminant transport. Once tested and verified with site-specific data, the models will be used to project future loading and water quality conditions.

Water Balance

Onondaga Lake receives water from two major tributaries (Onondaga and Ninemile Creeks) and several minor ones. The third largest contributor of water to Onondaga Lake is Metro (Figure 2). Metro treats wastewater from residential, commercial, and industrial sources within the service area. More than 90% of the flows entering the lake are measured (gauged).

In 2003, precipitation in Syracuse was 2.45 inches (6.2 cm) below normal.

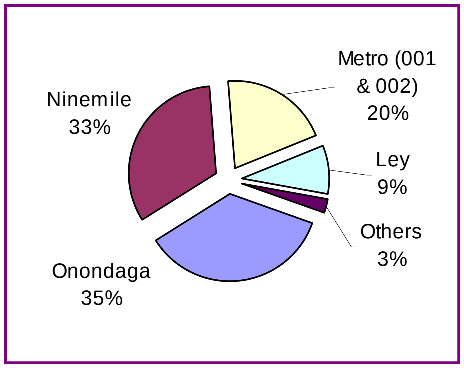

Figure 2. Annual flow contribution to Onondaga Lake, 2003 (gauged area)

Materials Balance

Results of the 2003 tributary and inflow monitoring program are summarized in Table 3. Note how the contributions of sediment, nutrients, microorganisms and chemicals vary by tributary. Onondaga Creek stands out as a major source of sediment and chloride. Treated effluent from Metro is a major source of nutrients, bacteria, and oxygen-demanding material.

Table 3. Percent contribution of gauged and ungauged tributaries, and Metro to lake's water and material load, 2003.

(Note: gauged flow constitutes approx. 93% of all inputs)	Onondaga Creek	Ninemile Creek	Metro Outfalls 001 and 002	Ley Creek, Harbor Brook, East Flume, Tributary 5A	Ungauged flow and direct precipitation
Water	34.2	31.3	18.2	11.1	5.2
Sediment	45.8	28.4	15.1	10.7	Not Determined
Total Phosphorus	16.3	14.0	62.3	7.4	Not Determined
Nitrate + Nitrite	21.5	20.4	53.3	4.8	Not Determined
TKN	11.6	12.3	70.8	5.3	Not Determined
Ammonia N	3.6	8.7	84.1	3.6	Not Determined
Bacteria	26.9	2.4	67.2	3.5	Not Determined
Chloride	38.5	29.7	21.0	10.7	Not Determined
Oxygen demand	16.8	15.0	62.4	5.9	Not Determined

Integrated Stream Assessments

Because physical features affect the distribution and abundance of life in streams, the AMP examines habitat as well as water quality conditions in the Onondaga Lake watershed. Surveys of physical characteristics of the streams are conducted at regular intervals, along with periodic sampling of the macroinvertebrate community. **Macroinvertebrates** are aquatic insects, worms, clams, snails and other animals visible without the aid of a microscope. These animals spend at least part of their lives associated with the sediments and macrophytes of streams and lakes. Macroinvertebrates are included in the AMP because their numbers and types are closely linked to water quality and habitat conditions.

Surveys conducted in 2000 and 2002 show that the macroinvertebrate communities of Onondaga Creek, Ley Creek, and Harbor Brook are affected to various degrees by pollution and habitat degradation. The macroinvertebrate communities of Harbor Brook and Ley Creek are the most severely impacted, based on standard indices calculated from the number and types of organisms present. It appears that a combination of habitat degradation, **nonpoint source pollution**, and oxygen-demanding material discharged by CSOs are affecting the macroinvertebrate communities of the three streams. Upstream segments of the tributaries are affected by nonpoint sources, while urban runoff and CSOs influence the community in downstream segments.

Metro Phosphorus Loading

Phosphorus removal at Metro is achieved using chemicals, such as iron salts and polymers, to coagulate and precipitate the nutrient and enhance its settling from the wastewater. Because of the importance of phosphorus to lake ecology, its removal from wastewater has been a central focus of the engineering improvements at Metro. Since 1987, the County has experimented with the amounts and types of chemicals added to the wastewater to maximize phosphorus removal. Phosphorus loading from Metro is plotted on Figure 3.

A phased limit for phosphorus discharged from Metro is included in the ACJ. The current (Stage I) maximum phosphorus discharge from Metro is 400 pounds per day; this limit has been consistently met since 1995. A Stage II limit of 0.12 mg/l (less than 90 pounds per day) is to be met by April 1, 2006. The County's currently planned improvements at Metro will result in meeting the Stage II limits or better by early 2005. Meeting the proposed stage III limits of 0.02 mg/l (less than 15 pounds per day) will be challenging. Small-scale tests to determine how much additional phosphorus can be removed will continue to identify appropriate technology and performance limits. NYSDEC will set final Stage III limits using a Total Maximum Daily Load allocation for all sources of phosphorus.

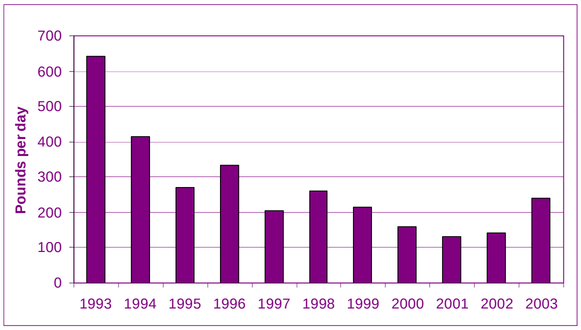

Figure 3. Annual phosphorus discharge from Metro outfall 001, 1993-2003.

Metro Nitrogen Loading

Metro is the major source of **ammonia nitrogen** to Onondaga Lake. The treatment plant was not originally designed to remove ammonia from wastewater and only recently have operational modifications been made to allow some **nitrification** (conversion of ammonia to nitrate, a nontoxic form of nitrogen) during warm weather. An enhanced aeration system has improved the treatment process since the late 1990s, resulting in much less ammonia reaching the lake (Figure 4).

Major improvements to Metro have been completed (as of mid 2004) to support year-round nitrification. This change in the treatment process is necessary to reduce the lake's ammonia nitrogen to safe levels for the aquatic community. The County has made excellent progress on the ammonia removal project. As of the publication of this report, Metro is meeting the final effluent limits of 1-2 mg/l (less than 1000 pounds per day) eight years ahead of schedule.

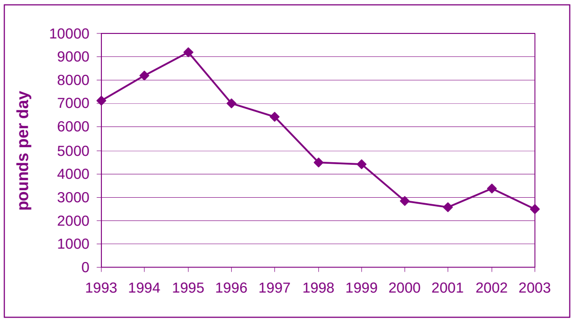

Figure 4. Average ammonia load from Metro, outfall 001, 1993-2003.

AMP 2003 RESULTS: ONONDAGA LAKE

PROGRAM SUMMARY

The County's comprehensive monitoring program of Onondaga Lake is designed to measure the effectiveness of controls on Metro and the CSOs. Samples are collected regularly throughout the ice-free season to characterize water quality conditions in the lake. Data are used to assess compliance with water quality standards and progress toward lake improvement. Experts in statistics have reviewed the monitoring program design to ensure that it will support firm conclusions regarding effectiveness of the control measures. Monitoring of the **macrophyte** community is conducted periodically, along with assessment of other major components of the lake's food web: **phytoplankton**, **zooplankton**, **macroinvertebrates**, and the **fish community**.

Indicators of Progress: Is the Lake Safe for Water Contact Recreation?

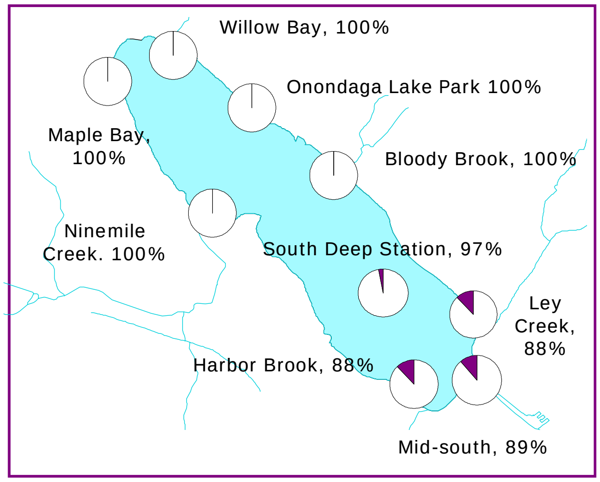

Figure 5. Percent compliance (white) of fecal coliform bacteria at Onondaga Lake nearshore stations, June– August 2003.

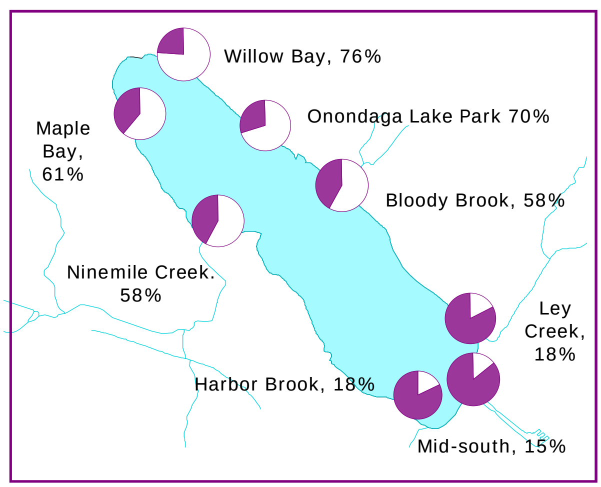

Figure 6. Percent compliance (white) of nearshore transparency, Onondaga Lake, June - August 2003.

Bacteria Levels

Restoring recreational uses of the lake is a major goal of the improvements to the County's wastewater collection and treatment system. The AMP includes sampling for indicator **bacteria** (fecal coliform bacteria) in nearshore areas that might support water contact recreation. Sampling is done during dry weather and following storms. Results of the summer 2003 nearshore bacteria monitoring effort are displayed in Figure 5. The picture displays the percent of summer 2003 measurements that comply with the bacteriological standards for safe swimming.

The southern end of Onondaga Lake occasionally exhibited high levels of fecal coliform bacteria following storms and does not routinely support water contact recreation. This finding highlights the need for continued progress with the CSO projects. However, microbiological quality improves greatly once away from the southern tributaries. Water quality in Willow Bay, Maple Bay, and Onondaga Lake Park showed no violations of NYS bacteria standards for safe swimming (200 colony-forming units per 100 ml of water) in 2003.

Nearshore Water Clarity

The NYS Department of Health recommends that water clarity in swimming areas be at least 4 ft (1.2 m) to maintain public safety. Onondaga County has monitored compliance with this guidance value at eight stations around the lake each summer since 1999. Figure 6 shows that nearshore water clarity was frequently limited during the summer of 2003.

Nearshore transparency results are affected by wind, waves, precipitation, and algae. Results can be highly variable from day to day. No trends of increased or decreased water clarity have been detected.

Indicators of Progress: Is the Lake Visually Attractive?

The Importance of Phosphorus to the Lake's Aesthetic Quality

Phosphorus is naturally present in all waters and is an essential nutrient for life. In most lakes, phosphorus is the limiting nutrient for algal growth; that is, phosphorus concentration is positively correlated with algal abundance. Until recently, phosphorus concentrations in Onondaga Lake were so high that algal growth was limited by other factors such as light levels. Reductions in phosphorus loading achieved since the mid-1990s have begun to shift the lake to a phosphorus limited system.

Excessive algae will make a lake appear turbid or green and diminish its attractiveness for recreational use. Decay of algae reduces the concentration of dissolved oxygen in a lake's deeper waters. Consequently, lake managers focus on controlling phosphorus inputs to protect recreational use and aquatic life. A 14-year record of summer average concentration of phosphorus in the upper waters of Onondaga Lake (the zone where plants and algae grow) is displayed in Figure 7.

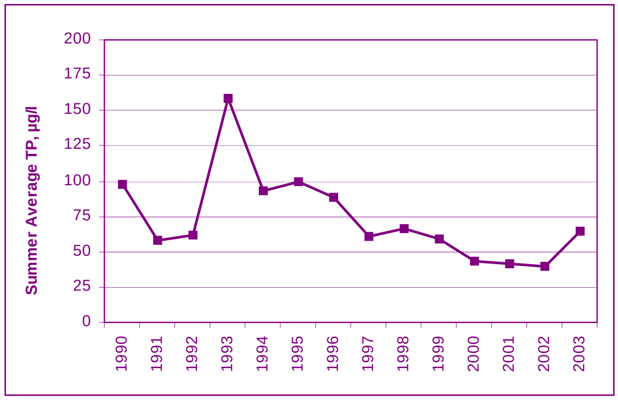

Figure 7. Summer average (June - Sept) phosphorus (TP) upper waters , Onondaga Lake South Deep Station, 1990-2003.

Algae and Water Clarity

The concentration of **chlorophyll-a**, the major photosynthetic pigment in plants, is used to estimate algal abundance. Chlorophyll-*a* concentration is used to compare algal abundance between lakes because of its ease of measurement. It is also used to track changes over time in individual lakes. Some agencies have guidelines on maximum concentrations of chlorophyll-*a* to protect recreational uses. In New York, concentrations exceeding 13 µg/l are considered to impair recreational use.

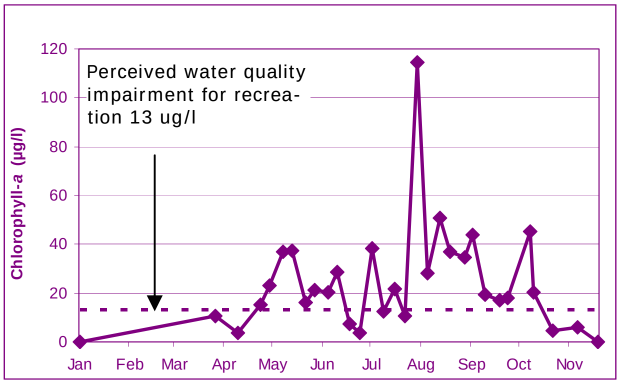

Figure 8. 2003 chlorophyll-*a* in the upper mixed layer of Onondaga Lake (South Deep Station)

Chlorophyll-*a* concentrations in the upper waters of Onondaga Lake averaged 30.4 µg/l during the summer of 2003. There was a tremendous amount of variability in this parameter, as plotted in Figure 8. Algal blooms began in May and persisted through much of the summer recreational period. The largest bloom occurred in August and extended well into the fall. Average 2003 summer chlorophyll-*a* concentrations were within the range of conditions measured since 1992 although there is much variability from year to year (Figure 9). As described later in this Executive Summary, changes in the lake's fish and zooplankton communities appear to be contributing to the abundant algae.

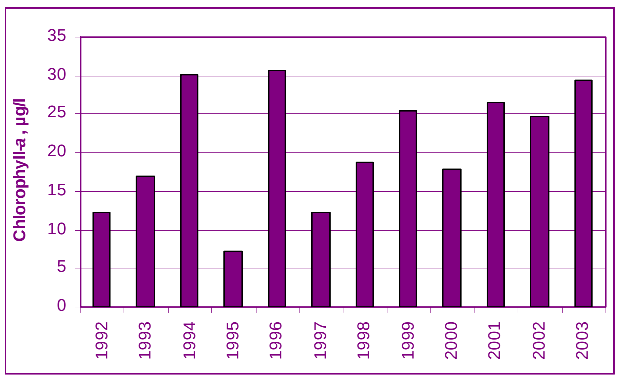

Figure 9. Summer average (June - Sept) chlorophyll-a concentration, Onondaga Lake South Deep Station (upper mixed layer data), 1992-2003.

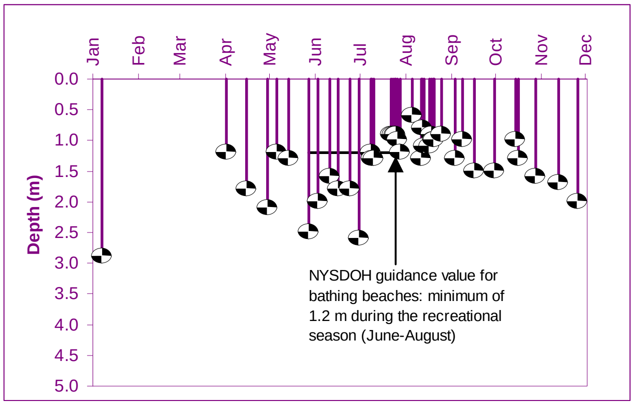

Figure 10. Secchi Disk transparency in Onondaga Lake South Deep Station, 2003.

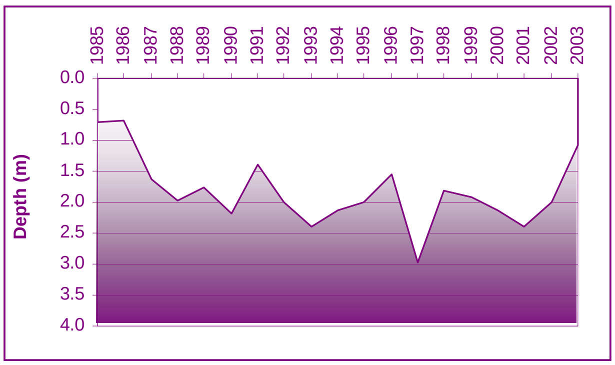

Figure 11. Summer average (June-Sept) Secchi Disk transparency, Onondaga Lake South Deep Station, 1985-2003.

Ammonia and Nitrite Concentrations

Ammonia and nitrite concentrations are major factors affecting the type and abundance of aquatic life in Onondaga Lake. Reductions in concentration of these harmful forms of nitrogen are required to meet **water quality standards and criteria** and protect a diverse aquatic community. With improved Metro effluent quality, concentrations are decreasing and habitat is improving for sensitive early life stages of fish and other aquatic animals.

The average ammonia nitrogen concentration in the lake's upper waters has decreased (Figure 12). Concentrations greater than approximately 1.4 mg/l (the standard varies with pH and temperature) exceed the NYS water quality standard for ammonia, designed to protect sensitive aquatic life. Most of the variation is due to Metro performance. The days of violation of the ammonia standard in the upper waters each year are decreasing (Figure 13), demonstrating continued progress towards compliance. Exceedences of the NYS standard have historically occurred in the winter and early spring as a result of higher inputs from Metro. The 2003 results (Figure 14) demonstrate compliance with NYS standards even early in the year. In addition, concentrations remained below the federal criteria for ammonia throughout 2003 (indicating full compliance).

The 2003 **Secchi disk transparency** measurements in Onondaga Lake are plotted in Figure 10. Water clarity was low during much of the summer, as expected given the intensity and duration of the algal blooms. It is significant that the lake did not exhibit the springtime high water clarity (clearing event) that had been typical during the 1990s. This is attributed to the loss of larger zooplankton, which are very efficient grazers of algae. Recent proliferation of the alewife appears to be causing the loss of the larger zooplankton; this fish preferentially feeds on larger zooplankton.

Similar to the chlorophyll results, there is year-to-year variability in average summer Secchi disk transparency (Figure 11). Water clarity is affected primarily by algal abundance, although inorganic sediment particles and dissolved materials may also affect the color and clarity of the water. The time period displayed in this graph encompasses many factors: changes in phosphorus loading, zebra mussels (first reported as abundant in 1999) and the loss of larger zooplankton noted since mid-2002.

Indicators of Progress: Can Onondaga Lake Water Quality Support a Balanced Community of Plants and Animals?

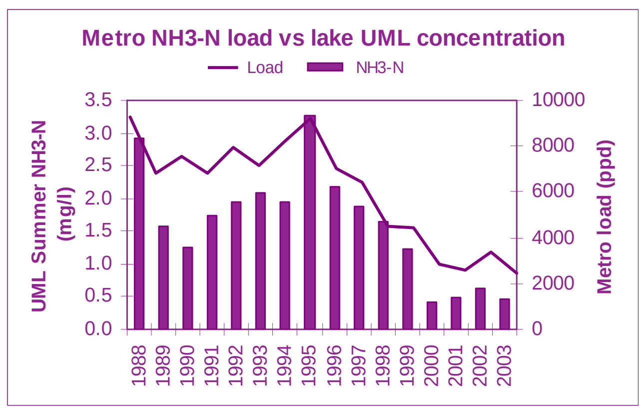

Figure 12. Summer average ammonia-N concentrations, in upper mixed layer of Onondaga Lake , South Deep Station, 1988-2003, and Metro ammonia load.

The concentration of nitrite measured in the lake's upper waters during 2003 is displayed in Figure 15. The standard for nitrite is 0.1 mg/l, a level considered safe for a warmwater fish community. In 2003, the nitrite concentrations hovered around the standard until the fall when the lake waters cooled and mixed. Nitrite concentrations continued to violate the standard through the end of the sampling period. This may represent incomplete transformation of the pool of ammonia that accumulated in the lake's lower waters. Because of the linkage between ammonia and nitrite, improvements to Metro are expected to reduce nitrite concentrations in the lake.

Dissolved Oxygen

The **dissolved oxygen** (DO) status of Onondaga Lake is closely linked to its annual temperature cycle. During summer, the lake's deeper waters remain isolated from the atmosphere. Light to support photosynthesis by algae or aquatic plants cannot reach the deeper waters; thus no oxygen production occurs. DO in the lower waters is used during decomposition of organic material settling from the sunlit layers above. When the DO is depleted, the waters become anoxic and other chemicals such as iron, ammonia, hydrogen sulfide, and methane accumulate.

When the lake cools in the fall, temperature differences that keep the water layers isolated begin to break down. Gradually, the deep anoxic waters mix with the upper waters. As the iron, ammonia, hydrogen sulfide, and methane mix into the upper waters, DO is reduced. To comply with state and federal standards designed to protect aquatic life, DO should remain above 4 - 5 mg/l in the upper waters.

Dissolved oxygen measurements obtained during the 2003 monitoring season are displayed in Figure 16. Note the rapid depletion of DO in the lower waters in late June, after thermal stratification had isolated the lower waters from the atmosphere. Note also the decline in DO in the upper waters during October. The upper waters lost about 4.0 mg/l of DO as they cooled and began to mix with the anoxic lower waters. Complete mixing occurred by late October, and concentration of DO gradually increased as the waters continued to mix and gain oxygen from the atmosphere.

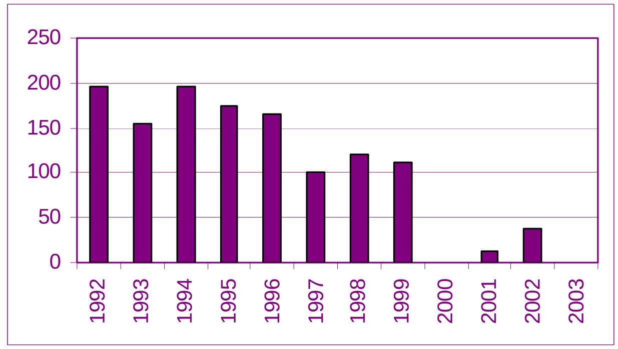

Figure 13. Days of violation (April 1—December 1) of NYS ammonia standard, Onondaga Lake upper mixed layer , South Deep station, 1992-2003. There were no violations in 2000 and 2003.

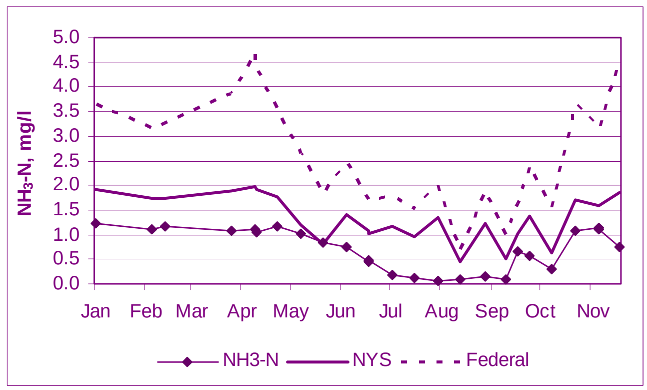

Figure 14. Ammonia concentrations at 3 meters compared with current NYS standard and federal criteria. Onondaga Lake, 2003, South Deep station.

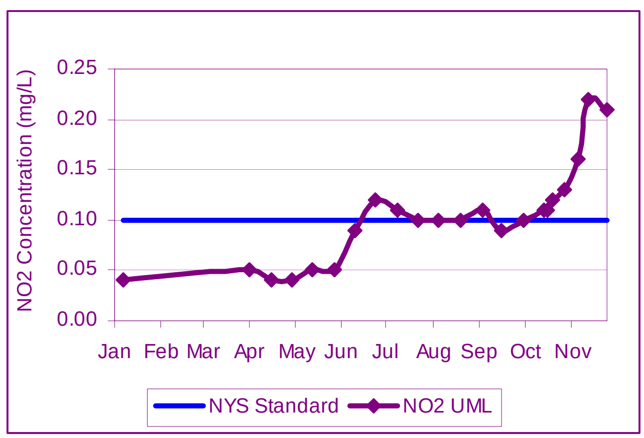

Figure 15. Average nitrite-N in upper waters (0-9m), Onondaga Lake, 2003 (standard is 0.1 mg/l), South Deep station .

Onondaga County deployed its water quality monitoring buoy at South Deep station in 2003. Suspended from the buoy is an array of monitoring and recording instruments; the DO data plotted in Figure 16 were measured by the buoy. Results are transmitted back to a computer at the OCDWEP offices on Hiawatha

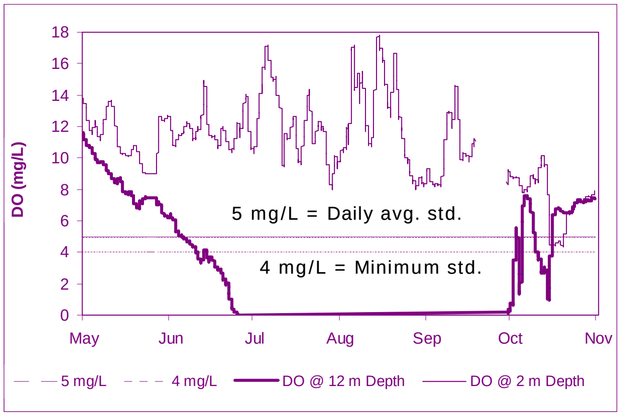

Figure 16. Dissolved oxygen (DO) in Onondaga Lake South Deep station, 2003. Gap represents missing data.

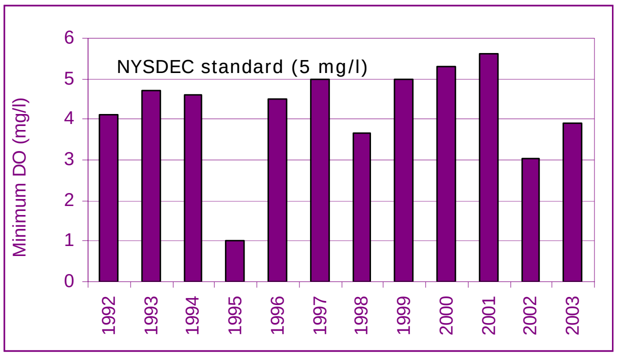

Figure 17. Minimum DO in upper mixed layer (0-9m) of Onondaga Lake during fall mixing, South Deep station, 1992-2003.

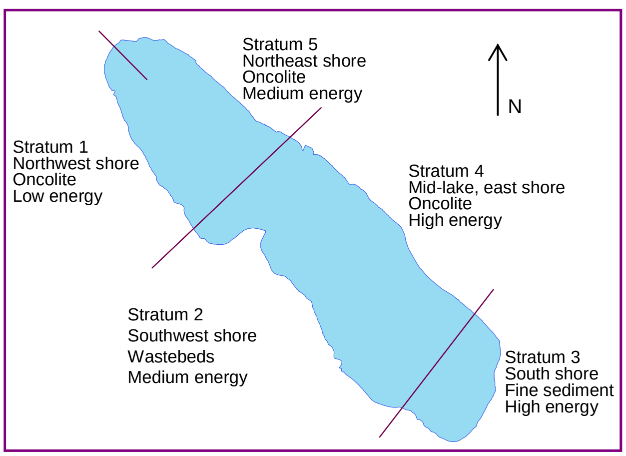

Figure 18. Strata used in Onondaga Lake biological programs.

Boulevard. The buoy is in operation from early spring to late fall. Data can be viewed through the County's website at ***www.ongov.net***. This near real-time water quality measurement system represents a critical advance in our ability to monitor and interpret lake conditions, especially during critical periods such as fall mixing.

Minimum DO concentrations measured in the lake's upper waters during fall mixing since 1992 are plotted in Figure 17. Note the variability in this measurement. Some of the variability depends on winds and air temperatures. However, the pool of iron, hydrogen sulfide, ammonia, and methane that has accumulated over the summer period ultimately affects oxygen depletion in the fall. As algal biomass is reduced, decomposition in the lower waters will eventually decline.

Elements of a Balanced Biological Community

Monitoring the biological community in and around the Lake is an important part of the AMP. Special organisms, known as biological indicators, are the focus of much of the monitoring program. The presence and abundance of these biological indicators can tell managers a great deal about the overall health of the ecosystem. While it may be natural to think of the lake as a uniform habitat, the nearshore areas of Onondaga Lake are subject to very different conditions of wind and waves; the differences in wave energy have created a wide variation in the type and stability of nearshore sediments. To assess the importance of these different habitat conditions, the AMP uses a stratified sampling design. Biological data are collected, analyzed and reported in five distinct nearshore areas (strata) that have different conditions of wave energy and substrate composition (Figure 18).

Macroinvertebrates

Sampling of the lake's macroinvertebrate community in the **littoral** (nearshore) zone is conducted every five years. No sampling was completed in 2003. Results of the most recent sampling event in 2000 reveal differences in the macroinvertebrate community between the northern and southern ends of Onondaga Lake (Figure 19). As expected, the macroinvertebrate community in the northern end of the lake is less affected by the pollutant inputs that dominate the southern basin: wastewater, contaminated and/or saline groundwater, and sediment. The combined influences of eutrophication and habitat degradation appear to be major structuring elements of the littoral benthic community. The impairment scale in Figure 19 was developed by NYSDEC; high numbers indicate better conditions. The next sampling event, scheduled for summer 2005, will indicate whether conditions are improving, particularly in the southern strata where loading reductions from Metro and the CSO abatement projects are most likely to affect nearshore water quality and habitat conditions.

Macroinvertebrates collected in the lake tributaries. Photo includes common organisms such as snails, dragonfly, water beetle, mayfly, and caddisfly.

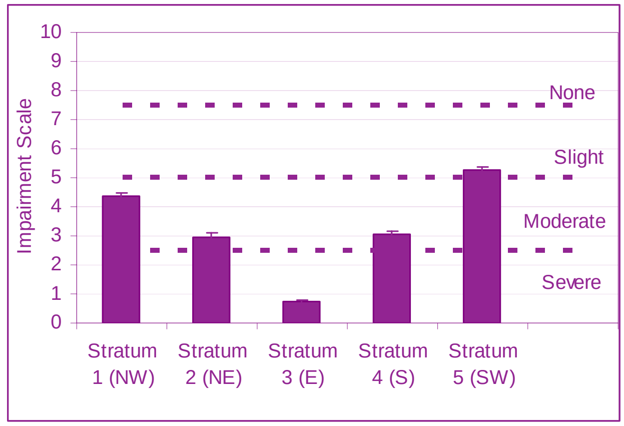

Figure 19 Status of the littoral macroinvertebrate community, assessed using standard indices of pollution tolerance, Onondaga Lake, 2000.

Macrophytes

Macrophytes are important to stabilizing the bottom sediments in the lake, and providing food and shelter for young fish. Detailed surveys are completed every five years and aerial photographs of the lake are obtained each year.

A baseline survey conducted in 2000 indicated a distribution among strata similar to that of the macroinvertebrates (Figure 20). Both the number of plant species in Onondaga Lake and the percent of the lake bottom covered with plants have increased. The survey will be repeated in 2005. Aerial photos indicate that the abundance of macrophytes in the shoreline zone is increasing.

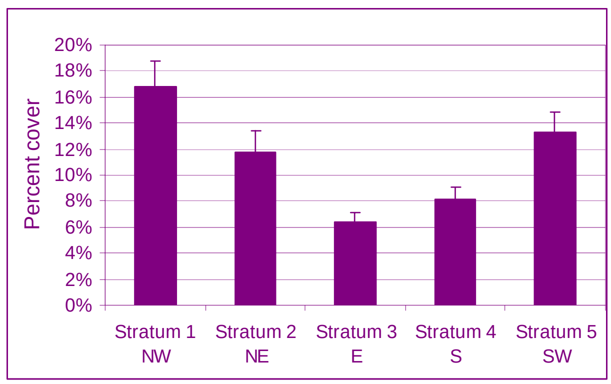

Figure 20. Percent cover of macrophytes in littoral zone of Onondaga Lake, 2000.

Phytoplankton and Zooplankton

Researchers from the Cornell Biological Field Station evaluated the community of **phytoplankton** and **zooplankton** in 2003, as they have done each year since inception of the AMP. Abundance and species composition are evaluated from samples collected from early spring through the late fall. Zooplankton size is measured and tracked over the year, as this is affected by the intensity of feeding by the fish community. Zooplankton density was reduced in Onondaga Lake in 2003, despite the abundant phytoplankton. The average size of the lake's zooplankton declined from its maximum value in March through early summer, indicating a surge in zooplanktivory (consumption of zooplankton by fish and other organisms). A second decrease in average size of the zooplankton was evident in late summer, which was likely associated with increased numbers of young-of-the-year fish feeding on zooplankton. This late-summer decrease in the average size of zooplankton is evident in Oneida Lake, as well as Onondaga Lake, each year as newly-hatched fish become large enough to graze on zooplankton.

Invasive Species

Invasive (non-native) species are an important factor affecting the Onondaga Lake ecosystem and, in fact, ecosystems throughout the Great Lakes Basin. The 2003 field investigations documented the presence of a predatory cladoceran zooplankton *Cercopagis pengoi*. This organism was introduced to the Great Lakes from the Caspian Sea region in Eurasia and is rapidly making its way into adjacent waterways. Shipping and ballast waters are the presumed mechanism for transfer of organisms from remote areas.

Indicators of Progress: Does the Lake Have a Self-Sustaining Warmwater Fish Community?

Fish are among the most visible elements of the food web of any lake and the AMP includes a major focus on the fish community. The County is evaluating the reproductive success of the fish community using a combination of classical and innovative techniques to count nests; sample larval, juvenile, and adult fish; and track changes in the fish community. Data are collected each year as improvements to wastewater collection and treatment are phased in. Cooperating anglers are recruited to keep annual diaries of their fishing efforts and successes, and report this information to the County. Data are used to evaluate which species are present, which are reproducing, what is their growth rate, and how they move between the lake and river. Standard methods are used so that the fish community of Onondaga Lake can be compared with that of other lakes. Experts in fish ecology oversee program design and implementation.

Since the program began in 2000, sampling of the juvenile and adult fish community has resulted in collection of approximately 22,000 fish representing 36 species. Smallmouth bass nests were documented for the first time in Onondaga Lake in 2000.

2003 fish survey results show that the lake is dominated by warmwater species that are tolerant of pollution. Notable in 2003 was the increase in the number of alewife; this fish is now the most abundant planktivore. Gamefish are widespread in the lake but more common in the northern than the southern end of the lake (Figure 21). This abundance pattern is consistent with other indices (macrophytes, macroinvertebrates, substrate quality) showing that the southern end provides poorer habitat quality.

Other gamefish, such as walleye and northern pike, are present but much rarer than bass. Panfish, such as yellow perch, pumpkinseed, and bluegill, are common in nearshore areas.

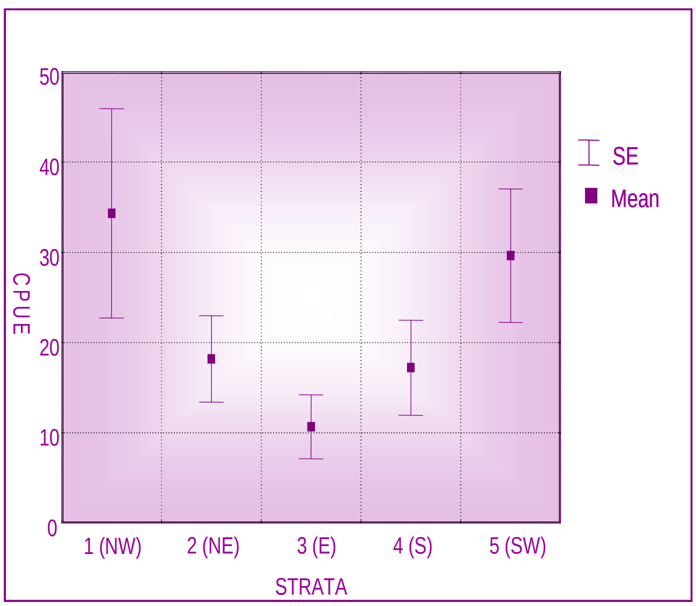

Figure 21. Smallmouth bass distribution in Onondaga Lake, 2000-2003. Scale CPUE is “catch per unit effort” a standard calculation of abundance used to estimate population size. SE is standard error of the mean, a measure of variability.

The AMP calculates several indicators to evaluate the condition of the lake’s fish community. Results indicate that Onondaga Lake supports a diverse assemblage of species, with planktivorous warmwater species, tolerant or moderately tolerant of pollution, most abundant. Fish appear to be in good condition with weights within expected ranges. Gamefish catch rates from electrofishing were typically on the low end of New York State averages for walleye and pike but close to average for bass.

Increased angling in the future could potentially reduce the size of gamefish populations, if reproduction levels are too low to compensate for the increased mortality. However, Onondaga Lake is part of a larger aquatic ecosystem, and it is clear that there is migration between Onondaga Lake, the Seneca River, and Oneida Lake. Therefore, the fish community in Onondaga Lake may be supplemented by fish moving in from other parts of the system.

AMP 2003 RESULTS: SENECA RIVER

PROGRAM SUMMARY

The Seneca River is an important part of the Onondaga Lake system. It connects Onondaga Lake to the greater Oswego River-Great Lakes system (Figure 22). Fish and other organisms, including invasive species, can move in and out of the lake through the Seneca River. Water quality of the river is directly affected by the outflow of Onondaga Lake. The capacity of the river to handle additional treated wastewater will affect the final alternatives for discharge of the Metro effluent.

In 2003, OCDWEP completed water quality surveys in the river to characterize water quality conditions, assess the impact of the zebra mussel on water quality, and support the Three Rivers Water Quality Model (TRWQM). Monthly surveys were targeted to low flow conditions when DO resources are most stressed. The distribution and abundance of mussels along a segment of the river extending from Jack's Reef to the Three Rivers junction were mapped in later 2003; this program will continue through 2004.

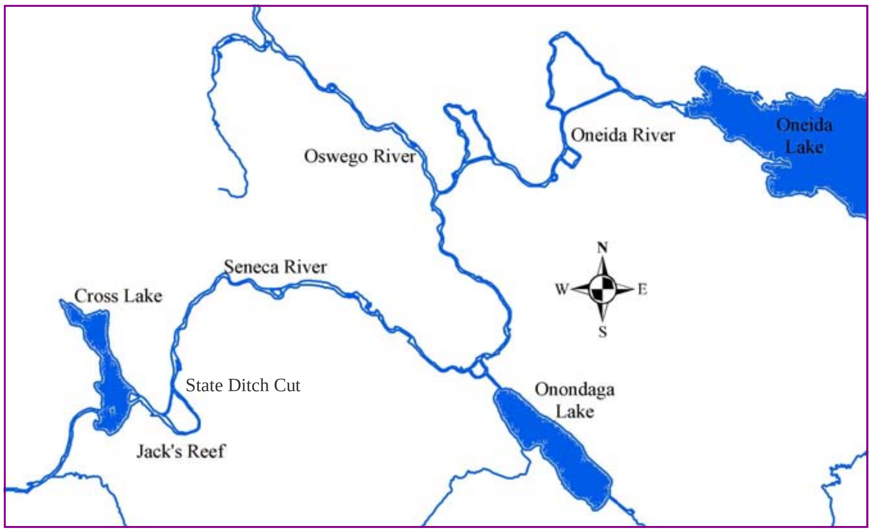

Figure 22. Onondaga Lake and the Seneca-Oneida-Oswego River System

2003 FINDINGS

Through the monitoring and modeling completed on the Seneca River, it is clear that zebra mussels have profoundly altered ecological conditions. In the early 1990s, the Seneca River was nutrient-rich and green with algae during the summer. Dissolved oxygen concentrations were variable, but remained at levels that could support a balanced aquatic community. Phosphorus was present primarily in the particulate form; that is, incorporated into algal biomass. Post zebra mussel conditions are different. Water clarity is high as phytoplankton are removed by active grazing. Dissolved oxygen levels are significantly lower due to the respiration of the benthic mussels. Phosphorus is now present primarily in the soluble form. Surveys along the river indicate that zebra mussel density is highest in the region of the State Ditch Cut, where the combination of hard substrate, moderate stream velocity, and abundant food source from Cross Lake provide ideal conditions for the mussels.

Results of the 2003 monitoring efforts indicate that quality of the Seneca River in the vicinity of Onondaga Lake is characterized by regions of low DO during low flow conditions (particularly in the lower waters, where the denser lake water creates weakly stratified conditions). Nutrient concentrations are high. Algal density is low; this is attributed to zebra mussel grazing. Violations of ambient water quality standards for DO and ammonia were recorded. Overall, conditions in 2003 were consistent with those measured in the river since the early 1990s when the zebra mussel first invaded the system. The Three Rivers Water Quality Model has been used to quantify the sources and sinks of dissolved oxygen in the Seneca River.

CONCLUSIONS

Onondaga County DWEP is responsible for a comprehensive monitoring program encompassing Onondaga Lake, the lake's tributary streams, and a segment of the Seneca River. In 2003, the County's state-certified environmental laboratory completed over 20,000 analyses to characterize the lake and its watershed. Trained technicians collected hundreds of samples of the biological community from microscopic algae to fish. This monitoring effort is designed to provide data and information needed to evaluate the effectiveness of improvements to the County's wastewater collection and treatment system.

Results of the 2003 AMP indicate that water quality conditions have remained relatively stable since 2000. Improved wastewater treatment is having a positive effect on the lake. However, profound changes in lake ecology are underway, apparently triggered by proliferation of the alewife (a fish). Alewife preferentially graze on larger-bodied zooplankton, such as *Daphnia,* that have been helping to keep the lake clear of algae. Detailed examination of the zooplankton community has led the AMP team to conclude that the abundance of larger zooplankton declined precipitously in mid 2002. Larger zooplankton were essentially absent from the 2003 samples. Loss of the larger zooplankton, which can consume lots of algae, has resulted in a zooplankton community dominated by smaller organisms, which are much less efficient grazers. The result is more algae, as was seen in increased frequency, intensity and duration of algal blooms during 2003. Other significant findings are summarized below.

- ❖ Pollutants such as sediment, nitrogen, phosphorus, bacteria, heavy metals, salts, and organic material flow into the lake each year from point and nonpoint sources. Much of the annual AMP effort is directed to quantifying the mass of material entering the lake. These data are used to define priority areas and assess the effectiveness of controls.
- ❖ Summer total phosphorus concentrations in the lake's upper waters averaged over 60 ug/l in 2003, well above the NYSDEC guidance value of 20 ug/l. Algal blooms persisted throughout the summer.
- ❖ Dissolved oxygen (DO) was depleted from the lake's deep waters during the summer, thus restricting the habitat for most aquatic organisms to the warmer upper waters. This phenomenon is seen in many productive lakes. However, Onondaga Lake also has low DO concentrations in the fall, when oxygen-depleted waters from deep in the lake are mixed through the water column. Fall DO levels in 2003 were generally within acceptable ranges for aquatic life, a sign of improving water quality. Ammonia nitrogen concentrations have reached levels that protect even the most sensitive aquatic organisms. Nitrite, in contrast, continued to exceed ambient water quality standards.
- ❖ During the summer of 2003, bacteria concentrations along the lake's southern shoreline occasionally exceeded public health standards following rainstorms. Conditions were greatly improved in the northern areas. The County will continue to monitor bacteria concentrations as part of the AMP's focus on documenting improved conditions as the CSO abatement projects are completed.

Seneca River at Onondaga Lake outlet.

- ❖ The biological programs are providing important information illustrating the linkages between improved water quality and the lake's community of plants and animals. Extensive monitoring indicates that the lake supports a balanced community of warmwater fish. Largemouth bass, smallmouth bass, and panfish are successfully reproducing in the lake; the growth rates of these warmwater fish are normal for New York lakes. A relatively high number of fish species are found in the lake. This is likely a result of the open connection between Onondaga Lake and the Seneca River.

Onondaga County's AMP is among the most comprehensive monitoring programs currently in place in any community. We look forward to bringing the highlights of the monitoring program to the public each year to build community appreciation and support for the restored lake and watershed.

GLOSSARY

Amended Consent Judgment (ACJ). An agreement signed in January 1998 by New York State, Onondaga County, and Atlantic States Legal Foundation committing the County to a 15-year program of improvements to the wastewater collection and treatment system and associated monitoring.

Ambient Monitoring Program (AMP). Annual water quality and biological monitoring program conducted in Onondaga Lake, the lake tributaries, and the Seneca River.

Chlorophyll-a. The primary photosynthetic pigment in algal (phytoplankton) cells, used as an index of algal abundance.

Combined Sewer Overflow (CSO). A relief point in the wastewater collection system that operates when the hydraulic capacity of the pipe is exceeded. CSOs direct a mixture of storm water and untreated sanitary wastewater to nearby water bodies.

Dissolved Oxygen (DO). The quantity of oxygen dissolved in water. DO concentrations vary with depth, season, and time of day in Onondaga Lake in response to photosynthesis and breakdown of organic matter (especially algal cells). DO levels are a major factor affecting the abundance and type of organisms living in the lake.

Eutrophic. A lake characterized by high levels of nutrients and biological productivity.

Fecal coliform. A type of bacteria whose natural habitat is the intestinal tract of mammals. While most fecal coliform bacteria are not harmful, they are used as an indicator of the potential presence of pathogenic (disease causing) microorganisms associated with recent sewage contamination.

Littoral zone. Shoreline habitat of a lake extending from the water's edge to the limit of light penetration to the sediment surface (often, the greatest depth occupied by rooted plants).

Macroinvertebrate. Aquatic insects, worms, clams, snails and other animals that spend at least part of their life cycle associated with sediments or macrophytes of streams and lakes. Numbers and types of these organisms are used to infer water quality and habitat conditions.

Macrophytes. Aquatic plants large enough to be seen without magnification. While most are rooted, some forms are free-floating. Macrophytes are an important component of the lake's food web.

Metro (Syracuse Metropolitan Wastewater Treatment Plant). Advanced secondary wastewater treatment plant on Hiawatha Boulevard being upgraded for enhanced removal of ammonia and phosphorus, and other improvements.

Nitrification. The biological conversion of ammonia to nitrate.

Nonpoint source (NPS) pollution. Pollution sources which are diffuse and do not enter receiving waters from a specific outlet. The pollutants (such as sediment, nutrients, microorganisms etc) are generally carried off the land by stormwater runoff.

Phosphorus. An element that is an essential macronutrient for plant growth; the limiting nutrient for phytoplankton growth in Onondaga Lake.

Phytoplankton. Microscopic algae and certain bacteria found in lake water.

Secchi disk transparency. A standard measure of water clarity obtained by lowering a 20-cm disk through the water column and recording the depth at which it is no longer visible.

Seiche. Periodic oscillation of lake water caused by external sources of energy, such as wind.

Water quality criteria. Best scientific judgment of the maximum contaminant level in water that will protect a designated use (such as water supply or swimming).

Water quality standard. An enforceable limit, usually numerical, of the maximum contaminant level in water that will protect a designated use. Standards may be the same as criteria.

Zooplankton. Microscopic animals found in lake water; primary consumers of phytoplankton.

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